

THE SEA OF ENERGY

A MEANS FOR THE PRESERVATION OF THE ENVIRONMENT
BY DRAWING KINETIC ENERGY FROM SPACE

John E. Moray
Kevin R. Moray

2505 South 4th East
P.O. Box #651045
Salt Lake City, Utah 84165

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THE SEA OF ENERGY IN WHICH THE EARTH FLOATS
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Cosray Research Institute

Presented to the 26th Intersociety Energy
Conversion Engineering Conference.

The great scientist Nikola Tesla theorized when he said, "Ere many generations pass, our machinery will be driven by a power obtainable at any point in the universe...throughout space there is energy. Is this static or kinetic? If static, our hopes are in vain; if kinetic - and this we know it is for certain - then it is a mere question of time when men will succeed in attaching their machinery to the very wheel-work of nature." T. Henry Moray succeeded in harnessing this universal energy.

In 1901 T. Henry Moray theorized that energy was coming from within the earth. Through continuous experimentation and in spite of the doubts held by the scientific community of that day, he discovered that the energy was not coming from the ground but from an outside source away from the earth.

The energy came in continuous surges, like the waves of the sea, more in the daytime than at night. At this time Moray had enough power to light a 16-candle power carbon lamp at about one half capacity. He labeled and defined his "Radiant Energy: The source of energy coming from the cosmos to the earth and radiating back from whence it came."

Dr. Moray was a man with many abilities. He worked as a civil engineer, an electrical engineer designing electrical layouts for many large metropolitan buildings, and was a certified member of the American Association of Engineers. Despite the many fields Moray was skilled in, his main desire was to see radiant energy become a usable source of energy.

Upon completion of his first Radiant Energy Device, many tests and experiments were conducted for the scientific and public communities. Channeling the waves of energy was done by way of an antenna. When set up and connected to the ground, priming and then tuning, the device would draw electrical energy. Results of this experimentation proved that the power generated had not originated from within the device. The device, through channeling radiant energy, produced 50,000 watts of power and worked for long periods of time.

Testing was conducted over a period of many years in remote areas free of housing, power wires, and telephone lines, all acknowledging to the legitimacy of T.H. Moray's Radiant Energy Device. A number of scientifically qualified individuals tested and signed letters of authenticity substantiating the device's capabilities. From the study of his radiant energy work, we have determined that Moray developed over thirty-six different semi-conductive and even super-conductive devices. His first germanium solid-state device (semiconductor) was submitted to the U.S. Patent Office in 1927 and was rejected on the basis that it would not work without a heated cathode.

For political reasons many people, organizations, and agencies of the day opposed him strongly. Despite the deliberate destruction of the R. E. Device, threats against his work and his family, and armed attacks by unknown assailants, T.H. Moray continued with his dream of harnessing a usable energy that the whole world could benefit from, and at the

same time save the earth from the many methods of energy retrieval which scar and pollute its land, air and seas.

Tests of the device were never conducted in secret and many people witnessed what he was doing. The device was always placed on the same table. The same hook-up was always made. The only external leads were the antenna and the ground, as described by E.G. Jensen. Jensen noted that the 60 watt incandescent lamp connected in series with the antenna did not light, even though the light on the secondary side did light. If the antenna was disconnected at this point, an 18 inch high frequency spark could be drawn out. The antenna was 70 feet in the air and 300 feet long. The wire was separated from the pole by two large ceramic insulators, entering Dr. Moray's basement laboratory through a ceramic insulator, to prevent grounding. This early generation device developed only 60 watts of power. This device was soon replaced by a second generation device.

The device had to be primed as it was not self-starting. When the pilot light was lit, and the tuning was proper, the load would come on. The device required a load at all times. He was able to power twenty 150 watt lamps, and fifteen 100 watt lamps, a flat iron, a space heater, and a motor. Each time he built a new device, he was forced because of cost, and the great effort, to cannibalize the preceding device; meaning that we never had more than one unit at a time.

In order to prove the Radiant Energy was not induction from power lines or radio stations, he took his device to outlying parts of the state, such as Strawberry Reservoir, where even a ranch telephone was more than 30 miles away. He took the device west of the Oquirrh Mountains in western Utah, to a desolate area known today as Dugway Proving Ground, (the United States Army Chemical Test Center), demonstrating adequately that the Radiant Energy would operate more than 50 miles from the closet power line, telephone line, and more than 90 miles from the closet radio station of those days. People, curiosity seekers, scientists, etc. flocked from all over the world to see the lights light, the motor run, the heater heat. Photographers well acquainted with the problem of an intense light exposure, testified of the 100 or 500 watt lamps used. Engineers such as A. B. Jensen tested the device on behalf of Mr. Gull, the head of Utah Securities and Exchange Commission, to determine that it was as represented.

E. B. Jensen speaks of Harvey Fletcher. Dr. Harvey Fletcher of the Bell Laboratories, completely examined the device. Later in writing to R. L. Judd, Dr. Fletcher stated that Moray had more power than could be explained by any means that he knew at the time. Dr. Fletcher spent hours examining the device and had ample opportunity to determine where the power came from, as he was hired to help develop the patents by R. L. Judd, the attorney for Dr. Moray. Dr. Murray Hayes, a patent lawyer and man of science, spoke of his conviction that he knew Radiant Energy was as represented.

You may ask, "What happened?" Many people do. "Why wasn't it developed?" Henry Moray found his own company, The Moray Products, stealing from him. Wallace Bennett, a United States Senator for the State of Utah, went out of his way to kill a NASA contract

for five million dollars, denying later that he did so. Dr. Henry Eyring deliberately stopped government contracts. The Eyring Research Institute has prepared a historical support document and reference material dated May 1979, which is obviously the support documentation for an Eyring Research proposal, and appeared to be a competitor. An interesting fact is, the first exhibit in the support document is a sworn statement by Dr. Harvey Fletcher, formerly of Bell Laboratories, supporting Radiant Energy. They do speak of other researchers in this field; however, the documentation is minor compared to the documentation of Dr. Moray's work. When I confronted Dr. Henry Eyring with this, he denied that the company had prepared the report that I had in my hand.

Others argue as the patent office argued, "Where is the source of energy?" In the rejection notice from the patent office, the examiner makes several mistakes, not the least of which is the fact that he assumes that the energy is originally electromagnetic in nature. But all Dr. Moray really said was that it is electrical AFTER it impinges upon his semi-conductors.

There are many sources of energy that are hypothesized today. Man has theorized that earth is a great dynamo. But no matter what hypothesis you wish to use in explaining the Radiant Energy Device, the fact remains that it did work. Valid experiments have been repeated many times under all types of conditions. Many saw it work. It is well established that the motor did run, the radio did play, and the lights did light. Sworn affidavits have been given, certifying that certain pictures were taken of the tests. Some of the witnesses are still alive, such as Chester M. Todd. Time does not allow the privilege of showing all the documentation. S. E. Bringham pointed out during a demonstration of the device that when the clip connecting the antenna to the device was disconnected, an 18 inch spark could be drawn from the disconnected wire to the clip.

Prior to the destruction of the device, Dr. Moray obtained a contract with the Rural Electrification Administration. Dr. Craig, his supervisor, testified in 1963 that he knew of the test results, even if he did not know how the device operated. Ben Crimm, an engineer for the REA, tested the device with a Mr. Wood, and John Jorgenson of Denver, Colorado. He spoke of the political maneuvering going on to get the REA to sponsor the project. Finally, Carmandy, the REA administrator who may have been removed because he signed the contract to develop Radiant Energy, gave Dr. Moray the terrific salary including per diem of \$25.00 a day.

After the destruction of his unit, Dr. Moray was attacked three times in his laboratory. He was shot in the leg. He and his family were threatened and fired upon from ambush. He decided it was safer to return to private research and withdrew from the REA contract. His connection with the REA resulted in the destruction of his device. It also succeeded in placing him in insurmountable debt. And so, in 1941, he began working on other research projects. He was no longer in the position to use the facilities of electronic organizations he previously had access to in the United States, and his contracts with Germany and England evaporated with the coming of World War II. And so, he was left to his own resources. Estimates of cost to carry on his research, Dr. Moray finally broke

away from many of the corporations he had formed, organizing a private company known today as COSRAY RESEARCH INSTITUTE.

The history of Dr. Moray's work is conclusive; he did produce an energy device, and this energy device, when it is restored, is capable of answering the world's needs with a non-polluting form of energy. We have the notes. It is only a matter of time before the required research money will be raised to bring his work to a conclusion. Henry Moray DID complete his work. He WAS successful in his energy experiment, and the evidence is overwhelming that he produced useful kilowatts of electrical power.

In order to carry on his work COSRAY has published the 5th edition of his book, adding the complete documentation and history so that the world could know that this non-polluting form of electrical energy is still available. This book is available to you in either hard-bound or paperback. Order blanks can be obtained from Cosray Research Institute, 2505 South 4th East, P.O. Box #651045, Salt Lake City, Utah 84165.

Thank you for your interest in our research. We are unable to furnish specific information to you with regard to Radiant Energy as the project is still considered propriety.

Over the 84 years of Dr. Henry Moray's life, he accumulated a wealth of notes, not only pertaining to Radiant Energy, but a wide range of other scientific projects. He established his own research organization for the purpose of continuing his research. Cosray plans to bring his work to a conclusion as soon as financial assistance will allow. Today, Cosray includes research conducted in two countries following the pattern set down by Dr. Moray. The House of Moray Research Foundation was established for this purpose.

We do not need technical help. It is merely a matter of time and money until this project can be completed. We need help in obtaining publicity and in raising funds for the House of Moray Research Foundation.

The Morays wish to encourage others to enter into this area of research, not to duplicate Dr. Moray's work, but to show independent verification, thus establishing it in the world.

Today a number of other researchers have entered the field, however, the Moray's have refused to endorse any of their work. From their published material no one we know has reproduced Radiant Energy. Claims of reproducing Radiant Energy from "The Sea of Energy" book are ridiculous. Others pretending to be friends deliberately attempt to discredit our work. We are not interested in other types of "free" energy devices, as to our knowledge, none have ever shown significant wattage.

We can solve the energy crisis with the help of interested financial backers which we are seeking. It is only a matter of time until Henry Moray's dream of unlimited pollution free energy comes true. We are well justified in again quoting from Tesla when he said that, "Throughout space there is energy." An energy like a sunset. An energy through which the earth floats, always oscillating like the waves of the sea throughout space.

THE SEA OF ENERGY IN WHICH THE EARTH FLOATS

For Beyond the Light Rays Lies the
Secret of the Universe

The Evolution of Energy and Matter
Originally compiled for the Layman in 1926 from
excerpts of the Writings first presented in 1914

by
T. HENRY MORAY
2505 South 4th East St.
Salt Lake City, Utah, U.S.A.
Revised and Printed in 1960

In the study of these pages one should consider that both matter and radiations have particle properties as well as wave properties. The particle properties are evident when recognized as highly localized events of very short duration with specific values of electric charge, energy and mass. The wave properties can be proven in different ways which have been proven and taught for so many years.

SCIENTIFIC RESEARCH IS OUR BUSINESS.
SCIENTIFIC DISCOVERY OUR CORNERSTONE

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4th Edition

Printed in the U.S.A.

1960

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INTRODUCTION

RADIANT ENERGY — the term Moray has used to describe that source of energy coming from the Cosmos to the earth and radiating from the earth back from whence it came. This is the energy the Moray device captures and could be described as those particles of energy pervading all space. In the evolution of energy and the evolution of matter these particles of matter and energy (one and the same thing) manifest under certain conditions as pure energy and under others as pure matter. Radiant Energy from the Cosmos, like radiant particles of matter, being composed of an infinitesimal quantity whose behaviors are described by mathematical equations similar to those used for describing electrical waves, keeping in mind to differentiate between wave length and frequency. Radiant- Energy being particles of energy, just as light is wave lengths and particles is comparable to the electron and magnetron; a ring of negative electricity traveling in a vortex with the speed of light. Streams of energy quanta, each quantum having energy and momentum where the electron revolves around the proton at a distance equal to the electron radius.

To Summarize — Radiant Energy as herein used is that energy existing in the luminescent medium of the Universe, kinetic and exercised in wave transmission and rendered sensible by conversion of its energy into a detectable frequency. The phenomenon of the transducer combined with fission. IN THE FINAL ANALYSIS RADIANT ENERGY IS A MEANS OF USING THE ENERGY RELEASED BY THE FISSIONABLE REACTIONS TAKING PLACE IN THE STELLAR CRUCIBLES OF THE UNIVERSE.

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WHAT IS NEEDED TO BE DONE TO COMMERCIALIZE THIS DISCOVERY

By following the procedure of "Syntheses" by first recognizing the Natural Law, to study the principle and then to allow the true apprehension of the principle to determine the Mechanism through and by which this power may be brought into practical use has been the method of Dr. Moray. Ninety percent of the project is completed. The remaining ten percent does not present any more difficulties than the standardization of a few highly specialized and intricate tubes and measuring devices, coupled with further routine research engineering in mechanical construction or prototypes of the unites for economy, efficiency and lasting qualities when produced commercially.

CHAPTER ONE

A NEW ERA IN ENERGY

Power from the Cosmos and the Earth

Dr. Nickola Tesla said over sixty years ago, "Ere many generations pass our machinery will be driven by power obtainable at any point in the universe. Is this energy static or kinetic? If static, our hopes are in vain; if kinetic, and this we know it is for certain, then it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of nature. "Nickola Tesla was not referring to so-called "atomic energy" or nuclear energy but to the energy which is continually bombarding the earth from outer space. Call it cosmic or what one will.

Enough energy is coming to the Earth to light one million, one hundred ninety-three thousand, six hundred, one hundred-watt lamps for every human being on the earth today. No fuel of any kind will be taken as a dead load for the energy can be "picked-up" direct by great ocean liners, railroads, airplanes, automobiles or any form of transportation, to say nothing of the heat, light and power available for use in all kinds of buildings; to pump water on the desert lands with equipment of only a fraction of the weight of any steam plant or any kind of engine in use today and at a fraction of the cost. A wild dream? A proven, practical reality as hundreds of people know who have witnessed the MORAY Radiant Energy equipment. Powered from the cosmos!

The total energies involved in "cosmic" radiations are individually and collectively very large. The methods or processes of their generation involve a basic relation to the total structure of the action of the universe. Physicists today believe that cosmic radiation consist primarily of protons and, some heavier nuclei. At times they pack a maximum allop of around 100 quadrillion electron volts. Coming continuously, with slight variations in time, their radiation have a uniform directional isotropy. The earth is therefore surrounded in an atmosphere of radiations with the cosmic rays coming continually to the earth from all directions. There may be a slight deflection of the weaker rays by the earth's magnetic field. There is every indication that our sun is not the source of any appreciable amount of these radiations. The origin, therefore, is from the universe as a whole. The total energy of cosmic radiation is more than the entire luminous output of all the stars and nebulae of the universe combined. Unlimited power is being delivered to everyone's doorstep.

The Moray radiant energy discoveries give the greatest amount of energy per pound of equipment of any system known to man. Electric power through an electric motor or an electric jet far exceed any form of engine in the delivery of power as there is no dead center, or lost motion, in an electric motor nor loss of push in an electric jet. A much higher starting torque is had than in any type of combustion engine.

Cosmic power is the most practical form of "energy harnessing" yet put to use by man whereby it is possible to utilize the vast source of energy of the universe without a prime mover at any point on the land, in the air, on the water or under the water, using the energy which exists in the universe and transforming it into useful purposes. An electrical generator is, in the true sense, not a generator, as it does not create electrical energy. Electricity is not made by the generator, it is merely pumped. From that standpoint, an electric generator might be referred to as an electric pump and the Moray radiant energy device as a high-speed electron oscillating device.

To account for the propagation of heat and light — that is, of radiant energy — man has postulated the existence of a medium filling all space. But the transference of the energy of radiant heat and light is not the only evidence in favor of the existence of such a medium. Electric, magnetic, and electro-magnetic phenomena (and gravitation itself) point in the same direction.

It is a matter of common observation that attractions and repulsions take place between electrified bodies, magnets, and circuits conveying electric currents. Large masses may be set in motion in this manner and acquire kinetic energy. If an electric current be started in any circuit, corresponding *induced* currents spring up in all very close neighboring conductors; yet, there is no visible connection between the circuit and the conductors. To originate a current in any conductor requires the expenditure of energy. How then is the energy propagated from the circuit to the conductors? If we believe in the continuity of the propagation of energy — that is, if we believe that when it disappears at one place and reappears at another, it must have passed through the intervening space, and therefore have existed there somehow in the meantime — we are forced to postulate a vehicle for its conveyance from place to place.

When a body is electrified, what we must first observe is that a certain amount of energy has been spent; work has been done, and the result is the electrified state of the body. The process of electrifying a conductor is therefore the storing of energy in some way in, or around the conductor, in some medium. The work is spent in altering the state of the medium, and when the body is discharged the medium returns to its original state, and the store of energy is evolved. Similarly a supply of energy is required to maintain an electric current, and the

phenomena arising from the current are manifestations of the presence of this energy in the medium around the circuit. Formerly an electrified body was supposed to have something called electricity residing upon it which caused the electrical phenomena, and an electric current was regarded as a flow of electricity traveling along the wire, while the energy which appeared at any part of the circuit (if considered at all) was supposed to have been conveyed along the wire by the current. The existence of induction, however, and electromagnetic actions between bodies situated at a distance from each other, lead us to look upon the medium around the conductors as playing a very important part in the development of the phenomena. It is, in fact, the storehouse of the energy.

Upon this basis Maxwell founded his theory of electricity and magnetism, and determined the distribution of the energy in the various parts of the field in terms of the electric and magnetic forces. The medium around an electrified body is charged with energy, and the electrical phenomena are manifestations of this energy, and not of an imaginary electric fluid distributed over the conductor. When we speak of the charge of an electrified conductor we refer to the charge of energy in the medium around it, and when we talk of the electric flow or current in the circuit we refer to the only flow we know of, viz. the flow of energy through the electric field into the wire.

The work spent in producing the electrification of a conductor is spent on the medium and stored there, probably as energy of motion. To denote this we shall say that the medium around the conductor is polarized, this word being employed to denote that its state or some of its properties have been altered in some manner by the work done on it — that is, by the energy stored in it. In the case of a conductor possessing what is termed a positive charge, the medium around it is polarized in a certain manner and to a certain extent depending on the intensity of the charge. If the charge be negative the polarization is in the opposite sense, the two being related, perhaps, like right-handed and left-handed twists or rotations.

Now consider the case of a body charged alternately, positively and negatively, in rapid succession. The positive charge means a positive polarization of the medium, which begins at the conductor and travels out through space. When the body is discharged the medium is once more set free and resumes its former conditions. The negative charge now entails a modification of the medium or polarization in the opposite sense. The result of alternate charges of opposite sign is that the medium at any point becomes polarized alternately in opposite directions, while waves of opposite polarizations are propagated through space, each carrying energy derived from the source or agent supplying the electrification. Here, then, we have a periodic disturbance of some kind occurring at each point, accompanied by waves of energy traveling outwards from the conductor.

The phenomena of interference lead to the conclusion that light is the result of a periodic disturbance, or vibration, of the medium, but as to the nature of the vibration — that is, as to the exact nature of the periodic change — or what it is that changes we possess no knowledge. We know that alternating electric charges are accompanied by corresponding changes of state, or vibrations, of the medium, and if the charge be varied periodically and with sufficient rapidity, we have a vibration at each point analogous to, and perhaps identical with, that which occurs in the propagation of light; a combination of wave and particle properties.

This, then, is the electromagnetic theory of the luminous vibration. In the older or elastic-solid theory, the light vibrations were supposed to be actual oscillations of the elements or molecules of the medium, about their positions of rest, such as takes place when waves of transverse disturbance are propagated through an elastic solid. Such a limitation is, however, unwarranted to some extent although we cannot afford to entirely disregard the particle theory of light. A combination of the theories have merit. We know that the change, disturbance, vibration, polarization, or whatever we wish to term it, is periodic and transverse to the direction of propagation. The electromagnetic theory teaches us nothing further as to its nature, but rather asserts that whatever the change may be, it is the same in kind as that which occurs in the medium when the charge of an electrified body is altered or reversed. It reduces light and heat waves to the same category as waves of electric polarization; the only quality of the latter required to constitute the former is sufficient rapidity of alternation. These speculations were given the strongest confirmation by important experiments of Professor Hertz many years ago.

When a resilient substance is subjected to strain and then set free, one of two things may happen. The substance may slowly recover from the strain and gradually attain its natural state, or the elastic recoil may carry it past its position of equilibrium, and cause it to execute a series of oscillations. Something of the same sort may also occur when an electrified capacitor is discharged. In ordinary language there may be a continuous flow of electricity in one direction till the discharge is completed, or an oscillating discharge may occur — that is, the first flow may be succeeded by a back-rush, as if the first discharge had overrun itself and something like recoil had set in. The capacitor thus becomes more or less charged again in the opposite sense, and a second discharge occurs, accompanied by a second back-rush, the oscillation going on till all the energy is either radiated or used up in heating the conductors or performing other work.

As stated above, when capacitors are charged with this radiant energy and then discharged through a circuit of proper impedance, reactance and inductance synchronizing the oscillations of the device with those of the Universe, we set up electrical inertia. That is, in the reversal of the current, the condensers are charged and

discharged and recharged slowly until the energy originally stored in them is radiated in kinetic energy through the device, which is kept alive indefinitely by the oscillations of the Universe through establishing resonance.

Considering oscillations, mechanical and electrical and or mathematical, we find that electrical resistance is the same as mechanical friction and current comparable to mechanical velocity. Inertia and inductance then may be considered analogous terms. In mechanics the greater the inertia of a body, the longer it will keep in motion. In the RE circuit, the greater the electrical inductance the longer the current continues to flow once it is established by a synchronized cosmic surge.

Expressed mathematically, the equations are the same for electrical or mechanical phenomena. That is

$R < \sqrt{\frac{4L}{C}}$ where R is the resistance in ohms L is the inductance in henries and C the capacity in farads an oscillatory discharge will occur and with a very powerful inductance inertia will assert itself. For low values of R the frequency of the oscillations can be shown by $f = \frac{1}{2\pi\sqrt{LC}}$. The rapidity of the oscillations i.e.

frequencies are governed by the quantity of the capacity and the inductance.

In the vibrations of the forces of the Universe we find the key to the sources of all energy. The real key in securing the energy needed in modern industry is the utilization of the energy resources of the Universe without being limited to mechanical prime movers. The answer may lie in the balancing of an energy generator that will oscillate because of the oscillations of the Universe. Some claim it will be found by a collapsing of the earth's magnetic field. Others seek it in the creation of an electron drag. Dr. Gunn, who was a civilian scientist for the U.S. Navy, stated years ago that the earth is a huge generator, generating over 200 millions amperes of electric current continuously.

The aurora borealis is considered to be very definitely an electrical phenomenon produced by the passage of electric charges through the rarified gases of the higher atmosphere.

The conversion of matter to energy in the stars is now generally accepted as demonstrated, and reasoning from what occurs in radioactive disintegration, during which energy waves are radiated, we may conclude that energy waves of very high frequency are sent out from the stars, one of which is our sun. Now the conversion of energy into matter will equally have to be accepted.

It is well known that air conducts electricity away from charged objects. This being true how does the earth, a charged object exposed as it is to the surrounding atmosphere, maintain its charge? Dr. Gunn and others have proven the earth has this charge. Physicists have shown that the earth has a negative charge which amounts to 400,000 coulombs, yet six feet above the ground the air is charged with more than 200 volts positive in respect to the ground. Therefore, if the air conducts electricity the earth's charge must be constantly passing into the atmosphere. It has been calculated that the earth has a continuous discharge into the atmosphere of 1800 amperes. At this rate the earth would lose 90% of its charge into the air in an hour, yet the earth's charge does not diminish but persists and has done so since the earliest of geological time. Where does the earth's source of energy come from? It has been found that the higher the altitude from the earth, ionization, which could be the media for the flow of energy, increases instead of decreasing. Many names have been given to the sources of energy which we may feel are different sources of energy. We carry on a great deal of research on cosmic ray — the universal electromagnetic field, earth's magnetic field and the energy being received on the earth from the sun's rays. Could it be all energy is from one source — vibrations? Since the source of energy is the universe, the generation of energy by rotary action and by all prime movers is an effect and not a cause. Would it be going too far to suggest that there is no such thing as heat, light, sound or even electricity; but all things are merely effects manifesting themselves in various forms because of the effect of vibrations on various media? Oscillatory energy action, be it in a leyden jar or another capacitor, man-made or in what we may call natural capacitors, all act the same. The oscillations will continue until they have reached their cycle of height and then there will be a back-rush returning to where the oscillations originated. Every oscillation, whether large or small, is completed during the same interval of time. The beat note of time, the heart beats of life, the oscillations of the universe all prove the same great fact that oscillations are governed by the same cycle of time, completed during the same interval of time. Waves of energy have a regular beat note, coming and going as the waves of the sea, but in a very definite mathematical order, coming to the earth from every direction with a definite rhythm that might be referred to as the Father of Time, the Sire of Gravitation.

We repeat, "Energy has a definite elastic or resilient rigidity and density, which is subject to displacement and strain." When a strain is removed, the medium will spring back to its old position and beyond, surging back and forth as the waves of the sea, and will continue to oscillate until the original pressure is used up. If the internal impedance is too great, there will be no oscillations, but it will merely slide back in a dead beat to its unrestrained state. Cutting down the resistance to the minimum and by synchronous or resilient ionic actions of the device with the ionic actions of the universe, recovery will be quicker and quicker until inertia will assert itself and lengthen out the time of final recovery by carrying the recoil beyond the natural oscillation and thus

prolonging the vibrations by oscillations. When the recovery is distinctly oscillatory and harmonics set in, the oscillations will continue because of the oscillations of the universe. These oscillations will be surgings with a definite beat note of the evolution of matter and the evolution of energy.

"In the far-off stellar crucibles of the universe we see the same laws being obeyed as in our laboratories. As we trace down to the almost infinitesimal constituents of the extremely minute atom, we find apparently matter does not exist at all, as the realistic substance which we have supposed it to be. There at its very foundation it seems to consist of energy charges which probably stimulate the motions of celestial bodies. It is becoming more and more certain that the apparent complexity of nature is due to our lack of knowledge, as the picture unfolds it promises a marvelous simplicity. Energy is emitted at various wave lengths, or frequencies which must be taken into account in laws of radiation... Now the physicist uses quanta as commonly as he does electron and atoms and molecules. Bodies are built of molecules, the molecules of atoms, and the atoms of electrons, ions, protons and high energy photons. Here we see the atomistic principle applied to "material" (matter) and then to electricity (What shall we call it?) Finally, a physical process — the radiation emitted by the electrons — is divided into quanta. With such pictures of the universe being constructed we may cease to be surprised at anything, and our interest and admiration will grow. Will we ever get to the final foundation?

"One of the most marvelous relationships that has ever been revealed in the entire science of physics is that between light and electricity. Knowing what we do at the present time in regard to the structure of atoms, this relationship is not quite so surprising. However, considering the total absence of this knowledge about a half century ago, pertaining to the existence of electronics in atoms of matter, the sudden revelation that light (and radiation in general) are vibratory phenomena was very startling and revolutionary." Even today persons unfamiliar with fundamental physics find it difficult to believe that energy traveling from yonder star to the earth is electromagnetic of many wave lengths of frequencies, with different effects depending on the media, being acted upon.

"Radiant here means proceeding from a center in straight lines in every direction. Energy is internal and inherent. "Energy" is defined as a condition of matter in virtue of which any definite portions may effect changes in any other definite portion. This was written in 1892, and discoveries since confirm it. Energy then, is a state of matter, or, rather, the result of a particular state or condition in which matter may be when any observed phase of energy appears."

It is recognized that in addition to possessing kinetic energy, the atom is capable of absorbing energy internally. This internal energy would seem to be associated with the configuration of the particles of which the atom is composed. While under ordinary conditions an atom is in what is known as the normal state, or the state in which we find matter apparently neither giving off, nor absorbing energy. However, the internal energy of the atom can be altered. When the internal energy of the atom exceeds that of its normal state it is said to be excited. Excitations may be caused in several ways, among which is the collision of the atom with rapidly moving positive or negative particles, or as in the breaking of lines of force in the modern electromagnetic generator, which is nothing more than an electric pump, for the electric generator does not create the electrical energy any more than the water pump creates water. Kinetic energy is given up when excitation causes rapidly moving particles to give up some or all of their kinetic energy to the atom during collisions. This is taking place in the Universe all the time. The electric motor and generator would never have been discovered except a dielectric (insulation) had been discovered. Discover a dielectric (a valve) for the energy of the Universe and a means of making a device oscillate with the oscillating energy of the Universe and one has the answer to harnessing the energy of the Universe. A limiting case of excitation is ionization, in which energy is absorbed by the atom sufficiently to allow a loosely bound electron to leave the atom against the electrostatic forces which tends to hold it within the atom. An atom which has given up one or more electrons is said to be ionized. It is possible that ionization, or in other words excitation, may take place in successive steps through absorption of quanta energy, or that is, through the evolution of matter and evolution of forces. The return of an ionized atom to a state of lower energy is associated with electromagnetic radiation. So also from the process of ionization which may result from a number of causes, and the one we are interested in is through cosmic radiation, electric energy becoming associated with the oscillation or vibration of the universe. The higher the frequency, the greater the ionization or excitation. All energy appertains either to matter or excitation of energy and continually passes from one to the other, or in other words, continually possessing kinetic energy. There, at its very foundation, matter consists of an energy charge which governs the very motion of the planets and suns.

Matter is susceptible to motion, and stress. All atoms appertain either to matter or energy and continually pass from one to the other, thus producing kinetic energy. There at its very foundation matter consists of energy charges which govern the very motion of celestial bodies...

To introduce a new way of using an old source of energy, be it called the collapsing of earth's magnetism or any hypothesis of a source of energy can only be justified by the necessity of explaining the insistent fact that a battery of vibratory units can be made to produce 50 KW of energy per unit of 60 pounds. Therefore, some hypothesis of theory must be found to attempt an explanation of the discovery of a device whereby energy can

be obtained by oscillatory means in harmony with the vibrations (oscillations) of the Universe. On the other hand the hypothesis may be taken that the oscillations are out of harmony with the harmonies of the Universe cutting lines of force of energy oscillations by oscillations. The viewpoint on the harmonics of the Universe depending on what yardstick is used in the valuation of the hypothesis used to explain the results. It all sums down to the fundamentals of electromagnetism or whatever name one has chosen to apply to the original source of energy which in the final analysis must be accepted as vibration or oscillation. The focus of our attention in any field of energy has the same dimensions as has the foci of attention in all the higher fields of vibratory energy. It also must be conceded that all energy is vibratory in its final analysis and therefore exists throughout all the Universe. It might be well not to throw this theory out of the window as some former theories have gone and later had to be brought back through the door because they refused to die but were kept alive by the fact that they may have best explained the reason why a modality which existed did perform as claimed.

No one can say that in all space, including that of the Earth's atmosphere, all matter is not being bombarded by high speed particles. Therefore is it too far wrong to say that throughout space there is energy and this energy is kinetic in nature and can be harnessed and used by man by oscillatory means without a mechanical prime mover? Not alone on the earth but in all the Universe.

It has been proven that this oscillatory energy will drive special constructed electric motors at a speed heretofore never dreamed possible. Tesla had a glimpse of the idea in his one wire motor. Also by this means of oscillatory action the clockwise vortex of the pull of gravity in the Northern Hemisphere can be made to rotate counter-clockwise and the counterclockwise pull of gravity in the Southern Hemisphere can be made to rotate clockwise. This is a complete reversal of the vortex of the earth's magnetic pull, or call it what you will.

Watson Davis, director of Science Service, Washington, D.C. in his book "The Advance of Science," 1934 writes "Cosmic Rays bombard the earth from outer space every second of the day and night. They penetrate everything including our own bodies. They carry the mightiest packet of energy yet known to science. They give rise to burst of material particles. —"

"Of all radiant energy rushing about the universe, the Cosmic Rays are thought to be by far the most important. Science deduces with astronomical accuracy that the universe's total radiant energy in the form of cosmic rays is from 30 to 300 times greater than that existing in heat, light, and all other forms combined. Of the imports of energy received by the earth, the cosmic rays equal approximately one-half of the total energy coming in from the stars, excepting the sun."

The important purpose for the quotations which have been given is to arouse attention to the fact that there are tremendous energies coming to the earth from outer space. These energies are only different manifestations of the energies we see in operation all around us. In many cases we are not even consciously aware of their existence. As Mr. Davis states, "They penetrate everything including our own bodies. "Everyone of us is actually alive by virtue of these energies. Every part and particle of the Universe is alive with them. The generators that now furnish our electric power do not create or originate any power or electricity; they merely direct "pump" the existing energy or electricity. In other words, so far as this is now concerned, electricity has always existed.

Vibrational waves of frequencies above the normal range of human ear perceptions are catalogued as ultrasonics. These are waves of frequencies of over 20 k.c. up to 500 m.c. Vibrations above and below these ranges act essentially the same.

Motion is manifest in everything in the universe. In other words, as in a musical note of a high or low C the vibrational rate, the frequency, is different but all "C" notes are essentially the same, differing only in harmonic and range frequency. This is the foundation upon which much of Moray's investigation of vibration is based. All matter possesses a natural rate of vibration. Moray's research in ultrasonics did not end at 500 m. c. but he took the harmonic of certain frequencies and utilized them for various results from breaking objects by vibrations to bringing down birds out of the air, from throwing the natural vibratory rate of living cells out of balance to the shearing off of animal, mineral and vegetable matter. Sometime it has required several frequencies to be transmitted over a media at the same time. Any material that has elasticity can propagate this type of ultrasonics research. The propagation takes the form of a displacement of oscillations.

The universe is singing and this symphony or frequency is what keeps every part of the universe and every atom in its proper orbit. We can see this in studies beyond the microscope or beyond the telescope, either instrument telling us the same story. Science agrees that all form of matter is vibrating at its particular rate of frequency and so it is with the various forms of energy, heat, light, magnetism and electricity, these are but forms of vibratory motion connected with and emanating from the same source, the great generator of the universe; or, in other words, all matter, energy or force in the evolution of matter and the evolution of forces manifests a rate and degree of vibration entirely of its own. Matter, vibrating at a certain rate of its individual character, may be transmitted into other substances by lowering or raising its rate of frequency. If the frequency is raised high enough its molecules will separate and the atoms are freed. Raise the vibration of the atoms still higher and higher and they will resolve themselves into the original elements of which all matter is constituted.

Matter then becomes a form of energy. Frequencies may be developed which will balance the pull of gravity to a certain degree of neutralization of the forces of gravity. One then goes beyond those of gravitation. The understanding then of the principle of vibration or frequency is to grasp the secret of energy, i. e. vibrations, in which lies the secret of all things.

The Salt of the earth is energy and the evolution of matter and the evolution of forces in the processes of the creation of all things. By the proper uses of these natural laws of energy and matter, matter is turned into energy and energy into matter.

In the Gamma Rays we find potentials which are equivalent to as much as 2,000,000 volts, yet their wave lengths are not the shortest known to the physicists. In octaves still higher lie rays which are known as Cosmic Rays. Who can draw a definite line and say how much higher other octaves exist than those known as the Cosmic Rays- Our starting point from the discovery of these different rays — vibrations — was electrical conductivity of the air. It has been discovered that conductivity is just as strong by night as by day, so that radiations emitted by the sun can scarcely be the cause of this energy. May we not, then, accept the theory that the sun, in and of itself, has no energy, but is merely a rebroadcaster of the greater generator — the sonic of the universe itself; that these two, then — matter and energy — are possibly one? Is the sum total of all that has been found out during the centuries of constant research to be judged by the small portion of the universe which is visible to man, who is only armed with his telescopes, or with the most powerful microscopes and spectroscopes ever made by man?

All space is saturated with vibrations, energies which are doubtless what we may call electrical in their ultimate character or very closely allied to electrical action. The relation of matter to energy and energy to matter then becomes the potential of the universe, one continuous series of oscillations, oscillating to and fro like a great pendulum across the universe. One might ask, "How can one get a steady source of energy from such surges?" Could not a steady flow of water be obtained from the waves of the sea?

In reference to electrons, neutrons, protons, photons, and ions, etc., it is our theory in using these terms that they are the energy of the universe, which have become disassociated here and there, and these innumerable infinitesimal particles constitute (by forces they exert and the disturbances they originate) the substratum of what our senses terms as matter, and by nature splitting matter the energy of the universe is born and matter "reborn."

Matter is susceptible to motion. The media is susceptible to stress. All atoms appertain either to matter or energy, and continually pass from one to the other, thus introducing kinetic energy. There at its very foundation matter consists of electrical charges which govern the very motion of celestial bodies — including radioactive radiations of energy and matter. The evolution of matter and the evolution of energy.

There are ample writings and scientific books written by experts which acknowledge that there is unlimited energy in the universe, but to say one is able to tap this supply is another matter. If I tell you there is water, good cold water, in a glass on your table, but you cannot drink it for a million years, what would you think? You know how to get the water out of a glass. Well, it is as easy to tap this energy now out in space as it will be in a million years from now. If it can be done then, it can be done now.

We speak of generating electricity: To be exact, we only transfer it from one place to another (pump it, if you please). We cannot generate it because we can neither destroy or create it. After we have used it to light our homes or do other work, it is like water over the wheel — no less water, only the lowering of potential. The electricity has "sunk back" from whence it came, ready and waiting for nature or man to raise its potential, when it again is ready to do man's bidding, or in other words in the evolution of energy it "sinks back" to its source. It is naturally very slowly but steadily being liberated from the universe only to return again.

Elements maintain an equilibrium by oscillations, rotations, attractions and repulsions, but this does not interfere with a transformation of equilibrium, which when the transformations of equilibrium are rapid enough become heat, light and electricity, i.e., matter is turning into energy and energy into matter.

There can be no "production" of current electricity, there will be no kinetic energy if there is no disturbance of equilibrium, that is to say change of potential of energy level. When one thinks of the oxygen and nitrogen molecules of the air all about us moving with the speed of bullets and striking us and everything with this speed, one can form some idea of the agitation taking place in the universe. The oscillations of the universe are part of this agitation.

The oscillations of these electrons, ions, photons, protons, etc. out in space are emitting electromagnetic waves of many wavelengths and frequency. In the Moray device it is so constructed that the frequency is very much lower on the secondary side than on the primary side and almost complete resonance established.

All radiant energy is now believed to possess mass or something equivalent to it. Mass and radiant energy are even considered to be interchangeable.

We are convinced the energies from the Universe are active radiations produced in "nature's cyclotrons" (nature's reactors) by the evolution of matter into energy and energy into matter.

"Scientific American" (1930) — "The earth itself is a huge electric dynamo generating enough current to supply light, heat, and other electrical needs to the 10 largest cities in the U.S. for at least a million years."

Researches on thermal reactions inside the earth, conducted by Dr. Ross Gunn, indicate that the earth is a great generator.

"Nature of the World and of Man" (Printed by the Univ. of Chicago Press, 1925) "The amount of light and heat (radiant energy) received by the earth from the sun is enormous. On the square yard exposed perpendicularly to the sun's rays radiant energy is received at the rate of one and one-half horsepower. The average rate for the earth through the periods of darkness as well as of light is three-eighths of a horsepower per square yard. This means that 300 horsepower are received on a building 50x150 feet in dimensions. Our planet is receiving energy at the rate of 160,000 horsepower per inhabitant of the earth at the present time.

"The earth receives but an insignificant fraction of the energy the sun radiates: only about one-two-billionth." "The Advance of Science," by Watson Davis, Director, Science Service, Washington, 1934.

Cosmic Rays bombard the earth from outer space every second of the day and night. They penetrate everything including our own bodies. They carry the mightiest packet of energy yet known to science. They give rise to bursts of material particles.

Hundred Billion Volt Wallops.

Preliminary analysis of Explorer VI data just published shows the belts shrunken in size and in intensity — at least this was the state of affairs during August and September of last year.

Another surprise came in the discovery of a third belt lying between the outer and inner belts found by Van Allen. Perhaps this new belt should be called the Arnoldy, Hoffman, and Winckler belt in honor of the three University of Minnesota cosmic ray scientists responsible for its discovery.

The three physicists from the Land of Lakes masterminded the construction of the radiation detection equipment which formed part of the payload of Explorer VI and analyzed the data it accumulated.

The new shape in radiation belts found by the Minnesotans confirmed a growing suspicion that the belts are not the stable pair of doughnuts once visualized, but a shimmering set of tenuous rings which may change markedly from day to day.

Radiation levels measured by Pioneer III, Pioneer IV, the Russian Mechta, and Explorer VI have shown significant variations.

Fortuitously, Explorer VI was in orbit and busily taking radiation measurements during a strong magnetic storm created by unusual activity on the face of the sun.

As a result, the step-by-step reaction of the belts to such a storm and a rather complete history of their return to normalcy was obtained for the first time.

The orbit of Explorer VI was ideal in several respects for the probing of the intensity and extent of the Van Allen belts.

Its orbit was highly elliptical, extending from about 4,100 miles from the earth's center at its near point to some 30,000 miles at its far point.

Moreover, the inclination of the orbit was such that the rocket passed from rather high northern magnetic latitudes to high southern magnetic latitudes.

Because of these two orbital characteristics, a large portion of the region of the belts was scanned in several days time.

That portion of the new data which has been processed to date indicates that the maximum normal radiation dosages in the belts during the period of Aug. 7 to Oct. 6 of last year was down significantly compared to that found earlier with payloads aboard Pioneers III and IV, and the Soviet Mechta.

On the night of Aug. 16-17, a strong geomagnetic storm occurred which brought a new surprise. During the first 24 hours of the storm, about two-thirds of the radiation in the outer zone was "dumped" on the earth.

Available evidence suggests that the lost radiation consisted largely of low energy electrons.

The outer belt soon recovered, in fact over-recovered, and near the end of the storm, on Aug. 18, the outer belt was found to contain about five times the total radiation found there before the storm.

This abnormally high radiation "fever" persisted for 10 days and was followed by a slow return to normal.

As yet, a satisfactory explanation of the "dumping" process in the radiation of the outer belt has not been found.

Tracing the probable dumping paths of this radiation to earth, the Minnesota scientists found that it should show up near the surface of the earth between magnetic latitudes of 52 and 62 degrees, with a peak appearance at 57 or 58 degrees.

On the very night of the magnetic storm, the counters aboard Explorer VI revealed the disappearance of radiation from the outer belt. Dr. Winckler observed an aurora over Minneapolis, at a magnetic latitude of 57 degrees.

The tie-in was inescapable. The observed aurora must have been caused by the jumped electrons from the outer belt.

Such electrons would produce more than the visible evidence of an aurora. They would produce X-rays. Previous observations by balloon had already indicated that such X-rays were often present at relatively low latitudes during times that visible auroras lay far to the north.

The Minnesota data thus gives support to the idea that under certain conditions at least, an aurora may consist of two parts, a visible aurora most likely appearing near the usual auroral zone, and an X-ray aurora, invisible perhaps to the naked eye, lying to the south.

The National Aeronautics and Space Administration picked up the tab for this work, and most likely will do so in the future as the Van Aliens, Arnoldys, Hoffmans, Wincklers and others bring new light to bear on the remaining mysteries of the earth-circling radiation belts. Salt Lake Tribune, June 19, 1960.

SPACE FILMS DISCLOSE FAR GREATER RADIATION

BEDFORD, MASS. (UPI) — Film packs exposed at altitudes up to 700 miles in an Atlas nose cone showed far greater radiation than previously discovered, according to the air research and development command.

"Particle tracks indicate that radiation in the (Van Allen) belts discovered by the Explorer satellites far outshadow the flux of primary cosmic radiation as measured by means of skyhook balloons at 20-mile altitudes," the report said.

"Counts in the Atlas-flown emulsions show that for every cosmic ray that penetrated the block, some 44,000 protons of the Van Allen belt were recorded.

"The accompanying photomicrograph of a section of the emulsion smaller than the head of a common pin shows a track produced by a heavy cosmic ray primary immersed in a sea of protons carrying kinetic energies in excess of four billion electron volts and thus capable of penetrating the Atlas nose cone.

"The more energetic of the trapped particles produced 'stars' or nuclear explosions inside the emulsion (film) 500 times more frequently than observed on earlier Aerobee rockets which reached only 100 miles, below the intense trapped radiation of the Van Allen belt." March 17, 1960, Deseret News

No other radiations "pack such a wallop" as Cosmic Rays. Compared with other energies here on earth, they rate thousands and millions of times as powerful. Cosmic Rays energies seem to lie between 100 million and more than 100 billion volts. It is not possible to be any too definite and positive, because estimates necessarily change with additional experiments and knowledge. Comprehension becomes difficult when energies reach billions of volts. The highest electrical pressure on high-tension power lines is 250,000 volts. The peak of artificial electricity production for experimental purposes is 20 million volts. Lightning is rated at about 1 billion volts.

Dr. Anderson's cloud chamber at California Institute of Technology in which the positron was discovered has furnished much information about cosmic ray energies. He found that some positrons are born of cosmic rays smashing into matter. The cosmic-ray energies deduced from the tracks left in the Anderson cloud chamber range from 100 volts to 3 billion volts. The Lemaitre-Vallarts theory together with Dr. Johnson's asymmetry measurements, give definite values for the energy of half of the cosmic radiation, and shows it continuously disturbed between 5 billion and 50 billion volts.

The figure of 100 billion volts is a result of Dr. W. Kolhorster's measurement of penetrating radiation in the depths of the Strassfurt salt mines. He found that the minimum energy of these rays had a penetration which was greater than ever before demonstrated. Dr. Axel Corlin of Sweden's Lund Observatory found radiation that still had energy after passing through somewhat greater depths and, therefore, the voltage figures can be made even higher. And energies of 100 billion volts or more are indicated by the great bursts set off by cosmic ray collisions, called the stosses, which have been observed particularly in Germany. The Moray RE devices have worked equally well in deep mines under water or high in the mountains and in an airplane.

It is about 100 years since science began to consider light, heat, magnetism, galvanism and electricity as natural forces. In the early part of the 19th Century school books termed these things imponderable substances. The corpuscle theory of light was taught and the sun was supposed to contain a never failing supply of these corpuscles. After the corpuscular theory had about faded man turned to the wave theory, but even the wave theory was based on a crude concept of a movement of the ultimate principles or atoms of matter. The electronic theory superseded the old theory and while the electron theory surpasses all former theories, could it be, as greater light leads us on, the electron theory will be found to lack "absolute" knowledge, and the Einstein Theory stand some revision, amendments, or even undoing?

CHAPTER TWO

REACTIONS BY MEANS OF ELECTRONIC EXCITATION

As I stated in 1914 in connection with the action of Moray RE tube values.

If two molecules were beyond each other's Molecular range and if the neighboring surfaces could, by any means as by the supply of electricity from without, be oppositely electrified, the forces of cohesion would be intensified momentarily by something akin to chemical affinity and cohesion would set in over Ultra-molecular distances. The opposite charges cannot be maintained electrostatically between two neighboring metallic surfaces, but they can be momentarily imparted by a sudden jerk of disruptive discharge or receive electric impulses, these are the things which are effective in promoting chemical cohesion. It is not to be supposed that the electrons in a polarized atom need to be disturbed in any great amount in order to produce chemical cohesion, polarization converts ordinary molecular force in cohesion into incipient but real chemical affinity.

It has long been known that electrical forces between charges are of the inverse square law type. The interactions of two moving charged particles free in space can be easily computed by our analogy to our well-known astronomical problems with due regard to the signs. Coulomb's Law states, "The forces exerted upon each other by two small charged bodies varies directly as the product of the charges and inversely as the square of the distance between their centers." The force also depends on the kind of medium in which the charged

bodies are placed $f = \frac{Q^1 Q^2}{4\pi p r^2}$ Where p is the permeability of the medium. As an illustration of the force

given by the Coulombs Law, if we have two small bodies each charged with one coulomb of electricity and these are placed in a vacuum with a distance of one meter between centers the force of repulsion will be 8.9×10^9 newtons or 2.25×10^9 lbs.

It is obvious that chemical molecules can be made to obey Coulomb's Law and may be subjected to the interactions of the electrical forces, the impact, or inter-molecular pressure, between the reacting molecules must be very large.

We know from proven experimental facts that at 10^{-2} cm. and even down to 10^{-5} cm. apart, gaseous ions at atmospheric pressure exert very feeble forces on each other. As the ions are being knocked around randomly by molecular impacts, Brownian movement whose impact forces are larger than the attractive forces. Only until they are within molecular distances to each other is the coulombic potential energy equal to or exceeding the average of translation.

$$\frac{ge^2}{4\pi p r_o} \text{ equal to or greater than } \frac{3}{2} Kt$$

r_o is the molecular distance

Inside this molecular distance the ions are actively drawn together; outside this sphere of radius r_o has an electric field given by the equation:

$$X = \frac{e}{r^2}$$

at 10^{-8} cm. X is 10^8 volts/cm., even at 10^{-6} cm. it is 10^4 volts cm. It is apparent that the coulombic force within such molecular distances between oppositely charged ions must be very great. The effect is analogous to the entrapping of comets when they pass near a planet, thereby rendering them permanent members of the solar system. Since the stoppage of comet like ions in an encounter with oppositely charged ions occurs well within the limits of atomic magnitude, 10^{-8} cm., so that the acceleration will be of the order of $U^2/2t=10^{26}$ egs., and the force needed to drop even a single electron will be 1/10 dyne. The power to stop and neutralize such electrons flying with 1/30 of the speed of light inside a molecular thickness can be estimated.

$$\frac{\text{energy}}{\text{time}} = \frac{1}{2} mu^2 \quad \frac{u}{2t} = 10^{27} (10^9)^3 10^8 = 10^8 \text{ erg / sec}$$

Reaction of excited atoms or molecules is of importance only under conditions of high electric densities, in view of the short time intervals involved, that is 10^{-8} sec. Some atoms can, however have electrons in metastatic state of excitation lasting some 10^{-4} sec. However, at lower electron densities second impacts can change the phenomena, and such atoms in impact with neutral atoms or molecules of an appropriate sort can lose energy by inelastic impacts causing excitation, ionization or dissociation of the molecules.

In any collision between a charged particle and a neutral molecule ionization takes place because of the electric force exerted on the planetary electrons in the molecules.

The Bohr Theory of spectral lines indicates that an electron should be able to lose energy to an electron in an atom or molecule as soon as it possesses an energy equal to $h\nu = 1/2 mv^2$; ν is the frequency of the energy radiated, h is the Planck constant therefore we have $h = 6.62 \times 10^{-27}$ erg/sec, ν =frequency, m =mass. When the disturbed electron returns from its orbit or state, it was suspected that the first inelastic impact at increasing energies should correspond to these excitations losses, leading to light emission, and not to ionization, the ionization potential being higher. It was found in complete conformity with Bohr's theory, the first inelastic impacts of electrons with atoms or molecules at lower energies, in general gives rise to the emission of light of the first line of a series of these atoms and that as the electrons' energies increase, the separate higher lines of appropriate frequency appear as the energy reaches a proper value.

At an appropriate energy of the impacting electron, the atomic or molecular electrons are completely removed from the atoms or molecules leaving behind the positively ionized atomic ions or molecular ions.

When an electron possesses more than an ionizing amount of energy, any superfluous energy which it has after causing ionization is distributed between itself and some electrons removed from the atoms or molecules.

A single electron of appropriately high energy can liberate as many as 4 to 5 electrons at once from an atom as in the outer electrons of mercury. The work on dissociation and the mechanism of ionization in certain gases such as the rare gases, nitrogen and hydrogen, has shown the possibility of the simultaneous excitation and ionization of the same atom by a single electron impact of appropriate energy.

It is found with few exceptions that the larger the diameter of the atoms and the larger the number of external electrons the smaller the excitation and ionization potential will be.

The probability of resonance and ionization is greatest at the precise ionization or resonance potential and falls off exponentially from that value on only to rise again as the next potential is reached. In any case it can be definitely stated that the probability of ionization and excitation calculated on the basis of the electron free path in a given gas the number ions formed are a maximum at the ionization or excitation potential; thereafter, they drop rapidly to lower values as the electron velocity increases.

We experimentally found the number of ionizing collisions per meter made by an electron, is approximately proportional to the excess of energy of the electron above the ionizing energy

$$n = C (E - E_1)$$

E is the actual energy of the electrons

E_1 is the ionization potential of the gas

C is a constant

The energy an electron must have before it can produce an appreciable amount of ionization is always considerably larger than the ionization potential. The ionization potential determines only the energy at which ionization by collision starts. The greatest amount of ionization occurs when the electron has an energy 5 to 10 times that given by the ionizing potential.

The minimum value of the potential at which definitely inelastic impacts of electrons with atoms or molecules set in and where the electrons lose all, or a large fraction of their energy at a single impact, is called the critical potential. It was first observed that the conductivity of gas was increased at the critical potential, or first ionization potential, that is, when an electron acquired an energy of equivalent volt V_0 , characteristic of a given gas, it was able on impact, to remove an electron from an atom which has an ionization potential of V_0 . This is expressed in electron volts.

The second ionization potential corresponds to the work required to remove a second electron from the atom or molecule, when the atom or molecule has already been ionized.

Unless ionization occurs, atoms and molecules can absorb only discreet amounts of energy, this energy has the effect of moving the most loosely held orbital electron or electrons in an atom to some larger orbit. Thus at normal temperature 80°F, the average kinetic energy of the gas molecules corresponds to less than 0.04e.v., that is, the fraction of the total number of molecules which has energies greater than that necessary for ionization of the gas is extremely small.

Because the mass of the electron is so very small the energy it loses in an elastic collision is only a small fraction of its total kinetic energy. The fraction f is given by the following equations:

$$f = 2.66 \frac{mM}{(m - M)^2} \frac{(1 - WM)}{Wm}$$

WM average mass of the molecules

Wm average mass of the electrons

f is approximately equal to m/M even when the average energy of the electrons is only 20% or 30% larger than the average energy of the molecules. Thus with a comparatively small electric field, if the electrons can make a sufficient number of collisions the average energy of the electron can become many times that of the molecules.

If the electric intensity were only 100 volts/ampere the average energy of the electrons in oxygen would be about 4.5 e. v. at 1 mm. Hg. This corresponds to a temperature of 35,000°k. Under conditions such as these the

actual kinetic energy of a fairly large fraction of the electrons would thus be larger than the ionization energy of the molecules and ionization could occur owing to the collisions of the electrons with neutral molecules.

The forces acting between an electron and a molecule vary much more than the inverse square law coulomb. This is represented by the following equation:

$$f = \frac{(D-1) O^2}{2 * 3,1416 N \pi 5}$$

this assumes spherical elastic molecules and ions, these attract each other at a distance r with a force f. Thus an electron can approach very closely to a neutral molecule before experiencing any force due to the nuclei and the orbital electrons. If then, the electron has made a series of collisions and its energy or velocity is sufficiently low it can attach itself easily to the neutral molecule to form a negative ion. However, at too low pressures, the electron mean free path is increased and collisions are few thus insufficient to bring about the formation of negative molecular ions.

Electrons of low velocity approaching an ionized atom or atomic ion or molecular ion, must be able to interchange velocities so that while one electron neutralizes the ionized atom, the other electron escapes with the total energy resulting from the process. Another example would be a free slow-moving electron approaching an excited atom, the energy of excitation is given to the slow electron while the excited electron returns to its normal orbit without radiation or to some intermediate orbit with radiation of lower frequency. A classical example for illustration is the irradiation of mercury vapor by the line 2537 Å; the mercury vapor becomes activated, is then in a metastable state; if these atoms collide with Thallium atoms while in this state, a thallium-electron would be raised to a higher level so that it emits the green thallium line. The difference between the energy of the 2537 Å line and the low-energy thallium line is converted into kinetic energy of the separating mercury and thallium atoms after impact. If the activated mercury atom strikes hydrogen molecules in the excited state the energy is converted into the work a dissociation of these molecules into atoms or molecular hydrogen fragments. If the excited mercury atom collides with an atom of lower ionizing energy, this may remove an electron from the neutral atom ionizing it, and itself returns to the normal state.

Methods of electronic excitation

A. Processes in the gas itself;

1. Rapidly moving electrons and beta particles from radioactive changes.
2. Rapidly moving positive charges, protons and alpha particles.
3. Rapidly moving positive ions in high electrostatic fields
4. Photo electric ionization by ultraviolet light, X-Ray and other rays beyond the light rays as coming from the Cosmos.
5. Through chemical reactions in the gas, e. g. e. oxidation of NO — NO₂ P — P₂O₃, P₂O₅, etc.
6. Possibly ionization and excitation of the gas may be caused by temperature alone without action of the walls, or by impact of rapidly moving neutral atoms or molecules from other sources, for example neutralized alpha rays,

B. Processes due to solid or liquid surfaces in contact with the gas.

1. Bombardment of metal by fast electrons, alpha particles, positive ions or recoil atoms giving secondary atoms.
2. Action of metastable atoms on solid surfaces giving secondary atoms.
3. Action of gamma rays, X-rays and light on solid or liquid surfaces giving electrons photoelectric effect.
4. Incandescent metals in general emitting large numbers of electrons called thermo-ionic emissions.
5. Incandescent surfaces having salts, phosphates, oxides, chlorides, or complex metal salts of mixed composition, at lower temperatures give positive ions such as sodium ions, potassium ions, barium ions, etc.
6. Chemical reactions at surfaces, oxidation of moist phosphorus, potassium, sodium, give ions of both signs, but more negative ions.
7. The atomizing of liquids into minute droplets by high velocity air currents tangential to the surface causes the smallest droplets to become negatively charged. If water is used which contains ions the larger droplets have ions in them and are predominately positive. The source of conductivity of the gas is the source of the charges on rain clouds and thunderstorms.
8. Frictional effects between solid particles suspended in gases, as typified by electron in sand storms.

9. Ionization of a gas can occur when the average energy of the molecules becomes so great that the energy transferred in a collision between two neutral molecules is sufficient to ionize one of them.
10. The collision of free electrons with neutral atoms or molecules. Ionization by collision between molecules and electrons in thermal ionization may involve several processes:
 - a. The electrons may ionize directly in colliding with a neutral molecule.
 - b. The electron may excite a molecule and subsequent electron may ionize it.
 - c. An electron might excite a neutral atom which subsequently in returning to its normal state would give off radiation and cause photo-ionization either in the gas or at the walls of the discharge.
11. The electric field is then one of the most important ionization agents.

An ion moving under the influences of the forces of the electric field is given by the following equations:

$$F = XAned$$

legend F — force; X — field strength; A — base area volume; n — ions/cc; e — charge; d — length parallel to field

This force acts on each ion between its 10^9 collisions/sec. with molecules to give it momentum in the field direction. At each of the 10^9 impacts some of this momentum is yielded to the neutral molecules with which the ion collides. As a result the molecules are set into a motion along X .

When a molecule captures a charge to become a molecular ion it moves in the electric field according to the following equation:

$$K = e/6 \times 3.1416 - a(1 - AL/a)$$

legend e — charge; coefficient of viscosity; a — radius of particles; A — constant, (.874); L — Mean free path.

The distance a molecule moves between impacts is called a free path, the mean free path is dependent on the velocities of the ions.

Now an ion that has fallen through a potential difference of one volt will have a kinetic energy of 1.6×10^{19} joule. That is,

$$qE = 1 \times 1.6 \times 10^{19} = 1.6 \times 10^{19} \text{ joule}$$

According to the equation: $qE = \frac{1}{2}mv^2$ we find that the velocity of the particle after falling through a difference of potential of E volts is entirely independent of the length of the path the particle has traversed and also entirely independent of the form or shape of the electric field. The electric field intensity may be distorted in any way we please. That is, it may be at a high at one point, low at another, but still if the total difference in potential is E volts, the velocity of the particle will be:

$$V = \sqrt{2q / m(E)}$$

E. g. an electron with the kinetic energy of one electron has a velocity of: $V = 5.93 \times 10^5$ meters/sec.

A hydrogen ion having a kinetic energy of one electron volt would have a velocity of 9.85×10^3 meters/sec. Or nearly 6.1 miles per second. Hence the mobility of charged particles, positively charged molecular ions and negatively charged molecular ions or atomic ions in the electric field may be controlled by simply controlling the difference of potential through which the particles are falling. Further, since the molecules are to react with one another the rate of reaction and the intensity of said reaction may be controlled at will.

A specific case in which the electric field performs the double function of molecular excitation and the creation of inter-molecular and atomic ions is being given by the system used by the inventor.

It is a system utilizing the principles of the wire corona with concentric cylinder at different pressures. The system is modified in conformity to the concept that chemical reactions must take place when the oppositely charged molecular ions from an appropriate activated catalyst are accelerated against one another in the wire corona, it consists of a cylinder made of a suitable catalyst from which positive atomic ions are emitted. The reactants (gases) streaming through the chamber parallel to the length of the wire attain the polarity of the negative molecular ions by the high electric field close to the wire. As these negative molecular ions are accelerated at the right angles to the wire in the direction of the electric field toward the positively charged catalyst cylinder, they are met by an avalanche of on rushing atomic ions from the catalyst. A certain amount of reaction takes place in that instant. (10^{-8} sec.) However, some of the negative molecular ions outside the mean free path of the positive atomic ions are free to rush headlong toward the positive cylindrical field where they are neutralized, and instantly given a positive charge by the avalanche of outrushing positive ions. These

positive molecular ions are accelerated back into the field and collide against the negative molecular ions coming from the direction of the negative electrode corona. This melee continues until the reaction has come to a point when the individual participants are either all gone or the mixture is outside of the electric field; backrush oscillations.

The Moray apparatus combined with other equipment, consists of a combination of specially constructed tubes which we will refer to as valves, "pressure transmitters," interceptors and oscillators. The valves are not rectifiers in the sense that they operate as radio valves in changing A.C. or H.F. to D.C. They have an actual valve action in stopping the "flow" of energy which may be thought of as oscillatory action similar to the waves of the sea, without rectification, from returning to the outer circuit, much as a retaining wall could stop the waves of the sea from returning. The other modalities and "tubes" of the device are equally unique in their performance. Although no new laws of energy are being advanced or claimed as having been discovered, the application in the method of utilization of the energy throughout space is unique in that "Generation" is accomplished by oscillatory utilization rather than by the conventional prime owner. These detector tubes have a synchronized pull with the specially developed oscillators of high faradic capacity and provide a means through which oscillating energy may pass to specially constructed valve oscillators whose relation to the first stage valve is such as to permit oscillations to come in from but not to return to the outer circuit with an automatic variable relation to the oscillations from the universe, and capable of setting up within their circuits initial oscillations which coincide with the oscillations of the universe.

Special provision is provided to stop R. E. tubes from becoming blocked in their dissipation of the charges created by the oscillations that continually accumulate based on the oscillatory capacity back rush effect common to capacitors and herein applied in vacuum tubes. This action of these devices has the effect of enlarging and prolonging the time of charge and discharge of the capacitors and the capacity energy in the circuit to an appreciable interval in perfect harmony with the natural energy wave through the interceptor's valves and oscillators in the circuit which set up in the circuit electrical pulsations corresponding to the energy waves captured by the interpreter and again kept from returning to the second outer circuit by "multi-walled" valves. The final tubes act as energy pressure transmitters with a means to prevent "shunting" condensation by a special form of "getter." This stops condensation accumulating at the base of the tubes which would block their ionic action.

One must "split" the energy discharge band into lines of variation, call this what you will, lines of energy or line of light beyond the "light rays." The oscillations, therefore, do not become simple oscillations but through the action of the Universe set up an energy flow — which might be referred to as the assertion of inertia. When inertia sets in the action will continue because of the oscillations of the Cosmos, otherwise one would have a complete dissipation of energy and no oscillations. The oscillations will vibrate during the same period of time regardless of the potential, but the rate of vibration of the device depends on the "capacity" of its modalities, i.e., condensers, etc.

Let us go from the known to the unknown. We have referred to a form of ionic action in place of the common electronic liberation accomplished in radio tubes. It is an accepted fact when various substances are bombarded with alpha particles they are found to give off electrons. This is the principle involved in various vacuum tubes. Thomson gave a similar action of liberation the name of Delta Rays. These Delta Rays or electrons are thought by some to originate in a type of ionization which might be referred to as "thermions," give off when the alpha particles strike the bombarded substance. Is it, therefore, possible some "particle" from the Cosmos, with greater penetrating power than Alpha particles, would penetrate quartz or various substances and set up a decided ionic action? One maybe could learn much from a glorified "monochromator."

Just as sodium, potassium, caesium, rubidium, barium, strontium, react to visible light, or let us say wavelengths, within a certain range, might not certain other substances or substance react to oscillations from the Cosmos or artificially produced radiations?

The universe is analogous to a radio transmitting station. It is continually emitting energy, only of a greater range of wavelength. Wavelengths and frequencies are truly the answer to all vibrant worlds of living things. The stellar laboratories providing environments as yet unproducable by man or perhaps only unrecognized. The terms cosmic energy, radiant energy (as used by Dr. Moray) can be thought of as synonymous terms of frequencies of unknown and undefined limits. In fact, limits of arbitrarily named ranges of the spectrum, which the spectrum has not defined so that the terms should be recognized as meaning a locality in the wavelength scale without being definitely "fenced." Energy must be absorbed to be utilized. Absorption converts energy into heat, chemical energy, mechanical energy, electrical energy and perhaps into forms unknown at the present time. "Vibrant with life" is more than a poetical phrase.

In its simplest form an ion consists of a molecule of air that has either one or more or one less than the quota of electrons for the electrically neutral molecule. The former is a negatively charged, the latter a positively charged ion. Positive ions are attracted toward negatively charged bodies while negative ions drift away from them. This process goes on and the medium loses its electrical charge at a rate that is proportional to the

abundance of ions, to the velocity at which the ions move towards the attracting medium. The velocity is less or greater if the ion is not the simple type but consists of a variable aggregate of molecules. Much could be written on this, but the above should suffice for the present purpose. Let us go on from, not stop at, the Ultra violet Light Theory of Aurora.

In some electronic tubes the electrons are not emitted directly from the filament but from an indirect Cathode which does not enter into the direct electrical function of the tube. Does this teach us anything toward an indirect generation of ions and ionic action? Could the opposite deflection of alpha and beta rays and the undeflected course of the gamma rays teach us anything about cosmic energy or radiant energy valves and oscillators?

The more perfect the ionic action the greater the velocity. The greater the mean free path and the greater the collecting voltage the greater the ionic gain of energy will be between collisions and the greater the amount of kinetic energy will be conserved. The collision will be "perfectly resilient."

The little we know about "space" and what it contains or may contain is so limited that we are forced to acknowledge anything is possible beyond our experiences. The actual material of space consisting of the matter of celestial bodies is a very small part of the whole. There may be many all pervading energies or matter that are more important than those we have detected. The very fact of our inability heretofore to detect them may make them all the more important in the cycles of our life and the things we know.

There is a multiplicity of phenomena which occurs at the same time in gas conduction, the known laws are largely empirical and approximate. Ohm's law is valid in only a few limited cases, conductivity changes markedly with the variety of gas and the gas pressure. In the detector and interceptor circuits it becomes more important to maintain oscillatory action than frequency stability.

The relationship and combination of natural vibration and forced vibration is particularly important. It must be remembered that a point of resonance will be reached at some frequency and the charge will reach a magnitude depending on the impressed force which, in the case of the universe, is immense — the effect of resonance, pure resonance.

Science claims complete resonance is not producible. Science also, at one time, said it was impossible to transmit the human voice over a copper wire. That is and will always be a fact, but the same results are obtained. Science also said it was impossible for a heavier than air device to "fly."

Resonance has been obtained where a return wire in an electric circuit is not necessary. Pure resonance offers many dangers to the inexperienced investigator. The walls of Jericho are an example of pure mechanical resonance. Marching feet, running dogs and some harmonics come within the danger zone for bridges and the other mechanical structures, as also the breaking of a water glass. Every substance has a natural mechanical vibratory resonance and a point of dissociation. This is also true in electrical or energy resonance.

The theory is that in perfect resonance the oscillations will become more and more vigorous until the vibration or oscillation will go on forever if properly "fed" or to the dissociation of the matter. However, while this will be true in theory, it is only partly true. In fact, if one can obtain resonance with the "great generator" of the universe with its multiplicity of vibrations corresponding to the natural vibration and pure resonance of the different substances — each substance has a different pure sonic, pure vibration, pure resonance, buildings may be made to fall, glass to break, matter to explode, but only such things as come within the exact vibratory ranges of that resonance will be affected. The vibratory rate and the resonance of water is not exactly the same as that of oil. Find the proper mechanical or energy resonance of certain "kinds" of matter and the constructive results will far outweigh the destructive. Gasoline and fire each have their place which must be honored and feared as also appreciated. Man can destroy himself now, so where will a pure controlled resonance make too great a difference? There are enough things which, in the hands of babes, ignorance or knaves can snuff out nearly everything now; so, where need pure resonance be feared? The writer has, as Tesla did, come very close to pure resonance with certain substances. Being in resonance to one substance as compared to another is not being in resonance to all substances.

Put together in pure energy resonance certain electrical responding modalities which synchronize with the resonance of certain vibrations of the universe and what have you? Usable energy from the universe. This energy may come to the planets as oscillations similar to the oscillations and the tides of the sea. The R. E. tubes received this energy in surges, which may last only a few micro-seconds but the pressure and the current in those surges are so large that sufficient energy is delivered to the equipment in resonance as to be un???ed and usable in multiples of flashes and a magnitude which will compete with the light of day. Remember resonance and pressure can do a lot of amplifying of energy. Also remember the vibrations going out from the sources in the universe must also return to their sources. Nothing is lost only a lowering of potential like water over the wheel.

The R. E. tubes present no new laws of physics. It may be a case of advancing further in the law and thereby obtaining results not at first deemed possible. This is the history of science. R. E. tubes possess greater ability to obtain "saturation" and thus charge the accompanying capacitors or condensers at a more steady rate which, when a certain voltage is reached, ionization occurs in the gases of the discharged tube and causes the

condensers of the valve circuit to discharge into other condensers of the oscillators and the other modalities of the circuit.

When ionization in the preceding tubes is no longer possible because of the reduced voltage, the process starts all over again. The first valve passes vibration of energy into an oscillatory circuit, ionization sets in, a discharge occurs and energy passes through another valve into other oscillators. The process is repeated from the first stage on to the second on to the third and so on, much like a bucket bridge. That is why I asked years ago, "cannot a steady flow of water be obtained from the waves of the sea or energy from the vibrations of the Cosmos?"

Many phenomena, especially those occurring in certain frequencies, are still unexplained and there are numerous places where the classic theory and observed facts do not agree.

When a vibration of any kind strikes a boundary between two media of different vibratory impedances at an angle of less than 90 degrees, a transformation of the vibratory rate may be changed into another vibratory rate. The R. E. Device, therefore will continue to capture energy by resonance, or call it what you will, as long as the "keep alive" vibration of the Cosmos continues to oscillate the various stages of valves and oscillators in the circuit. Simple is it not? Just a case of the trapping of energy which is everywhere present in the primary circuit and causing it to oscillate through the secondary circuits through a blocked circuit of no return.

Our experiments have proved that there is an energy which exists in the universe which, by proper development of equipment can be made available for commercial use.

One may say all "energy" comes from the sun. Can one prove the sun is the foundation of all "energy?" Or is the sun a retransmitter of energy? That light is an electrical phenomena has been amply proved. The atoms in those distant stellar crucibles have moving electrons which are emitting electromagnetic waves of many lengths and many frequencies, which can be tuned to certain ranges of wavelengths. Our eyes and other senses respond to some of these frequencies but there are many beyond those which we loosely term light. The photographic plate records some of these and also invisible radiations of shorter wavelengths or higher frequencies known as ultra violet radiations. There are radiations measured by their heating effect of longer wavelengths or lower frequencies which we call infrared radiations. There are electromagnetic radiations of shorter wavelengths. These are generally known as "Roentgen Rays." There are rays of still shorter wavelengths; these are of unlimited power. These are born and put into locomotion from the very "Source or Foundation of Energy." What is a man to do with such a picture of the universe other than let our interest and admiration grow? But will we ever get to the final foundation? Anything is possible beyond our experiences. And as Tennyson said

"One God, one law, one element
And one far-off divine event
To which the whole creation moves"

Electricity is vibrations. Substance is a vibrating medium. All substances are really combinations of one primordial substance i.e. vibrations. Electrons in motion go to constitute an electric current. What electricity is to matter, so is electric force to common mechanical force, and electrical inertia to mechanical inertia. By inertia, we mean the ratio of force to acceleration.

Here on earth we have many "receiving stations" which are tuned to certain ranges of wavelengths.

Energy was defined in 1892 as a condition of matter, in virtue of which, any definite portion may effect changes in any other of definite portion. Later discoveries have since confirmed this. Energy then, is a state of matter, or rather, the result of a particular state or condition in which matter may be, when any observed phase of energy appears.

Cosmic rays, cosmic vibrations and matter may appear to consist of two entirely different things, but the fact is, these two subjects are actually joined together. Those highly penetrating rays which we call cosmic rays, originate somewhere in the remote spaces of the universe and continually bombard our earth with continuous vigor day and night, year after year.

We must not think of cosmic rays, infra ray and ultra-violet, X-ray, gamma or any ray, or particle as simple in character. None of them in any sense of the word consist of a simple frequency of ray. Ultraviolet rays, X-ray, gamma rays, cosmic rays and so on all consist of various wavelengths or frequencies. That is all ultraviolet rays are not of the same frequency, all X-rays are not of the same frequency any more than all radio waves (hertzian waves) are the same frequency. All are exceedingly complex in their make-up. This complexity is what has given them such an important place in the study of the physical sciences.

The great study of matter and cosmic rays so closely tied together, will open up greater and greater fields of science for the practical good of the human race.

Experiments have also satisfied us that gravity is akin to, if not an "electrical" oscillation, so well balanced that we might, for the lack of a better name, almost call it a "Wattless energy" until some force is exerted to oppose its potential and then gravity opposes such force. This means gravity can be controlled and unlimited advancement made in air navigation.

Facts prove that matter is capable of dissociation fitted to lead it into forms in which it loses all its material qualities. Among the most important Dr. Le Bon noted the emission by all bodies of particles endowed with immense speed, capable of making the air a conductor of electricity, of passing through obstacles, and of being thrown out of their course by a magnetic field. None of the forces then known were able to produce such effects, particularly the emission of particles with a speed almost or equaling that of light; it was evident that science then found itself in the presence of absolutely unknown facts. Several theories were put forth in explanation of them. One only — that the dissociation of atoms, which Dr. Le Bon advanced at the commencement of these researches — has resisted all criticism and on this account is now almost universally adopted.

It is now nearly seventy years since Dr. Le Bon proved by experiment that the phenomena observed in substances termed radioactive — such as uranium — could be observed in all substances in nature, and could only be explained by the dissociation of their atoms.

The action of light on any substance, a lighted lamp, chemical reactions of very different kinds, an electric discharge, etc., cause these effluxes to appear. Substances termed radio-active such as uranium or radium, simply present in a high degree a phenomena which all matter possesses to some extent. When Dr. Le Bon formulated for the first time this generalization, though it was supported by very precise experiments, it attracted hardly any attention. In the whole world one physicist, the learned Prof. De Heen, alone grasped its import and adopted it after having verified its perfect correctness. But the experiments being too convincing to permit of long challenge, the doctrine of the universal dissociation of matter at last triumphed. The atmosphere was then cleared, and physicists no longer denied that this dissociation of matter — this radioactivity as it is now called — is a universal phenomenon widely spread throughout the universe; and, as Prof. J. J. Thomson demonstrated, exists in most substances — water, sand, granite, clay, bricks, etc.

What becomes of matter when it dissociates? Can it be supposed that when atoms disaggregate they only divide into smaller parts and thus form a simple "dust of atoms"? We shall see that nothing of the sort takes place, and that matter which dissociates dematerializes itself by passing through successive phases which gradually deprive it of its material qualities until it finally returns to the rate of vibrations whence it seems to have issued as energy.

When the fact is once recognized that atoms can dissociate and reappear as energy and then from energy back to matter then the question arises as to whence they obtain the immense quantity of energy necessary to launch into space, particles with a speed of a same order as light or *greater*.

The explanation in reality is simple enough, since it is verified that far from being an inert thing only capable of giving up the energy artificially supplied to it, matter is an enormous reservoir of energy, intra cosmic energy.

Such a doctrine years ago assailed too many then accepted fundamental scientific principles to be at once admitted. Accustomed to regard the rights, the rigid principles of thermodynamics as absolute truths, and persuaded that an isolated material system could possess no other energy than supplied from without, a majority of physicists long persisted in seeking outside of it the sources of the energy manifested during the dissociation, not disintegration of matter. Gradually we are coming to see the facts.

The reality of this form. of energy is proven by experimental facts. Cosmic energy is the most powerful of known forces, and is the origin of most others including intra atomic energy.

Matter, formerly regarded as inert and only able to give back the energy originally supplied to it, is, on the other hand, a colossal reservoir of energy intra-atomic and intra-cosmic energy which can be expended without borrowing anything from without.

It is from the intra-sonic energy manifested during the dissociation of matter that most of the forces in the universe are derived, notably electricity and solar heat.

Force and matter are two different forms of one and the same thing. Matter represents a stable form of intra-atomic energy; heat, light, electricity, etc., represent instable forms of it (cosmic energy).

In the dissociation of atoms, the stable form of energy termed matter is simply changed into those unstable forms known by the names of electricity, light, heat, etc.

For the examination of these several propositions let us, as a basis of presentation, take them as proved and seek at once the changes they bring about in a general conception of the mechanism of the universe.

The problem of the nature of matter and of force is one of those which has most exercised the sagacity of scientists. Its complete solution has escaped us because it really implies the knowledge, still inaccessible, of the first cause of things. Scientific theories heretofore set forth have not allowed us to completely solve this great question. They lead, however, to a conception of matter and energy far different from that in use at the present day, cosmic energy.

We can arrive at the conclusion that matter is an immense reservoir of energy solely constituted by a system of vibrating atoms maintained in equilibrium by the rotations, attractions and repulsions of matter's component parts. From this equilibrium result the material properties of bodies such as weight, form, and apparent permanence. Matter also represents movement, but the movements of its component elements are confined within a very restricted space. This conception leads us to view matter as a variety of energy. To the known

forms of energy — heat, light — there must be added another — energy from the cosmos which embraces but surpasses intra-atomic energy. This energy is characterized by its colossal greatness and its unlimited accumulation with everything in the universe.

It follows from the preceding statements that by dissociation of matter one is simply giving to the variety of energy which fills all space in a different form — such as, for example, what we call electricity or light but in reality are radiations or forms of vibrations, their proper status.

We will endeavour to give an account of the forms under which this energy of the universe may be condensed within the atom, and the cosmos, but the existence of the fact itself has a far greater importance than the theories it gives rise to of simple atomic energy. Without pretending to give the definition so vainly sought for of energy, we will content ourselves with stating that all phenomenality is nothing but a transformation of equilibrium. When the transformations of equilibrium are rapid, we call them electricity, heat, light, all forms of vibration. When the changes of equilibrium are slower, we give them the name of matter. To go beyond this we must wander into the region of hypothesis and admit that the elements of which the aggregate is represented by forces in equilibrium, are constituted by vortices formed in the midst of the universe. These vortices possess an individuality, supposed by some to be ephemeral but which the evolution of matter and of energy prove to be eternal. The individuality disappears, and the vortex dissolves as soon as the forces which maintain their existence cease to act but others form elsewhere, i.e. eternal creation, eternal evolution, eternal energy and matter.

The equilibriums of these elements of which the aggregate constitutes an atom, may be compared to those which keep the planets in their orbits. So soon as they are disturbed considerable energies manifest themselves, as they would were the earth or any other planet stayed in its course.

Such disturbances in planetary systems may be realized, either without apparent reason, as in very radioactive bodies when, for diverse reasons, they reached a certain degree of instability, or artificially — as in ordinary bodies when brought under the influence of various excitants — heat, light, or other forms of vibration.

These excitants act in such cases like the detonator of an explosive — that is to say, by freeing quantities of energy greatly in excess of the very slight cause which has determined their liberation. And as the energy condensed in the universe is immense in quantity, it results from this that to an extremely slight loss in matter there corresponds the creation of an enormous quantity of energy.

From this standpoint we may say of the various forms of energy such as heat, electricity, light (all vibrations), represent the last stages of matter before it returns into the cosmos from whence it came.

If, extending these ideas, we wish to apply them to the differences presented by the various simple bodies studied, we should say that one simple body only differs from another in rate of vibration. If we could deprive any element of a sufficient quantity of the energy it contains, we should succeed in completely transforming it.

As to the necessarily hypothetical origin of the energies condensed within the atom, we will seek for it in a phenomenon analogous to that invoked by astronomers to explain the formation of the sun, and of the energies it stores up. To their minds this formation is the necessary consequence of the condensation of the primitive nebula. If this theory be valid for the solar system, an analogous explanation is equally so for all matter.

Such a theory clears away the classical duality of matter and energy. These are two identical things under different aspects. There is no separation between matter and energy, since matter is simply a stable form of energy and nothing else and continually changes from one to the other in the cosmos.

We can only understand things by fitting them into the common frame of our thoughts. The essence of energy being unknown, we are compelled to materialize it in order to enable us to reason about it. We thus arrive — but only for the purposes of demonstration — at the following definitions: Energy and matter represent entities of the same order. The various forms of energy — electricity, heat, light — are manifestations of matter in action. They only differ in the nature and the stability of the equilibrium formed in the heart of the cosmos. It is through these manifestations that the universe is known to us.

The illustrious Faraday endeavored to clear away the duality existing between matter and energy. Others made the same attempt, by pointing out that matter was only brought home to us by the intermediary of forces acting on our senses. But all arguments of this order were considered as having a purely metaphysical bearing. It was objected to in Faraday's time that it had not been possible to transform matter into energy, and that this matter was necessary to animate the former. Scientific principles, considered assured, taught that nature as a kind of inert reservoir could create the liquid it holds. Everything seemed then to point out that nature and energy were irreducible things as independent one of the other as weight is of color. It was therefore not without reason that they were taken as belonging to different worlds.

The transformation of matter into energy having been demonstrated, it follows that energy may be transformed into matter.

The facts summed up in the preceding pages show that matter in a set form is not eternal but as a rate of vibration or energy is eternal, that it constitutes an enormous reservoir of vibrations, and that it disappears by

transforming itself into other forms of energy or matter before returning to its source, being in reality just another cycle in the process of creation.

It can therefore be said that if matter cannot be created, it cannot be destroyed but returning to its source begins a cycle again. The elements of a substance which is burned or sought to be annihilated by any other means are transformed and are but a change of vibration. They may lose every quality of matter, including the most fundamental of them all — weight — but that only shows gravity lost its power over such elements because of a change in vibration. The theoretical importance of these principles is considerable but self-evident.

It is easy to deprive matter of all its attributes, save one. Solidity, shape, color, chemical properties may disappear but there remains a rate of vibration. The very hardest body can be transformed into an invisible vapor. But, in spite of every one of these changes, the mass of the body, as measured by its weight, remains invariable, and by changing or restoring rates of vibrations can be made to reappear; this constituted the one fixed point in the mobile ocean of phenomena, vibration. It enables the chemist, as well as the physicist, to follow matter through its perpetual transformations, and this is why matter remains something mobile and eternal.

The importance of permanence and, therefore, the indestructibility of vibration which one recognizes throughout the changes in matter, being the only characteristic by which this great unknown conception can be grasped, necessarily became preponderant.

These fundamental dogmas, the bases of modern science, the researches detailed in this work tend to destroy. If the principle of the conservation of energy — which is simply a bold generalization of experiments made in very simple cases — likewise succumbs to the blows which are already attacking it, the conclusion must be arrived at that nothing in the world is eternal in a set form but subject to changes of rate of vibration. The great divinities of science could also be condemned to submit to that invariable cycle which rules all things.

On the ruins of former doctrines and after centuries of persistent efforts, there sprang up two sovereign powers which seemed eternal — matter as the fundamental woof of things and energy to animate it, the two being one on different rates of -vibration. With the equations connecting them, modern science thought it could explain all phenomena. In its learned formulas all the secrets of the universe were enclosed. The divinities of old time were replaced by ingenious systems of differential equations.

Discovery is rarely spontaneous; it only appears so because the difficulties and the hesitations which most often surround its inception are generally unnoticed.

The public troubles itself very little with the way in which inventions are made, but psychologists should certainly be interested in certain sides of the problems of inventions. In fact, they will find therein valuable documents on the birth of beliefs, on the part played, even in laboratories, by suggestions and illusions, and finally on the preponderant influence of prestige considered as a principal element of demonstration which much of the time surplanted facts.

The generality of the phenomenon of the dissociation of matter would have been noticed much sooner if a number of known facts had been closely examined, but this was not done. So also is this true of the law of oscillations by vibrations of the universe. These facts were spread over very different chapters of physics. For example, the loss of an electric charge occasioned by ultraviolet light has long been known, but not one little thought connecting the fact with a cathode ray. More than 75 years ago Niepe de Saint-Victor saw that, in the dark, salts of uranium caused photographic impressions for several months; but as this phenomenon did not seem to be connected with any known fact, it was put to one side as the oscillations of the cosmos are now. For hundreds of years the gases of the oscillations or vibrations of the universe have gone unappreciated. The common link which connects them appeared clearly when we established that the dissociation of matter and the forms of energy which result from it are to be ranked among the most widely spread natural phenomena. Flames had been observed to discharge electrified bodies without any one determining the exact cause of this phenomenon/. The loss of electric charges through the influence of light had been known for many years but it was regarded as a fact peculiar to a few metals with no suspicion of how general and important this law was.

All this phenomena and many others, such as electricity and solar heat — are very dissimilar in appearance, but are the consequences of the same fact — namely, the dissociation of matter.

The discovery of the dissociation of matter by radiation has allowed us to penetrate into an unknown world ruled by new forces, where matter losing its properties as we had known it, becomes a form which passes without difficulty through obstacles, and possesses a whole series of unforeseen properties, the farreaching effect of which we have yet a great deal to learn about.

With the discovery of the universal dissociation of matter is linked to that of intra-atomic energy and energy of the cosmos by which science has succeeded in explaining some radioactive phenomena.

The origin of intra-atomic energy is not difficult to elucidate, if one supposes, as do the astronomers, that the condensation of our nebula suffices by itself to explain the constitution of our solar system. It is conceivable that an analogous condensation of the cosmos may have begotten the energies contained in the atom. The latter may

be roughly compared to a sphere in which a non-liquefiable gas was compressed to the degree of thousands of atmospheres at the beginning of the world.

The reason this force (the most widespread and the mightiest of all those of nature) has remained unrecognized so long is in the first place because man lacked the reagents necessary for the proof of its existence and then, because the theory and atomic edifice erected by science were so stable, so solidly fixed in our minds that its dissociation and connection with the cosmos remained extremely slight. Had it been otherwise the world would long ago have utilized cosmic energy*

But how is it that a demonstration so simple as that of the existence of cosmic radiant energy has not been made since the discovery of radioactivity, and especially since the demonstration of the generality of this phenomenon? This can only be explained by bearing in mind that it was contrary to all accepted principles to recognize that matter or the energy of the universe could by itself produce energy. Scientific dogmas inspire the same superstitious fear as did the gods of old, though they have at times permitted all their liability to be broken.

The fact of the existence of a considerable condensation of energy within the atoms of the universe only seemed at first to annoy us because it was outside the range of things formerly taught us by experience; it should however be remarked that, even leaving on one side the facts revealed by radioactivity, analogous concentrations are daily observable. Is it not strikingly evident, in fact that electricity must exist at an enormous degree of accumulation in all substances of the universe since it is found by the electrolysis of water that one gramme of hydrogen possesses an electric charge of 96,000 coulombs? One gets an idea of the degree of condensation at which electricity existed before its liberation in all the universe. Elementary treatises have long since pointed out that barely a twentieth part of the above quantity would suffice to charge a globe the size of the earth to a potential of many thousands of volts. The best static machines of our laboratories hardly give forth. 1/10,000 of a coulomb per second.

They would have, consequently, to work unceasingly for a little over 30 years to give the quantity of electricity contained within the atoms of one gramme of hydrogen.

As electricity exists in a state of considerable concentration in all matter, it is evident that the atoms of the universe should have been regarded many years ago as a veritable capacitor of energy. One should have recognized the quantity of this energy must be enormous; it was only necessary to appreciate the magnitude of the attractions and repulsions which are produced by electric charges before us. It is curious to note that several physicists years ago have touched the fringe of this question without perceiving its consequences. For example, Cornu pointed out that if it were possible to concentrate a charge of another sphere also having a charge of one coulomb, the force created by this repulsion would equal 918 dynes, or about 9 billions of kilogrammes.

What about the stars and planets of the universe? We know that by the dissociation of water we can obtain from one gramme of hydrogen an electric charge of 96,000 coulombs. This energy would be enough (and this is exactly the hypothesis enunciated by J. J. Thomson) to dispose the electric particles at suitable distances within the universe to obtain through their attractions, repulsions, and rotations, extremely powerful energies in an extremely small space. The difficulty was not, therefore, in conceiving that a great deal of energy could remain within any atom, not just a radioactive one, but that nature was supplying us from the universe usable energy if we but reached out to harness it. It is surprising that a notion so evident was not recognized long ago.

Calculation of radioactive energy has been made within those limits of speed at which experiments show that the inertia of matter does not greatly vary.

Science formerly established a complete separation between matter and energy. The classic ideas on this decision will be shown in the following passage of a work by Prof. Janet:

"The world we live in was thought, in reality, a double world; or, rather it was composed of two distinct worlds — one the world of matter, the other the world of energy. Copper, iron, and coal are forms of matter, mechanical labor and heat are forms of energy. These two worlds are each ruled by one and the same law. Matter can neither be created nor destroyed. Energy can neither be created nor destroyed, therefore we can rightly observe that as energy and matter are one in different stages we have but one world in the evolution of matter and energy.

"Matter and energy can assume various forms without matter transforming itself into energy or energy into matter — We can no more conceive energy without matter than we can conceive matter without energy."

It is utterly impossible," Lord Kelvin wrote, "that the heat produced can proceed from the stored energy of radium. It therefore seems to me absolutely certain that if the emission of heat continues at the same rate, this heat must be supplied from outside."

Lord Kelvin fell back on the commonplace hypothesis formed at the outset on the origin of the energy of radioactive bodies, which were attributable, as it was then believed, to some mysterious forces from the ambient medium. This supposition had no experimental support. It was simply the theoretical consequence of the idea

* Let us here remind the reader this theory was first given to the world by Moray as early as 1914 and 1926 first published in printed book form in 1931.

that matter being entirely unable to create energy, could only give back what had been supplied to it. The fundamental principles of thermodynamics which Lord Kelvin had helped so much to found, tell us, in fact, that a material system isolated from all external action cannot spontaneously generate energy. Experiment is superior to principles, and when once it has spoken, those scientific laws which appeared to be the most stable are condemned to rejoin in oblivion, the used-up, worn-out dogmas and doctrines of the past.

It would be desirable, even in this so-called atomic and space age, to have the theory which explain the facts, and to enable science to know whether the energy is borrowed from the atom itself or from external sources from the universe.

Many physicists, like Lord Kelvin, held to the end to the old principles; that is why the phenomena of radioactivity, especially the spontaneous emission of particles animated with great speed and the rise in temperature during radioactivity, seem to them utterly unexplicable, and constitute a scientific enigma, as M. Mascart said. The enigma, however, is very simple with the proper explanation. Today there is an enigma on the use of cosmic power for commercial purposes.

One can hope, however, that ideas so opposed to classical dogmas as oscillatory cosmic energy and the transforming of matter into energy and energy into matter will soon be widely acknowledged.

The fact is that the scientific ideas which rule the minds of men at various epochs have all the solidity of religious dogmas. Very slow to be established, they are very slow likewise to disappear. New scientific truths, although they have experience and reason as a basis, are only propagated by prestige, that is, when they are enunciated by those whose official position gives them prestige in the eyes of the scientific world. Truths of such great importance as Ohm's law which governs the whole of electricity, and the law of the conservation of energy which governs all physics, were received, on their first appearance with indifference or contempt and remained without effect until the day when they were enunciated anew by individuals endowed with influence. Now we limit the conservation of energy without fully understanding what truths it embraces.

It is only by studying the history of sciences that one succeeds in understanding the genesis of beliefs and the laws governing their diffusion. We have just mentioned two discoveries which were among the most important of the 19th Century, and which are summarized in the laws, of which one can say that they ought to have appealed to all minds by their marvelous simplicity and their imposing grandeur. Now tradition fences them in where we fail to see their magnitude. Not only did they strike no one, but the most eminent scientists of that time did not concern themselves about them except to try and cover them with ridicule. Are we different today?

That the simple enunciation of such doctrines should have appealed to so few shows with what difficulty a new idea is accepted when it does not fit in with former dogmas. Prestige, we repeat, and to a very slight extent, experience are alone the ordinary foundation of our convictions — scientific and otherwise. Even the most convincing experiments have never constituted an immediately demonstrable foundation when they clashed with long established accepted ideas that we hate to discard even when the old dogmas have been proven wrong. Galileo learned this when, having brought together all the philosophers of the celebrated University of Pisa, he thought to prove to them by experiment that, on the contrary to the then accepted ideas, bodies of different weights fell with the same velocity. Galileo's demonstration was assuredly very conclusive, since by letting a small leaden ball and a cannon shot of the same metal fall at the same moment from the top of a tower, he showed that both bodies reached the ground together. The professors contented themselves with appealing to the authority of Aristotle and would not change or modify their opinions. For years it has been the same with R. E. demonstrations especially by those who never saw the device.

Galileo lived a long time ago, but the degree of receptivity of minds for new things has not sensibly increased.

*When Ohm discovered the law which immortalized his name and, on which the whole science of electrical measurement rests he published it in a book filled with experiments so simple and so conclusive that they might have been understood by any child in an elementary school. Not only did he fail to convince anyone, but the most influential scholars of his time treated him in such a way that he lost the berth he occupied, as a college professor, and, to avoid dying of starvation, was only too glad to take a situation in a college at 1,200 francs per annum, where he remained for 6 years. Justice was only rendered to him at the close of his life. Robert Mayer, less fortunate, did not even obtain this belated satisfaction. When he discovered the most important of modern scientific laws, that of all the examples of the conservation of energy the vibrations of the universe is the greatest example, he had great difficulty in finding a publisher who would consent to publish his findings; no scholar bestowed the least attention upon it, no more in fact than on his subsequent publications, among which was the one on the mechanical equivalent of heat, published in 1850. After attempting suicide, Mayer went out of his mind, and remained for a long time unknown, to such a degree that when Helmholtz re-made the same discovery, he was not aware of the work of Mayer. Helmholtz himself did not meet with any greater encouragement to begin with and the most important of the scientific journals of that day, the *Annals de Poggendorff*, declined to insert his celebrated memoir, "The Conservation of Energy," regarding it as a fanciful speculation unworthy of the attention of serious readers.*

Although matter was formerly considered inert, and only capable of preserving and restoring the energy which had first been given to it, it was necessarily established that there existed within it forces sometimes in considerable amounts, such as cohesion, which forces were independent of all external agents. Other forces, such as radiant heat and electricity, which also issued from matter, might be considered simple restitutions of an energy borrowed from the cosmos.

If the cohesion which makes a rigid block out of the dust of atoms of which bodies are formed, or if that affinity which draws apart or dashes certain elements one upon the other and creates chemical combinations, or if the osmotic attractions are repulsions which hold in dependency the most important phenomena of life, are visibly forces inherent to matter itself, then it was, with the old ideas, impossible to determine the source of this energy. The origin of these forces ceases to be mysterious when it is known that the cosmos is a colossal reservoir of energy that fills all space. Observation has long ago shown that any form of energy lends itself to a large number of transformations, and we can conceive how energy from the cosmos may be the source of all molecular forces — cohesion, affinity, etc. — of matter. We are far from being acquainted with their character, but at least we see the source from which they spring, the universe where matter is "born" from energy.

Outside the forces plainly inherent to matter that we have considered, there are two — electricity and solar heat — the origin of which has always remained unknown, and for which we can find an explanation in the theory of intra-atomic energy and inter-cosmic energy, the cradle of the intra-atomic energy.

When we approach in detail the study of the facts on which their theories are based, we find that electricity is one of the most constant manifestations of the dissociation of matter. Matter being nothing else than cosmic energy itself, it may be said that to dissociate matter is simply to liberate a little intra-atomic energy throughout the universe and to oblige it to take another form. Electricity is precisely one of these forms.

Throughout the years the role of electricity has constantly grown in importance. It is at the base of all chemical reactions; it is a universal force, and one must connect all other forms with it. That a force with the manifestation importance and universality of electricity should have remained unknown for thousands of years constitutes one of the most striking examples of apathy in the history of science, and is one of those facts we must always bear in mind to understand how we may be surrounded with every powerful force without fully realizing their existence. Power from the cosmos radiant energy is another similar example.

For centuries all that was known about electricity could be reduced to this, that, certain resinous substances when rubbed attract light bodies. Could not other bodies enjoy the same property? By extending the friction to larger surfaces might not more intense effects be produced? This was the one question of inquiring. However, ages passed before a mind arose penetrating enough to ask itself, "The where and why-for," — one inquisitive enough to verify by experiment whether a body with a large surface when rubbed would not exercise an action superior in energy to that produced by a small fragment of the same body. From this verification which now seems simple, but which took centuries to accomplish, we saw emerge the frictional electric machine and the phenomena it produces. Why not now let it emerge from the oscillations of the universe and put into the hands of man a power which he one time thought the gods alone possessed the secret to.

Electricity was then only produced very laboriously and was considered a very exceptional phenomenon. Now we find it everywhere and know that the simple contact of two heterogeneous bodies suffice to generate it. The difficulty now is not how to produce electricity, but how not to give birth to it during the production of any phenomenon whatever. The falling of a drop of water, the heating of a gaseous mass by the sun, the raising of the temperature of twisted wires, the burning of a match, and any action capable of modifying the nature of a body, are all generators of electricity.

If all chemical reactions are electrical reactions, as is now proven to be the case, if the sun cannot change the temperature of a body without disengaging electricity, if a drop of water cannot fall without its manifestation, it is evident that electricity's role in all forms of life must be preponderant. This, in fact, is what the world is beginning to admit. Not a single change takes place in the cells of the body, no vital reaction is effected in the tissues without the intervention of electricity. M. Berthelot showed the important roles of the electric tensions to which plants are constantly subjected. The variations in the electric potential of the atmosphere is enormous, since they may oscillate between 600 and 800 volts in fine weather, and rise to 15,000 volts at the least fall of rain. This potential increases at the rate of from 20 to 30 volts per metre in height in clear to from 400 to 500 volts in rainy weather for the same elevation. "These figures," Berthelot said, "give an idea of the potential which exists either between the upper point of a rod of which the other extremity is earthed, or between the top of a plant or a tree, and the layer of air in which that point or that top is bathed. M. Berthelot also proved that the effluves generated by these differences of tension can provoke numerous chemical reactions—the fixation of nitrogen on hydrates of carbon, the dissociation of carbonic acid into carbonic oxide and oxygen, etc. Why go back to these scientists of yesteryear? Only to show that much we are doing today does not originate with the Atomic Age! There were thinkers before our day. After having established the phenomenon of the general dissociation of matter, let us ask ourselves if the universal electricity, the origin of which remained unexplained, was not precisely the consequence of the universal displacement of matter. Experiments fully verified this

hypothesis, and they proved that electricity is one of the most important forms of intra-atomic energy liberated by the displacement of matter. The various methods employed to obtain electricity, notably friction, only hasten the dissociation of matter. Now let us turn to vibratory oscillations of the universe.

CHAPTER THREE

THE DISSOCIATION OF MATTER

As we study the dissociation of matter, so will the importance of this phenomenon proportionately increase. After recognizing that, electricity may be considered one of the manifestations of the vibration of matter.

To maintain that stars such as the sun can keep up their own temperature by the heat resulting from the dissociation of their component atoms, seems much like saying that a heated body is capable of maintaining its temperature without any contribution from outside.

Atomic reactions cool, simply because the rise in temperature produced during the dissociation of its atoms producing the incandescence is far too slight to compensate for its loss of heat by radiation. The substances which, like radium, most rapidly dissociate, can hardly maintain their temperature at more than 3° to 4° C. above that of the ambient medium. Suppose, however, that the dissociation of any substance whatever were only one thousand times more rapid than that of radium, then the quantity of energy emitted could more than suffice to keep it in a state of incandescence.

The whole question therefore is whether, at the origin of things, that is to say at the epoch when atoms were formed by condensations, did they not possess such a quantity of energy or rate of vibration that they have been able ever since to maintain the stars in a state of vibration, thanks to their slow dissociation. This supposition is supported by various experiments. J. J. Thomson arrived at the conclusion that the energy now concentrated within the atoms is but an insignificant portion of that which they formerly contained and lost by radiation. Independently and at an earlier date, Prof. Filippo R'e arrived at the same conclusion. If, therefore atoms formerly contained a quantity of energy far exceeding the still formidable amount they now possess, they may, by dissociation, have expended during long accumulations of ages a part of the gigantic reserves of forces piled up within them at their source in the universe. They may have been able, and consequently may still be able, to maintain a very high rate of vibration, i.e., stars, like the sun and the heavenly bodies. In the course of time, however, the store of intra-atomic, energy within the atoms of certain stars may at length be reduced, and their dissociation and rate of vibration become slower and slower. Finally, they have acquired an increasing stability, have dissociated very slowly, and have become such as one observes them today in the shape of cooled stars like the earth and other planets.

If the theories thus formulated are correct, and this the experiments of the Moray Radiant Energy discoveries so indicate, then intra-atomic energy manifested during the dematerialization of matter constitutes the fundamental element from which most other forces are derived. So it is not only electricity which is one of its manifestations, but also solar vibrations, the primary source of life and of the majority of the forces at our disposal. This study, which reveals to us matter in a totally new aspect, permits us to throw unforeseen light on the higher mechanics of the universe.

The interest now being shown in spontaneously radioactive substances consists in their emitting in considerable quantity,, elements which other bodies only produce in much smaller quantity. By thus enlarging on this general phenomenon, we encourage it's study in more detail, as also the rate of vibration in all things.

Rutherford, who studied radioactive substances with great success and, with Curie, discovered facts concerning rays from them, led to the designation of the radiations as Alpha Beta Gamma. The Alpha radiations are composed of positive ions, the Beta radiations of electrons identical with those constituting the cathode rays, while the Gamma radiations are similar to the X-rays. Did these pioneers build better than they realized in showing the way?

Alpha particles are formed of positive ions. They are deviated by an intense magnetic field, but in the opposite direction to the Beta rays or particles. The radius of curvature of their deviation is 1000 times greater than that of the Beta particles. They form 99% of the total radioactivity of radium. They render air a conductor of electricity. Their action on a photographic plate is much less than that of the Beta rays, and their force of penetration very slight, since they are stopped by a sheet of paper. This weak power of penetration enables them to be easily differentiated from the other radiations to which paper is no obstacle. Of all the emission of radioactive bodies, it is the Alpha particles especially which make the air a conductor of electricity, and it is the Beta particles or rays which produce photographic impressions. When a radioactive body is enclosed in a glass tube nearly all the Alpha particles are stopped by the glass walls but inside those glass walls great things take place because of their electrical conducting ability.

It is supposed, from various calculations, that the Alpha particles must have a mass equal or superior to that of the hydrogen atom and a like charge. Their speed, as calculated from the extent of their deviation by a magnetic field of given intensity, is one-tenth that of light. For uranium and thorium, it is for one gramme, 70,000 per second, and for radium a hundred thousand millions. This emission may last without interruption for more than 100 years.

The emission of alpha particles, positive ions, is, together with the production of the emanation, the fundamental phenomenon of radioactivity. The emission of beta particles and that of the gamma rays, which together form hardly 1 % of the total emission, should represent a further stage in the dissociation of radioactive atoms. How puny are these compared to the total energy in the cosmos but how close the relationship.

On striking phosphorescent bodies the alpha particles render them luminous. It is this property which is the basis for the operation of the spinthariscopes, an instrument which renders visible the permanent dissociation of matter. It consists of a screen of sulphide of zinc, above which is placed a small metal rod, the end of which has been dipped in a solution of chloride of radium. On examining the screen through a magnifying glass, there can be seen spurting out without cessation, a shower of small sparks produced by the impact of the alpha particles and the emission may last for centuries. This shows the extreme smallness of the particles coming from the disaggregation of atoms. This emission is visible because each particle is made apparent through the enormous degree of lateral perturbation produced by its shock on the sensitive surface, in the same way that raindrops falling into the water produce ripples which exceed their diameter. One may, by using certain varieties of phosphorescent sulphide, succeed in making screens showing the phenomena of dissociation, not only with salts of radium, but also with other substances. Herein is the door to greater discoveries.

The high speed of the alpha particles seems very difficult to explain. This speed is intelligible enough in the case of the beta rays, which, being composed of atoms of pure electricity, and having a very small inertia can acquire a very high speed under the influence of limited forces; but the Alpha particles whose dimensions would appear to be identical with that of the hydrogen atom, a velocity of 30,000 kilometres per second seems to be more difficult to explain. It could prove profitable if these experiments of Rutherford and his co-workers were taken up again.

These velocities may not be produced instantaneously; they are only comprehensible on the hypothesis that the particles of atoms can be compared to small planetary systems animated with enormous velocities. They would preserve their speed on leaving their orbits as does a stone launched from a sling. The invisible speed of rotation of the elements of matter would therefore be simply transformed into a speed of projection perceptible only by proper instruments.

Beta rays are considered to be composed of electrons identical with those of the cathode rays. They are formed of negative electric atoms freed from all matter. Their mass is similar to that of the cathode particles, the thousandth part of that of the hydrogen atom. Their velocity varies between 33% & 96% of that of light.

They immediately render luminous by impact bodies capable of phosphorescence, even when separated from them by aluminum foil. The phosphorescence is very bright in platinocyanide of barium and some kinds of diamonds which are rather rare, but are capable of phosphorescence.

In addition to alpha and beta particles, the first charged with positive, and the second with negative electricity, radioactive bodies emit an extremely slight proportion (less than 1%) of gamma rays which are entirely analogous, as to their properties, to X-rays, but possessing a higher power of penetration, since they can penetrate several centimeters of steel. This property enables them to be easily distinguished from alpha and beta rays, which are stopped by a lead plate a few millimeters thick*.

One of the singular properties of alpha-beta-gamma emissions is that none of them can touch a gaseous or solid body without immediately causing, no doubt through the disturbance produced by their enormous velocity, a dissociation resulting in the production of secondary rays, which are similar in their properties to the primary rays, but less intense. These secondary radiations also impress photographic plates, render the air a conductor of electricity, and are deviated by a magnetic field. They are able to produce by their impact tertiary rays having the same properties. It is the secondary rays produced by the gamma rays which are the most active. A photographic impression through a metallic plate is sometimes intensified by the interposition of that plate, because the action of the secondary rays then superimposed on the primary rays. Herein may lie a prototype of the action of the universe.

Emanations can be cheaply drawn from any highly radioactive body either by dissolving in liquid placed in a receiver communicating with a closed tube and subjecting the radioactive substance to certain ray bombardment or by bringing them to a red heat in a similar apparatus and bombarding them with rays. The emanation drawn into the tube renders it phosphorescent. It can be condensed in liquid air. This condensation is revealed by the localization of the phosphorescence.

At ordinary temperature radioactive bodies in a solid state emit the emanation, but only a hundredth part of the quantity omitted in a state of solution and under bombardment of certain rays. By introducing sulphide of zinc into a bulb containing a solution of chloride of radium, the disengagement of the emanation renders the sulphide phosphorescent. Radium, when heated, loses the greater part of its activity because of the quantity of emanation it gives off, but it regains it again in about 20 days. The same loss occurs when a solution of this salt is heated to boiling.

* Written by Moray in Europe in 1914 when these penetration values were valid.

When solid chloride of radium has been brought to a red heat, or a solution of it has been boiled for some time, or better still, subjected to special ray bombardment, it still preserves a quarter of its primary activity, but this latter is then solely due to the alpha particles as can be noted by the weak penetrating power of the rays emitted, when can no longer pass through a sheet of paper. It is only after a certain lapse of time that the appearance of the beta rays, capable of passing through metals, again takes place. The activity of the emanation is lost rather quickly. The rapidity of this loss varies according to the substance. That of actinium is destroyed in a few seconds, that of thorium in a few minutes, that of radium only at the end of three weeks, but is reduced to one-half in 4 days.

Radium and thorium produce different energy levels of emanations, that is, of dissociations which begin with the emission of the emanations. Five or six have been counted. The first engenders the second, and so on. They, no doubt, represent successive stages in the evolution of matter.

To these emanations are due three-fourths of the heat continually produced by radium, which maintains its temperature of 3° or 4°c. above its surroundings. If radium be deprived of its emanation by heating, it gives out about a quarter of the heat it emitted before heating. Almost all of the rise in temperature is due to the alpha particles. If some emanation of radium is left for several days in a tube, one can observe the spectral lines of helium which were not there before.

Before drawing too many conclusions from this transformation, it must be first remarked that helium is a gas which accompanies all radioactive minerals. It was from these bodies that it was first obtained. This gas enters into no chemical combination, it will not liquify and can be kept for indefinite time in the tube in which it is enclosed, a catechist of interesting effect.

This derivative from radium is a special helium since it appears to possess the property of spontaneously vanishing. Its only resemblance to ordinary helium seems to consist of the momentary presence of some spectral rays.

The emanation disintegration products of the radioactive bodies represents one of the intermediate substances. It is partly material, since it can be condensed and dissolved in certain acids and recovered by evaporation. But it is only incomplete material, since it ends by entirely disappearing and transforming itself into electric particles and secondary particles. This transformation, which takes place even in a sealed glass tube, has been proved by experimentation.

Matter and energy! Where can one draw the line? The part played by various radiating substances in the phenomena of energy and life is a very predominant one. Most often it is the indirect reactions which reveal their existence in the phenomena of life and allow them to be isolated. All we know of them in their physiological reactions is that they lose their properties if deprived of the infinitely small quantities of mineral matter which they contain under a form that we suppose to be in the ionic state.

Why go into these reactions? Because they may to a degree help us to understand natural phenomena of the cosmos and of life because there is a parallel of phenomena.

Among the substances of which one might strictly say act only by their presence is found the vapor of water, which in extremely small amounts play an important part in various reactions. Perfectly dry acetylene is without action on hydride of potassium, but in presence of a trace of humidity the two bodies react one on the other with such violence that the mixture becomes incandescent. Well-dried carbonic acid is also without action on hydride of potassium, but in presence of a slight quantity of steam it produces a formate. It is the same with many other bodies — ammonia gas and hydrochloric gas, for example, which ordinarily combine with the emission of thick white fumes, but do not do so after having been carefully dried. It will be remembered that by adding to dried salts of quinine traces of water vapor they become phosphorescent and radioactive.

Although catalytic actions were known many years ago it was only in later years that they proved to play a preponderant part in the chemistry of living beings. It is admitted that the diastases and various ferments whose role is so important act only by their presence.

On closely examining the role of bodies acting by their mere presence, we note that they behave as if energy were transported from the catalyzing body to that catalyzed. This fact can hardly be explained unless by acknowledging the catalyzing body is undergoing the commencement of atomic dissociation. We know that, by reason of the enormous velocity possessed by particles of matter during its dissociation, considerable quantities of energy can be produced by the dissociation of a quantity of matter so small as to elude all attempts to measure it. The catalyzing substances could therefore be simply liberators of energy in matter on the earth and in all the universe. As in the atomic pile the fission material is worn out so also platinum black and the colloid metals are eventually worn out — that is to say, by use they lose a great part of their catalyzing action. The theory involved indicates all matter and energy simply represent a state of equilibrium between the internal elements of which it is formed and the external elements acting upon it. If this connection is not plainly apparent in some bodies, it is because they are so constituted that their equilibrium maintains themselves without perceptible changes within the limits of fairly large variations of the medium. Water can remain liquid in variations of temperature ranging

from 0° to 100°C., and most metals do not appear to change their state within still wider limits of heat or of rates of vibration. However, these facts do not answer all the questions.

Succession of changes will be accompanied by the liberation of a certain quantity of the intra-atomic energy contained in matter. This is going on all the time in the cosmos to such an extent man with his man-made devices can never hope to compete. So why not use "nature's gift" of cosmic reactions? The actions by mere presence which are of such importance in the phenomena of life, may perhaps find an explanation in this theory. It was such studies on phosphorescence which led men to this hypothesis. It will be recollected that pure substances, various sulphides, phosphates of lime, etc., are never phosphorescent normally, and only become so when brought to a red heat for a length of time with traces of other various bodies — such as bismuth, maganese, etc. On the other hand, this elevation of temperature always provokes a dissociation of matter. It is therefore reasonable to suppose that the elements proceeding from this dissociation have an active part in the compounds then formed, which gives to such bodies the capacity of phosphorescence and sometimes other properties.

The combinations so obtained have precisely the characteristics pointed out above as belonging to extreme mobility, that is to say, of disintegrating and then regenerating themselves very rapidly. A ray of blue light falling on a screen of sulphide of zinc, illuminates it in the tenth of a second, and a ray of red light falling on the same screen, disintegrates the phosphorescence in the same space of time, that is it brings the screen back to its original state. These two contrary operations, necessarily implying two converse reactions which may be indefinitely repeated.

These facts prove that by reason of the enormous quantity of intra-atomic energy contained in matter, a loss substance too small to be detected by an analytical balance may be accompanied by a very greater liberation of energy. We have no need to do this artificially because it is being done for us in the cosmos.

It is possible even without the action of heat to verify in ordinary bodies the existence of a constant emanation from the dissociated matter, though this emanation normally is extremely small in quantity. This all proves that the evolution of creation is going on continually.

To cause it to be apparent, it is necessary to compel it to accumulate in a restricted space. In order to demonstrate this, fold a sheet of metal so as to transform it into a small cylinder similar to the one which encloses the ball of a condensing electroscope. The lower opening is then closed and it is left for 8 days in darkness, and then, still keeping it in darkness so as to avoid any possible influence from light place the cylinder on the insulating disc of the electroscope or special ray counter instruments to examine its radioactivity. It will be found, after having charged the whole system, that a definite discharge per minute is obtained. As the metal rapidly loses that which it has accumulated, the discharge soon ceases. Many bodies other than metals such as box-wood cylinder will produce the same effect, also certain gas-filled tubes.

The metal, after ceasing to act on the electroscope or counter still has not exhausted its provision of radioactivity. It has simply parted with the quantity it can emit at the particular temperature at which the operation was effected. As with phosphorescent bodies or radioactive matter, it only has to be slightly heated to cause it to again yield a more considerable emission of active effluves. The only difference between all matter is in the rate of vibration or wavelength, the difference resulting in transmutation; changing and restoring. A matter of changing from one rate of vibration to another, evolution in its true sense, evolution from one rate of vibration to another or transmutation, energy changing into matter and matter into energy as we wrote back in 1925.

Cosmic rays are constantly creating radioactive carbon and the fusion of small atoms together to make larger ones gives off more energy than so-called "splitting" of the larger uranium or plutonium atoms, the uranium energy release ratio being only 1 to 1000—that is only 1/1000 of the heavy atoms changed in the uranium "atom splitting" process.

"Nuclear fission" action is not confined to highly radioactive substances. "Atom splitting" is taking place naturally on this earth, in the universe, and on other planets and suns, and there is absolutely no need of the unnecessary hysteria that has swept the world over "atom splitting" as it has been going on naturally from the very beginning of time. Energy and matter cannot be considered strangers nor as a science just being introduced to the world. When the evolution of matter and the evolution of forces is considered nothing new is being advanced: When we consider radium giving off 3 distinct forms of energy — alpha, beta, gamma — we cannot help but see a relationship between electricity & matter. Alpha ray? Alpha particle (matter) Beta Ray (the electron, but still matter).

Radium also emits an emanation which has the characteristic properties of matter (radon gas nuclei of helium, ionized helium, another gas generated by alpha rays) from radium which can be condensed into a liquid. Its volume varies inversely with its pressure (Boyles law) . Thorium gives off 3 solid substances — mesothorium, radio thorium, and thorium X.

Now, if we turn to vegetable matter, we find energy is also being given off similar as in the case of radium, thorium and other radioactive matter. This time, however, we find direct electrical energy being given off.

Various vegetables and fruits will do for the experiment. A "volta pile" can be made of potatoes, grain, apples, onions, etc. Let us consider the apple. In a "volta pile" made of 25 apples (50 halves) one can obtain enough e.m.f. to light a flashlight globe. It will also be found that the living animal cell like the vegetable cell is giving off energy and consuming oxygen and giving off carbon dioxide and an electrical potential.

We find in vegetable, mineral and animal matter the same relationship 'and dependence on oxidation and electrical energy — oxidation in stellar space, evolving energy into matter and matter into energy. Here we see energy and matter and matter and energy vibrating together.

Regarding the force of energy from the cosmos, noted experts in photography have found the light produced from this source of energy is much whiter than that obtained from ordinary electrical energy. Also, this light burns into the film when photographed due to the great intensity and pure white light produced, yet the light is easy on even weak eyes.

It was also noted that detail from these films could only be obtained by holding back dense areas to about 10 times that of normal exposure even when non-halation film and super flash bulbs were used., but the pictures are sharper. Let us again state, "An electrical generator is in the true sense not a generator. It creates nothing. Electricity is not made by the generator, it is merely captured or pumped. From that standpoint an electric generator is an electric pump, and a radiant energy or cosmic energy device, a high-speed oscillating energy resonator.

Let me be permitted to say again, if we reverse our imagination on what the telescope has taught us of the stellar universe, we will find that beyond the microscope we have the particles of which everything about us consists, obeying every law that is found everywhere from stellar space to atomic space. We find bodies in motion and *when we think of how small the proton and electron are, and yet obeying the same laws of the universe, we may see the economical wastefulness of science tryin to crack the atom, when nature, or call it what you will, is accomplishing the sane thing for us in stellar and inter-stellar spaces. Why do something nature is already doing for us?...* Let's use what nature offers as I first suggested many years ago. From this conception, we might see that Democritus came close to a great scientific truth in his bold statement, when he declared that all physical phenomena reduced itself to one single item-motion — or as we might repeat, "vibration," "the sonic of the universe." Let me repeat, "Do not forget the atom is but a counterpart of the universe itself, and that light and other radiations exert a mechanical pressure upon every object they strike, and that all these radiations are essentially electrical in their character. There is a breaking down and a building up of the atom continuously, and it is this evolution which is producing, eternally, unlimited power."

May it not yet be shown that the dissipated energy which results from so much transformation of matter which has heretofore been unavailable — or should we say, unused by us where it has only appeared to be unavailable should now become available to us, an unlimited source of power through the Moray discoveries of application of these forces? And that matter and energy are possibly one is the sum total of all that has been found during the centuries of constant research. Are matter and energy to be judged by that small portion of the universe which is visible to man, who is only armed with his limited yet most powerful telescope, or with his most powerful microscopes?

As I have said before, I repeat again, "All space is saturated with energies which are vibratory in their ultimated analysis and very closely allied to electrical action. The relation of matter to energy and energy to matter then becomes the potential of the universe, one continuous series of oscillations, oscillating to and fro like a great pendulum across the universe. A steady flow of energy can be had from the surges of the universe just as a steady flow of water may be obtained from the surgings of the sea."

Electrons are spontaneously being emitted from the nuclei found in nature and every new discovery on the subject bears out the claim that all "space" is filled with energy millions of amperes at very high voltages. Let "A" equal the atomic mass and "N" the nuclear mass. Let "Ze" represent atomic nuclear charge, "Ma" mass and a mass number "A". We then have the energy found in nature from a given substance to be:

$$\begin{aligned} \text{Energy} &= Mn(Z^a) - Mn(Z+1)^a - me(e) \\ \text{Energy} &= Ma(Z^a) - Zm(e) - Ma(Z_1)A(Z_{-1})m(e) - M(e) \\ \text{Energy} &= Mz(Z^a) - Ma(Z_{+1})A \end{aligned}$$

This is based on the disintegration of radioactive material, natural or artificial; but, the same action is taking place in the "sonic" (vibrations) of the universe with all matter and energy.

As long as the universe has existed charged particles now called cosmic rays" have been bombarding every planet or object in the universe, including all living bodies, at tie rate of twenty tunes per second and with a force great enough to penetrate deep into the rocks of the earth.

Cosmic rays have been called "the death cry of the universe" or "by-products of the destruction of matter in the cosmos." In the process of the evolution of matter and evolution of forces there is no "death cry," only the "song of creation." There is no destruction of matter or energy, only the cycle of matter and energy. The creation is going on continually. You subtract in one place only to add in another.

CAPTURE OF ENERGY BY RESONANCE

With the Radiations of the Universe

Oscillating Discharge — When any elastic substance is subjected to strain and then set free, one of two things may happen. The substance may slowly recover from the strain and gradually attain its natural state, or the elastic recoil may carry it past its position of equilibrium, and cause it to execute a series of oscillations; something of the same sort may also occur when an electrified condenser is discharged. In ordinary language there may be a continuous flow of electricity in one direction till the discharge is completed, or an oscillating discharge may occur—that is, the first flow may be succeeded by a back-rush, as if the first discharge had overrun itself and something like recoil had set in. The condenser thus becomes more or less charged again in the opposite sense, and a second discharge occurs, accompanied by a second back-rush, the oscillation going on till all the energy is either radiated or used up in heating the conductors. However in the case of RE the oscillations go on forever because of the actions of the universe. It is known that high frequency currents may be classified as to their oscillating characteristics, i.e. damped or undamped. The energy from the Universe being of both types, depending on conditions beyond the scope of this writing, we have a back rush effect as explained before in the RE device.

The purpose of the capacitors in the RE circuit is to act in their capacity of stored energy discharged. If the resistance is low, an oscillatory discharge takes place: The discharge and recharge on the opposite plates continues in the ordinary sense until the energy which was originally stored is dissipated. In the case of the RE device a different effect is established because the oscillations from the Universe, trapped by the RE valve, continue to enter the circuit as waves of the sea beat upon the shore. With negligible resistance in the device, no energy is lost in heat and the oscillations continue.

With the explanations given, is the obtaining of energy from the energy oscillations of the Universe any less understandable than the obtaining of energy from a mechanical prime mover? To use mathematical language: exact conditions exist in both cases be they mechanical or electrical systems. The electrical prime mover, the so-called electric generator or the Moray energy oscillator all have the same scientific facts. In a mechanical system, the greater the inertia the greater the tendency of the body to keep in motion once it is set in motion. In an electrical circuit, the greater the inductance with resistance cut to a minimum, the greater the tendency of the electrical energy (current) to continue to flow once it is started.

From the above it then becomes clear that if $R < \sqrt{\frac{4L}{C}}$ where R is the resistance in ohms L is the inductance in henries, and C the capacity in farads, oscillating discharges take place. For low resistance value i.e. R, the frequency of the oscillations may be expressed $f = \frac{1}{2\pi\sqrt{LC}}$

Let Q be the charge of the capacitor at any instant, C its capacity, R the resistance of the circuit, and L its coefficient of self-induction. Then if I be the intensity of the current and E the electromotive force, we have the equation

$$E - IR = \frac{d}{dt}(LI) = L \frac{dI}{dt}.$$

In this case $E = \frac{Q}{C}$, and $I = -\frac{dQ}{dt}$. Therefore

$$L \frac{d^2Q}{dt^2} + R \frac{dQ}{dt} + \frac{Q}{C} = 0.$$

The solution of this equation is

$$Q = Ae^{\mu t} + Be^{\mu' t}$$

where μ and μ' are the roots of the equation

$$\mu^2 + \frac{R}{L}\mu + \frac{1}{CL} = 0,$$

or

$$\mu = -\frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} - \frac{1}{CL}}.$$

Writing

$$\alpha = \sqrt{\frac{R^2}{4L^2} - \frac{1}{CL}},$$

we have

$$\mu = -\frac{R}{2L} + \alpha, \quad \mu' = -\frac{R}{2L} - \alpha,$$

and

$$Q = e^{-\frac{Rt}{2L}} (Ae^{\mu t} + Be^{-\mu t})$$

where A and B are constants determined by the initial conditions, viz. that initially we have $Q=Q_0$, and $I=0$, which give

$$+B = Q_0, \text{ and } A\mu + B\mu' = 0,$$

or

$$A = Q_0 \left(\frac{1}{2} + \frac{R}{4L\alpha} \right), \text{ and } B = Q_0 \left(\frac{1}{2} - \frac{R}{4L\alpha} \right).$$

Hence at any time we have

$$Q = Q_0 e^{-\frac{Rt}{2L}} \left\{ \left(\frac{1}{2} + \frac{R}{4L\alpha} \right) e^{\mu t} + \left(\frac{1}{2} - \frac{R}{4L\alpha} \right) e^{-\mu t} \right\}.$$

Consequently the current at any instant is

$$I = -\frac{dQ}{dt} = \frac{Q_0}{2CL\alpha} e^{-\frac{Rt}{2L}} (e^{\mu t} - e^{-\mu t}).$$

Hence if α be real — that is, if we have $R^2 > 4L/C$ — the quantity Q will gradually diminish to zero as the time increases.

If, however, we have $R^2 < 4L/C$, then α will be imaginary, and writing

$$\alpha' = \alpha\sqrt{-1} = \sqrt{\frac{1}{CL} - \frac{R^2}{4L^2}}.$$

the above formulae become at once

$$Q = Q_0 e^{-\frac{Rt}{2L}} \left(\cos \alpha' t + \frac{R}{2L\alpha'} \sin \alpha' t \right),$$

and

$$I = \frac{Q_0}{CL\alpha'} e^{-\frac{Rt}{2L}} \sin \alpha' t.$$

In this case the current starts from zero and rises to a maximum; it then falls to zero and becomes reversed, after which it passes through a series of oscillations. The discharge therefore does not take place in a single flow from one capacitor to the other, *but a back-rush sets in, and a series of currents, or oscillations, occur alternately in opposite directions.*

The current attains its maximum intensity when

$$\tan \alpha' t = 2L\alpha'/R \quad (\text{maximum current}).$$

The zero value of the current is reached when

$$\alpha' t = n\pi \quad (\text{zero current}),$$

and consequently the charge at the same time is at its maximum, for we have $I = -dQ/dt$. Thus the charge oscillates backwards and forwards, attaining positive and negative maxima after the lapse of equal intervals π/α' , the time of a complete oscillation being

$$T = \frac{2\pi}{\sqrt{\frac{1}{CL} - \frac{R^2}{4L^2}}}$$

If the resistance be small compared with the reciprocal of the capacity we may use the approximate formula

$$T = 2\pi\sqrt{LC}$$

The successive maximum charges occur when $I=0$, or $\alpha' t = n\pi$; they are therefore

$$Q_0, \quad Q_1 = -Q_0 e^{-\frac{\pi R}{2L\alpha'}}, \quad Q_2 = -Q_0 e^{-\frac{2\pi R}{2L\alpha'}}, \quad Q_3 = -Q_0 e^{-\frac{3\pi R}{2L\alpha'}}$$

The quantities therefore diminish in geometrical progression, and the energy of the charge diminishes correspondingly on each oscillation, being lost in heating the circuit.

Whether the discharge is continuous or oscillatory therefore depends on whether $4L$ is less or greater than CR^2 , and an oscillatory discharge may be obtained either by increasing L or sufficiently diminishing C and R .

These predictions on analysis have been confirmed, as Thomson suggested, by examining the spark, during discharge, by means of a revolving mirror. In Feddersen's experiments the image of the spark in a revolving mirror was viewed through a telescope. When the resistance of the circuit was high the spark was merely drawn out in width — that is, at right angles to its length; but when the resistance was sufficiently reduced, so that the oscillating discharge might occur, the band was reduced to a broken image consisting of a series of strips, each strip corresponding to a discharge. As stated we have discovered the oscillation of the Universe corresponds to oscillation of electric capacitors depending on the frequency of the energy involved going on into infinity. The arithmetic progression becoming geometrical.

The drawings, circuits and theory have been pronounced by leading men of science as scientifically mathematically, electrically, sound and correct.

It is generally accepted now by science, and Moray's device proves, there is energy coming from the Cosmos and that the earth is surrounded by such a field of energy; That the earth floats in a sea of energy.*

EARTH FLOATS IN ELECTRICAL SEA

By Alton L. Blakeslee-Associated Press Science Writer*

BOULDER, COLO., Oct. 12 (AP) — High overhead floats a fantastic *electrical sea*.

It girdles the earth, reaches at least 150 miles deep. It writhes with storms and savage winds. Powerful electro-jet currents course through it.

It is, pulled by tides, pocked by peculiar clouds, bombarded by cosmic rays.

Created by the sun's cruelest rays, this sea is the ionosphere a *vast belt of electrons* and electrified atoms or ions. It begins 60 miles up, goes at *least 200 miles high*.

In sparsest form it apparently *reaches thousands of miles into desolate space*.

It's a shield between you and a deadly sun.

Were it not there, absorbing the sun X-rays and most power ultraviolet light, life on earth would perish.

Were it not there, you might never hear a radio. Short wave radio communication depends upon bouncing or reflecting radio waves back to earth from this electrical sea.

Strange quirks in the ionospheres sometimes perform magic. Miami police calls are heard in California.

Or a picture from a TV station hundreds of miles away suddenly appears on the screen.

Exploring this sea is a major activity of the International Geophysical Year, a co-operative 64-nation effort to learn more about our earth, sun and space.

Fingers of radio itself are a prime method of ionosphere exploring. Literally thousands of times a day over the world special radio beams are darting up and bouncing back to measure heights, intensities and other changing peculiarities of the ionosphere.

When the full story is pieced together, scientists hope to answer some puzzles of the high atmosphere and *find new or improved ways of putting the ionosphere to human service*.

THE RADIO fingers and other techniques already have disclosed much of the story, explains Robert W. Knecht, a project leader in sun-earth relationships at the National Bureau of Standards Boulder laboratories.

In reality the ionosphere is our outer atmosphere of ultra-thin air. X-rays and ultraviolet light from the sun rip into molecules of oxygen and nitrogen, tearing out their electrons, electrifying billions-times — billions of atoms.

Usually the ionosphere has distinct layers.

About 60 miles high is the E layer, then the denser, F-1 region at about 120 miles, the F-2 layer at 200 miles.

The E LAYER reflects low-frequency or long radio waves. Higher frequencies or shorter waves penetrate through it, bounce back from higher layers. Sufficiently *high frequencies barrel right on through into space*. Usually this is what happens with TV signals.

During IGY, nearly 200 special radio-sounding stations from pole to pole are intently exploring the ionosphere. Each shoots up pulses of radio waves, sweeping through a quick range from long to short waves in 15 seconds, then timing and recording the echoes from different layers.

A few will make continuous recordings of the seething electrical sea.

For the ionosphere, far from being a static shell, changes, minute by minute, hour by hour, season by season. It is a sensitive link between events on the sun and earth, Knecht points out.

Great flares or explosions on the sun sometimes create a much enhanced D layer about 40 to 50 miles up. This absorbs rather than reflects radio waves, producing radio blackouts and interference. Other sun flares have no effect, for reasons not yet understood.

NOTED PHYSICIST ANNOUNCES NEW ENERGY SOURCE

Nickola Tesla, the renowned physicist and inventor who developed the great AC motor, the fundamental principle of radio, and the practical transmission of alternating power foretold the discovery, many years ago of a hitherto unknown source of unlimited energy, "so practical that the machinery to harness it will last 500 years, and so basic that it will undo existing theories.

"They called me crazy, in 1896 said Dr. Tesla, when I announced the discovery of cosmic rays, Dr. Tesla said, "Again and again they jeered when I discovered something new and then years later saw that I was right. Now I suppose it will be the same old story when I say I have discovered a hitherto unknown source of energy, unlimited energy, that can be harnessed.

"The initial cost will be relatively big. After that hardly anything and unlimited power for the asking."

Dr. Tesla has given the world the arc lighting system, the Tesla coil and rotating field principle for alternate current and innumerable other electrical devices.

Dr. Tesla did not live to reduce to practical application the discovery he referred to above.

This energy, or as Moray explains it— these oscillations of Energy are picked up by the Moray device and the oscillator tubes of the device itself. As stated, these surgings or oscillations of Energy coming and returning to the Universe are picked up by the Moray Device because the Moray Device is tuned to oscillate in harmony with the oscillations of the universe just as musical instruments can be made to oscillate together. Every oscillation, whether large or small, is completed during the same interval of time. The beat note of time, the heart beats of life, the oscillations of the Universe all prove the same great fact that oscillations are all governed by the same cycle of time, or, as stated above, completed during the same interval of time, and as Moray stated years ago, these waves of energy have a regular beat note of time, coming and going as the waves of the sea, but in a very definite mathematical order of time, coming to the earth from every direction, stronger in the day time than at night, but always coming with regular beat note that might be referred to as the Father of time, the Sire of Gravitation.

Below will be found excerpts from some Scientific books.

"ASTRONOMY," by Robert H. Barker, Ph.D. Professor of Astronomy, University of Illinois, page 303:

"Another problem relates to the apparent lavish expenditure of this radiation. Of all the energy that pours forth from the sun, less than one part in 200 million is intercepted by the planets and their satellites. The remainder spreads through interstellar space with little chance, so far as we know, of being recovered. The suggestion that the sun shines only in the directions of material that can intercept it makes an appeal from the point of view of economy, but appears to have little else to recommend it. It would seem that nature is squandering its resources of energy so prodigally that it must end in bankruptcy; but doubtless we have at present an imperfect account of the situation."

Quoting from "Foundations of the Universe" by Luckiesh of General Electric, pages 41-43:

"The great success of the atomistic principles as it is involved in the kinetic theory of matter was one of the wonders of the modern scientific age. It is to be expected that there will be found other applications equally fascinating and promising. It is now being pressed further into the service of explaining the structure of matter..."

"When Maxwell (1873) propounded the electromagnetic theory of light (radiation), his achievement was epochal. The exact manner in which the radiant energy traversed space was not known, and the next epochal event was the founding by Planck (1900) of the quantum theory. Here we have the atomistic principle applied to energy instead of being confined to the material of the universe as it had been. In other words, in the quantum theory we have the atomistic idea applied to physical processes. We now have the atom of matter, the atom (electron) of electricity, and the atom (quantum) of action (a product of energy and time). Planck assumed the emission of radiation (from the sun, a lamp filament, etc.) to occur discontinuously. He conceived elements of energy of equal magnitude analogous to the equality of electrons, or atoms of a given element. Radiation or radiant energy is emitted of various wave lengths or frequencies which must be taken into account in laws of radiation *** now the physicist uses quanta as commonly as he does electrons and atoms and molecules. Bodies are built of molecules, the molecules of atoms, and the atoms of electrons (and protons) etc. Here we see the atomistic principle applied to "material" (matter) and then to electricity. Finally, a physical process — the radiation omitted by the electrons — is divided into quanta. With such pictures of the Universe being considered we may cease to be surprised at anything, but our interest and admiration will grow. Will we ever get to the final foundation?"

Matter and energy, are possibly one, is the sum total of all that has been found during three centuries of incessant research in all that portion of the Universe visible in a forty-inch telescope armed with the most powerful spectroscope ever made.

It is the experience of the writer that all space is saturated with inconceivably minute corpuscles of energy. Reference is made to the discoveries of Professor J. J. Thomson. These are doubtless either electricity in its ultimate refinement, or very closely allied to it, or its immediate carries... The earth and sun, all suns and dark bodies in space, all granular matter move through the primordial cosmical mass of electrical energy as would a

wire screen through water. The wide spaces in diamond, glass, steel, flint or any thing else allow these 'Bodies smaller than atoms,' as Thomson calls them, to pass through."

From the definition of energy it is the potential of the Universe. When matter is in a phase allowing it to be active, it effects other quantities of matter at a distance. The method of transfer is known to be by means of wave and corpuscular motion. Each impulse moves from the emitting to the receiving mass on a rigorously straight line. One continuous set of oscillations in this right line is called a ray. Each negative or "Thomsonian corpuscle" makes a double vibration to and from like a pendulum straight across the direction of the ray — i.e., at right angles to it, the corpuscles move over and return to the original position had before the excursion. Since the corpuscles are negative and can be drawn out of their original straight path by the action of magnetism, the entire wave motion of the Universe is electro-magnetic. This is what Maxwell theorized many years ago. Thomson proved the theory a fact.

"After one corpuscle makes an oscillation across the direction of the ray and return the next does likewise, and the next, and so on. After the first corpuscle makes the swing, another distant from it 186,000 miles in the same straight line will also make a vibration at the end of the first second of time."

"ATOMS AND RAYS," by Sir Oliver Lodge, Fellow of the Royal Society of Science and holder of five or six Doctors degrees from colleges, with honors from a score or more and who held offices of President in a dozen or more Scientific Societies, printed in 1924:

The term 'light,' strictly speaking, means that kind of etherial radiation which is able to affect the eye. But it is common knowledge that there are many other varieties of radiation besides these to which the eye is sensitive. It is not clearly known why the eye is sensitive to some kinds of etherial radiation, and not to other kinds. That, no doubt, can be ascertained; it is a question for physicists and physiologists in collaboration. But the eyes of animals and insects as well as of man, all appear to be sensitive to a limited range of etherial radiation, which is therefore called light. Other kinds of radiation can affect a photographic plate; other kinds, again, can stimulate the chemical actions going on in the leaves of plants, and thereby supply the energy needed for vegetable growth. Another kind — a rather deeper harmonic as it were — supplies everything on earth with warmth, and by evaporating water contributes to most of the phenomena of weather. Other kinds, again, are omitted when individual electrons traveling at a high speed in a vacuum, encounter the obstruction of a target; this kind of invisible radiations being called X-rays. And, at the opposite end of the scale, another kind of radiation is emitted and is known as the Hertzian waves employed in radio.

In speaking of these kinds of radiation as different, we are not speaking quite accurately. They differ only as treble notes differ from bass notes; they differ in rapidity or rate, of vibration, wave-length or frequency. They do not differ in any other essential particular. Through the whole range — from the telegraphic waves, which may be a mile long, to X-rays, of which the wave-length is actually smaller than atoms, and only expressible in billionths of an inch — they all travel we assume at precisely the same speed. They are all of the same electromagnetic character; they are all subject to the same laws of interference, of reflection, refraction, and polarization, which have long been studied in the department of physics known as optics.

T. Henry Moray would qualify the above statement by saying there are speeds greater than 186,000 miles per second.

"Whatever an electric charge is, or is not, it is certainly a focus of energy. And if we could imagine an vortex, containing the known mass of the electron and circulating with the velocity of light, its energy would be equal to that of the electric field in the space surrounding the electron. This coincidence, if it be a coincidence, can hardly fail to have some meaning. And there are those who are beginning to think that the whole material universe is built up of energy in various states of self contained or intrinsic motion; by which adjectives it is intended to discriminate between rotatory motion, like that of a top or a whirlpool, and ordinary locomotion, are shifting from place to place.

"Those who hold this view of the universe are strengthened in their position by the statements of Einstein on energy in general. It is well known that all the ordinary energy we are acquainted with, such as the motion of railway trains, cricket balls, and such like, is merely relative — relative to the earth, or to some other piece of matter. There is nothing absolute about it. But Einstein gives an expression for what one might be inclined to call absolute energy, in which the only relevant velocity is the velocity of the Cosmos. And all the phenomena we observe in nature, at any rate in inorganic nature — omitting the phenomena of Life and Mind for the present, as lying outside our physical ken — may be regarded as due to, and as demonstrating, slight modifications of the portion affected by this great velocity, in form which enables it to appeal to our animal-derived senses. For the spinning motion itself is impalpable and beyond the ken of our instruments, until it partially exhibits itself as transmitted waves in the form of radiation."

"All the energy that we experience can be resolved into vibrations or tremors. But all electric and magnetic phenomena, and therefore, all chemical activity, are likewise known to be modes of manifestation of vibrating space, the complete manner and meaning of which have still to be worked out."

"So the question arises, What is Matter? Is that too a manifestation of some peculiar properties in the medium? We know now that matter is built up of protons, neutrons, electrons, etc. But when we come to analyse these into their fundamentals, we find far more than a hint that they are but special modifications in the all-pervading energy, and are essentially resolvable into kinetic energy of a specific kind. Hence we are beginning to think that all matter itself is a form of energy."

"Energy is the chief thing in the physical universe that directly appeals to us. We apprehend it under a great variety of forms. And it is becoming probable that what we call matter is one of these forms. Most of the forms of energy that we know are convertible one into another. The energy of motion turns into heat; so does the energy of electric currents, unless it is converted into the energy of chemical separation or electric charge. Conversion from one form to another, without loss, is the sign-manual of energy. And the proof that matter is a form of energy will not be clinched until it can be demonstrated that matter too is convertible into other forms of energy."

Many attempts have been made to harness the forces of nature directly to produce usable power. Other types of energy besides sunlight are constantly bombarding the earth with waves and particles, or surrounding it in much the same manner as its atmosphere or the very space in which it exists. Among these are the gravitational and magnetic fields and the cosmic rays.

The features of cosmic radiation would enable R E transformers using cosmic radiations as a primary source to operate with relative independence as to position or season. It is also evident that such a device would show possibilities of efficient operation in moving vehicles within the earth's atmosphere and in space at continuous high power levels.

Such an energy transformer or converter has been built. It has been operated at full load continuously with no expenditure of fuels of any type without a mechanical prime mover, kept alive by the oscillations of the energies from the cosmos; An energy converter, or transformer, which would be capable of converting the high frequency, high level energy of the cosmic radiations into current of usable frequency and voltage.

Basically the theory of operation is as follows. Oscillations are started in the first stage or circuit of the device by exciting it with an external energy source. The circuit is "tuned" until the oscillations are sustained by harmonic coupling to the cosmic wave frequencies. The reinforcing action of the harmonic coupling increases the amplitude of the oscillations until the peak pulses "spill" over into the next stage through a special detector or valve which prevents the return or feed-back of energy from succeeding circuits. These "pulses" drive this stage which oscillates at a lower frequency and is again reinforced by harmonic coupling with the ever present cosmic waves. The second stage drives a third stage and additional stages are coupled until a suitable power level at a usable frequency and voltage is obtained by means of special transformers. (See schematic drawing of R E device).

Once the machine is in operation and delivering power it does not require any continuance of the excitation forces necessary to start it. The oscillations are sustained as long as it remains properly tuned and the external circuit is completed through a suitable load.

The special tubes which appear to be the key to the success of this device are Ionic cold cathode tubes which require no external power sources.

Practically speaking, the present method of securing energy with prime-movers has been used too long. We have used it so long, that we have let ourselves believe that there is no other way to secure it. Present methods are expensive and cumbersome. Think of the power sites, and steam plants, the transmission lines, the transformers, and many other kinds of equipment that are now required to supply our electricity. The present system is unreasonably expensive. When we begin to realize the tremendous energies, electrical energies, that surround us, we should actually be ashamed that we have been so dilatory in our efforts to improve upon this crude, cumbersome, and expensive method of furnishing heat, light and power.

Books could be filled with accounts of the struggles for existence of a new idea or a new way of doing things. You need only read the story of the development of the telephone, and the railroad, the airplane, automobile, and so on, and you will begin to appreciate the cost in sacrifice, money and unselfishness to promote a new and revolutionary movement, irrespective of the vast good it accomplishes when established for the use of humanity. (See Ralph Parleys "Pockets of Paradise").

CHAPTER FIVE

HISTORY OF RADIANT ENERGY

Experimentation and Development

The thought has occurred that the reader would find a brief history of Dr. Moray and his work a valuable background. With this in mind, the editors of this chapter have gone through a great deal of correspondence and many of the papers of Dr. Moray. The material would fill many volumes but of necessity had to be condensed to what was felt to most clearly demonstrate the purpose in mind and give the reader the most comprehensive approach to the work.

The story of Henry Moray is the story of a man working alone, whose discoveries and theories have been years ahead of his time. His many pamphlets and writings have advanced ideas with which science is coming more and more into agreement. His active mind has delved into many fields of science and always come up with many new and startling discoveries.

Henry Moray was born August 28, 1899 in Salt Lake City, a son of James C. and Petronella (Larson) Moray. His father was a well known mining engineer and an active pioneer in the early mining activities in Western America. He was educated in the public schools in Salt Lake City. As a young boy, he could hardly wait for school to close afternoons so he could run to the public library to read books about electricity. Such men as Michael Faraday and Nikola Tesla were his heroes. As early as 1905 he was experimenting with then so-called wireless and other electrical devices.

In 1907 he started experimenting with alternating currents of High Potential and High Frequency and with rays beyond the light rays. His main interest has always been with high frequency phenomena. He attended the L.D.S. Business College, the L.D.S. University, and a course in electrical engineering from Pennsylvania. In 1912 he went to Europe and while there over a period of years did advance study in electrical engineering.

Through the years he has kept abreast of the latest developments in science through diversified and extensive reading and has built up a personal scientific library of very extensive proportions.

On November 28, 1917, he married Ella Ryser. They had five children: Henry Junior, Ella Evelyn, Sylvia, John Eugene, and Richard Ryser.

Prior to 1921 when he decided to devote all of his time to private research, he was an electrical engineer and designer for the Utah Power and Light Co., Phoenix Construction Co., assistant chief electrical engineer Aarastad Construction Co., and assistant division electrical engineer for the Mountain States Telephone and Telegraph Co. He also worked as a civil engineer for the Denver and Rio Grande Railroad. During this time he designed the electrical layouts for important power plants and for some of the largest buildings of that time in the west. He was a certified member of the A.A.E. (American Association of Engineers), and a past secretary of the Independent Electric Co.

Time and space do not allow a full discussion of the various Moray devices as the primary purpose of this paper is a presentation on RE. A very complete and detailed record of letters, articles, pamphlets, etc., are on file in the records of The House of Moray in Salt Lake City, Utah.

Dr. Moray and radiant energy are so closely related that one cannot be separated from the other. It is not the purpose of this history to give a complete picture of Radiant Energy but a discussion is necessary as it seems that all of the other work which Moray has done is received on the basis of how the party or parties involved feel about Radiant Energy. During the past years, Dr. Moray has turned to many other fields of endeavor, continuing to build on Radiant Energy as finances from other works would allow. Since 1926 this work on Radiant Energy has been paralleled among other things by an intensive study of radiations and radio active substances.

Through the years Dr. Moray's chief wish has been to be free of bothering business details so that he could concentrate on research. Yet every time he has turned business details over to someone else, chaos has resulted. One of the chief needs has been to find someone who combined the unusual talents of a good business manager with a knowledge of science, who was dedicated, trustworthy, unselfish, and tough enough to withstand the rough road which had to be traveled. The qualities of trustworthiness and toughness seem to have been lacking the most often. It has been hard to find administrators with the special skills needed.

Progress through all of history has been slowed and sometimes thwarted by selfish interests. But in spite of all obstacles, the world slowly crawls forward.

James DuPont in a speech before a group of Kiwanis and Chamber of Commerce representatives asked how many businesses would be in existence today if it were not for inventing and scientific research. This work requires something which no money can buy and which no educational training can supply and without which no research or inventing business can thrive — the power of creative imagination. The pioneering today is on the frontier of scientific research. It is no place for the faint of heart.

Independent research in the United States today travels a rough road. The problems lie in two directions. 1. Financial: It is very difficult for all individual or small group of individuals to collect sufficient funds for equipment which is very specialized and very expensive and to be able to pay competent help. 2. Business management: Few research workers have the time for involved business and financial details on top of the full schedule necessary for scientific advancement.

People, like objects, seem to lie governed by the laws of inertia. Anything which tends to change the existing status quo is viewed with alarm; particularly if they cannot understand or explain the new in view of present knowledge. Through the years continual experimentation and refinement has gone forward, but always in the long run the work has fallen back onto one man and his resources.

At the onset Radiant Energy received much attention, but it got off to a bad start because of the desire for personal advancement and power by groups of promoters.

Many have asked what is this thing Moray has called Radiant Energy which has caused so much discussion over so many years? In lay terms it is the harnessing of the power of the universe to man's need for electrical energy here on earth. Many attempts have been made to harness the forces of nature directly to produce usable power.

As early as 1904 Nikola Tesla on experimenting with A.C. currents of High Potential and High Frequency said "There is a vast quantity of available energy in space and it will not be long until men will attach their machines to the wheelwork of nature.

Radiant Energy was first presented years before the world was ready to accept it in principle or to understand its magnitude. History has again shown the unwillingness of men to accept and adapt to drastic change or new ideas. Dr. Moray realized the magnitude of his discovery and has felt the burden of responsibility for what could well be the future of mankind. He has had a sincere desire to place his knowledge where it would do the most good for all and not into the hands of a few who were selfish for power and wealth. In this undertaking he has been thwarted on all sides, even from quarters where there was no knowledge of or connection with the work.

Because of conflicting interests, some people would like to sit back or deliberately interfere with the development of Radiant Energy until Dr. Moray makes a slip and the invention becomes public use. The many offers for Radiant Energy have to be carefully considered for intent and chances for successful presentation. Some interests have even tried to tie the invention up and prevent future development. As has been said before, time and space do not allow a lengthy review of the happenings through the years, but a few high lights may be of interest.

On July 24, 1925, while conferring with Senator Reed Smoot at the senator's invitation in his offices in the Hotel Utah in Salt Lake City, Dr. Moray offered his Radiant Energy discovery to the United States Government gratis. The senator thanked Dr. Moray for his offer but stated that the U. S. government would decline such an offer on the grounds that the government was not running in competition with public utilities.

In the early years of its development during many, many tests the Radiant Energy device was minutely examined. Many people saw this device with no other purpose in mind than to prove it a fraud. None was ever able to find any evidence of fraud and admitted that it was beyond their comprehension.

During this time there seem to have been four main points of dispute, all of which were thoroughly dealt with. These objections were: 1. The power was obtained from a hidden wire connected with the electric light circuit. 2. The power came from batteries. 3. The power came from induction. 4. There existed no such energy in the universe so that it couldn't be as represented.

Let us look at each of these objections in view of the records of people who saw these demonstrations. Only a few of the more comprehensive descriptions can be examined here.

The question of batteries is most conveniently dealt with at the same time as the idea of a hidden wire connected to the electric light circuit.

On March 16, 1929 Mr. T. J. Yates, E.E., and M.E., a graduate of Cornell University with a great deal of experience in the electrical field, wrote a complete and detailed description of the apparatus and experiments which he saw of the Moray Radiant Energy device. He made and related several basic electrical tests which proved that the source of power present was not from an ordinary light circuit or from batteries. He made tests which would have produced a short circuit if the circuit had been connected to the electric power source. None was produced. He checked the main switch, and examined the table which held the device for hidden wires. He opened the main control switch on the lights in the building with no visible effect upon the Radiant Energy circuit. He tested the terminals for a battery type discharge and found that the tests indicated a condenser type discharge. He tested and made sure that energy was passing through the apparatus. He emptied the boxes which contained the apparatus -and found no batteries nor any place big enough to hold them. He also made the observation that the lights even though standard globes burned a different color, brighter and whiter, than those on the regular light circuit. In conclusion he said, "One is therefore forced to conclude that the electrical energy was received from some other source and difficult as it is to understand, with our present knowledge of electrical

generation, no other conclusion can be drawn from the demonstration as above described than that the energy was received by and through the apparatus as claimed by Dr. Moray." (See Footnote)

TO WHOM IT MAY CONCERN:

This is to certify that on the evening of March 16, 1929, in connection with Dr. H. H. — of — City, I witnessed a demononstration at the home of T. H. Moray, 2184 South 5th East Street, Salt Lake, City, Utah.

Dr. Moray claims to have devised and invented an apparatus that will produce electrical energy without the use of prime mover, and this is the apparatus demonstrated on the occasion above referred to.

The subjects of this article will be treated in the following order:

1. Description of Apparatus
2. Demonstration
3. Objections that I have heard
4. Tests
5. Conclusions

1. Tile apparatus consists of an antenna, a lead-in and a ground wire. These are connected to the terminals of a switch. Two wooden boxes were placed on a table. In one of these boxes was a high-frequency transformer and in the other box were two sets of condensers, 10 large condensers in one set and 10 small condensers in the other set; two composition cylinders, each about 1 1/2 inches diameter and four inches long; each of these weighed about three or four ounces; and another box approximately hemispherical in shape about 2 inches in diameter and weighing about 2 ounces; and a coil of wire. These piece. of apparatus were connected by a number of wires by which lite hook-up was connected.

Two of these wires were led out to the switch. One was attached to the blade of the switch and the other to the jaws of the switch so that when the switch was open the antenna, lead-in apparatus in the boxes, and ground wire, were all in series.

Two other wires leading out of the box were connected to six 100 watt lamps connected in multiple during part of the demonstration, and to a flat iron during part of the demonstration.

2. Demonstration.

During the demonstration the apparatus was connected in series as above described, except that a small switch connected in series with tile coil was left open.

Dr. Moray stroked the coil with a small magnet for three or four minutes; he then closed the small switch and the lamps were lighted and remained bright as long as the circuit was left closed, which was about 60 minutes. He then connected an electric flat iron. In a short time tile iron was hot. When the ground wire was disconnected and when the lead-in was disconnected the light went out.

3. Objections that I have heard.

1. That the power is obtained by a hidden wire from the electric lighting circuit.
2. That tile power is obtained from batteries.

4. Tests.

Before and after the demonstration I closed the big switch which connects the antenna and ground. If the antenna or lead-in were connected to the lighting circuit this would have produced a short circuit. I further tested by closing and opening the switch several times to see if any sparks appeared, but there were no sparks. I placed my wet finger between the blade and the jaws of the switch and could not feel any electricity. I touched my hand to both sides of the switch and the wall to check for ground but could not feel anything. We turned the table over and examined it carefully for hidden wires but found none. With the apparatus all connected the same as when operating the lights, the contacts with the switch were moved but produced no arcing. This indicates that the circuit was dead.

While the demonstration was being conducted and the lamps were receiving their energy through the apparatus the main switch that control the lights in the house was opened. All lights on the house circuit went out but the lights on the aerial circuit was not altered — were neither brighter nor dimmer at that time. *Thus the lights could NOT have received their power from that source.*

The condensers were THOROUGHLY tested. The terminals were shorted, the positive to the negative. If they had been batteries they would have showed a spark, but no sign of spark appeared. They were then tested by connecting them to the electric terminals. After thus being charged the large condenser gave a vigorous discharge, showing a brilliant strong arc and a loud snappy sound showing a sudden discharge as condensers are supposed to do and batteries never do.

The small condensers were less vigorous in discharging but the some snappy discharge indicated a condenser and not a battery discharge. These tests proved positively that condensers and not batteries were in the cases supposed by some to contain batteries. The boxes were completely emptied thus leaving no possible place for batteries to be stored.

During the time that the lights were burning the connections with the big switch were moved along the switch and vigorous arcing occurred, thus proving that electrical energy was passing through this apparatus.

5. Conclusions.

The electric lamps received energy from some source and during the demonstration, which lasted for about an hour, the lights were brilliant at all times; just as bright at the last as the first of the demonstration.

The lights on demonstration were a different color and seemed brighter than those on the house circuit.

The electric energy that lighted the lamps and heated the flat iron was not received from batteries in the boxes.

The electric energy that lighted the lamps and heated the flat iron was not received from the house circuit.

One is therefore forced to the conclusion that the electric energy was received from some other source and difficult as it is to understand, with our present knowledge of electrical generation, no other conclusion can be drawn from the demonstration as above described than that the energy was received by and through the apparatus ac claimed by Dr. Moray.

T. J. YATES

Mr. Yates has an M.A. in Electrical Engineering, Columbia University.

On December 13, 1930 Mr. Yates saw another test which he again described in detail. he noted a slight change in the apparatus which made a great improvement in the performance. He again described a careful examination of the system for any other source of electricity. He states that he inspected everything and that not an inch of space was overlooked. We will now quote directly from the letter.

"A crystal radio set was cut in on the lead-in wire from the antenna on one side and to the ground wire on the other side and perfect reception was had. If there had been power from other sources on the antenna or lead-in, by connecting the radio set to the ground wire, reception would not have been possible but a loud, humming

sound would be produced. This was demonstrated by connecting the radio set to the house lighting system. When the system was working, the lights were burning bright. The terminal attached to the antenna was disconnected. A vigorous arcing occurred and the sparks jumped over an air gap as much as six inches. This would indicate that the power was high voltage and the nature of the sparks indicated a high frequency.

I do not understand the principle by which Dr. Moray produces the electric energy. The condensers and the coils of wire are common. The two cylinders called "oscillators" and the small conical shell called the "detector" are the only things not commonly known, but the system works. It produces electric power in abundance and does all that Dr. Moray claims for it.

I do not own any stock or interest in the company that is promoting this enterprise and my only purpose in issuing this statement is in the interest of the advancement of science. I consider this development a great advance in the science of producing electrical energy.

Very truly yours
(Signed) Thomas J. Yates

This letter was subscribed and sworn to before a Notary Public on the 18th day of December, 1930.

In later R. E. devices a HF brush discharged of 18 inches in length was sustained and 50 KW of energy obtained.

Another distinguished feature of the Radiant Energy device is the characteristic whiteness of the light globes. Regular light globes purchased on the open market were used in all of the demonstrations, yet the light produced was quite different than that in an ordinary electric circuit.

On Jan. 5, 1938 Mr. Chester Clawson wrote the following. "For many years I was a producer of independent motion pictures and in this work necessarily used high-powered open-arc lamps. Through my exposure to these powerful lights my optic nerves were affected by the ultra-violet rays and ordinary light has always caused me considerable discomfort so naturally I was particularly impressed with the fact that in looking at your board of some thirty-five hundred-watt lamps, all burning at the same time, the light was very much less troublesome to my eyes.

Photographers have also noticed the different quality of the light produced with this device. In June of 1937 Mr. Keen Polk, a photographer whose experience covers thirty years during which he had been a newspaper photographer; official photographer of the United States over seas; and head photographer for the U. S. government in Washington, D.C. wrote "I began taking photographs of the Moray Energy machine, while it was being operated, some six years ago. The purity of the light has always greatly impressed me. The light appears to be much whiter than the light in bulbs lit with the ordinary electric current. To my eyes, it appears that there is less of the ultra-violet and red rays, than are contained in the regular light.

In all of the demonstrations that I have photographed, Moray has used the standard market electric light globes. The light produced by this machine is superior to any of the special lights used in my photographic work. On June 25, 1937 I photographed seven negatives and discovered that this light is rather difficult to properly photograph on account of its extreme brightness.

On July 6, 1938 Mr. W. Earl Lyman of the Utah Photo Material Co. wrote to Dr. Moray: During the latter part of May 1938, I photographed your Radiant Energy Machine and was very much impressed with same.

In my opinion the bank of lights photographed were much brighter than the Mazda Lights of similar work I have had to do.

I used a non halation film and was sure I could offset the light with a large #3 Super Flash Bulb, but your light burned into the film much deeper than I expected.

The pure white light you get should be a great help in photography."

Processing the negatives taken of the lights of the Radiant Energy device has also presented some unusual problems not ordinarily found in pictures of this type as is illustrated in the following three letters to Dr. Moray:

"Dear Sir:

We wish to thank you for the recent business you have given us, and hope we may have the pleasure of serving you again.

"For your information we wish to state that in all cases where negatives included any of your lights we found them to be of greater intensity than ordinary illumination. They seem to burn into the negative to such a degree that we found it necessary to cut special masks to hold back the immediate area of illumination in order to obtain any outline of the globes whatever. We found the average negative required about ten times the normal exposure in the areas where lights were used. This is especially interesting as in photographing ordinary lights when shining directly into the lens of the camera the light outline can be plainly seen even though the negative is dense at point of illumination and in the case of your lights the only detail possible to obtain had to be brought out through holding back the dense area as mentioned above."

Very truly yours,

The Sun Photo Service

Signed D. R. Silvers

In a later letter Mr. Silvers again writes: "In regards to your inquiry on the change of light values or negatives changing their properties of value during a period of years, we state that, to the best of our knowledge any changes would have to be uniform in over all negative value and the ultimate results in printing would remain the same.

At the time we printed your latest group of negatives, we understood the photographer used a No. 3 flash bulb which under ordinary circumstances would offset any area of intense light or bank of lights other than the source of the No. 3 flash bulb.

We found that is not the condition in this case. This source of light seemed to burn into the negative to such an extent that we had to shade out the light in order to obtain a background which the No. 3 flash bulb should leave illuminated.

To summarize, we found that in order to obtain a balance print quality, we had to mask out or eliminate this source of light in order to obtain any detail in the balance of the picture."

"In March of 1957 Mr. L. E. Remington, manager of the Shutter Bug in Salt Lake City wrote to Dr. Moray: In our Photo finishing plant we have recently made photographic prints from negatives supplied by you. Included in all of these negatives were banks of lights.

Needless to say, producing satisfactory prints from these negatives was extremely difficult, due mainly to the fact that the intensity range on the negative was far beyond the limitations of the photographic papers. On some of the negatives the range was so extreme that even with intense "burning in" we were unable to produce a print that satisfactorily covered all areas of the negative.

We noted several interesting characteristics in the negatives of these lights in contrast to normal incandescent or fluorescent lights. The intensity of these lights appeared greater than normally produced. They also, in some cases, produced a circular halo effect that has not been encountered previously. The most interesting observation was that, in spite of the intense density of the negative image of these lights, there was no complete "blocking up" such as would normally be found with other lamps."

As has been noted, electric light globes (standard articles bought on the open market) behave differently when used with the Moray Radiant Energy device than when used with regular current. The globes become exceedingly hot in one spot about the size of a dime, due to the fact that the gas in the globes becomes incandescent under the influence of the very high frequency current and because of the incandescent gas, the luminosity is much higher and whiter than with ordinary current.

Before we leave the question of outside power sources, let us consider one more letter written Dec. 22, 1958.

"To Whom It May Concern:

In the spring of 1938, I was invited by the Securities Commissioner of the State of Utah to accompany Mr. Gull to the Laboratory of Dr. Henry Moray and inspect the Moray Radiant Energy equipment. My father, Mr. J. C. Jensen, an engineer, was also present. He has seen many tests made of the Moray equipment. This invitation was given me because I am an engineer and battery expert.

After seeing the Moray equipment light 30 one-hundred-fifty watt standard light globes, heat a 1000 watt soldering iron and operate a special high frequency motor for some time over an hour, I placed my measuring instruments on the antenna and ground connection. They were electrically dead. They were checked in detail for hidden wires, there were none. The box in which the equipment was housed was opened by commissioner Gull and myself. Every part of the equipment was taken out of the box, weighed and tested. Tests were made with sensitive volt and amp meters to determine if the box could contain batteries or if any of the equipment had any sort of battery action in them. They did not.

There were no hidden wires and nothing from which any battery current or any other power could have been obtained other than as claimed by the inventor.

The commissioner then requested permission to bore holes in the box in which the equipment had been housed in order to satisfy himself that everything had been taken out and there were no hidden compartments. This was done to the complete satisfaction of all present.

I have been asked for my comments concerning tests and demonstrations of Dr. Moray's Radiant Energy equipment, and the above is a review of the test and demonstration which I witnessed. I endorse this equipment as represented by Dr. Moray."

Signed A. B. Jensen,
Salt Lake City, Utah

A letter dated Sept. 26, 1928 written by Air. E. G. Jensen, relates that on Sept. 25, 1928 in Dr. Moray's Laboratory, a demonstration was given for the benefit of Dr. Harvey Fletcher in which three one-hundred-watt lights were lit and also a 575 watt flat iron was heated. After the demonstration, the apparatus was dismantled

for Dr. Fletcher's inspection and the various circuits and hook-ups were explained. Dr. Fletcher remarked, "It was a wonderful demonstration."

A feature of the demonstration was the breaking of the antenna circuit which caused a brush discharge spark of about nine inches to occur. Dr. Fletcher stated that the current was evidently high frequency. On the Thursday preceeding this demonstration, Dr. Fletcher spent several hours with Dr. Moray who explained the various circuits to him in detail. This conference was attested to in a letter dated Sept. 27, 1928 and signed by Robert L. Judd. At this time Mr. Judd relates that Dr. Fletcher had to return to the Bell Telephone Laboratories in New York and would be unable to make further investigations, but felt that he could accept any findings of Dr. Carl Eyring. He also suggested that one weakness of the device might be the inability to function over a long period of time and suggested an endurance test.

On Oct. 10, 1928 Mr. Robert L. Judd wrote a letter to Dr. Fletcher at the Bell Telephone Laboratories in New York. In this letter Mr. Judd recounts the details of an endurance test arranged with Mr. E. G. Jensen, Dr. M. O. Hayes, and himself. They set up the machine in a heavy tin covered trunk with a small hole in the top and another in one end through which the globes attached to the machine could be observed. After making some tests, the trunk was closed and locked and the key delivered to Dr. Hayes. The trunk was then sealed in three different places with the standard freight car seals. The details of each day were recounted, the principals involved visiting the laboratory many times to check the device. After a week the trunk was opened and the device carefully tested.

Mr. R. F. Haffenreffer, Jr.
Fall River, Massachusetts
Dear Mr Haffenreffer:

It has been some little time since I have had anything worth while to tell you about our electrical mechanism. We have though just finished a most interesting demonstration that I am sure you will be pleased to hear about.

You will remember that I told you of our unsuccessful attempt to have an examination of the mechanism made by Dr. Fletcher of the Western Electric Co. of New York, when he was here a year ago, and of our inability to make much headway since that time. I think I have told you that Dr. Fletcher is a very close friend of mine whom I met when we were both attending the University of Chicago. At that time he was working to get his doctors degree in physics and was assistant to Dr. Milican, and helped very materially in the demonstration and establishment of the ionic and electronic theory of matter. A few years after his graduation lie was called into the staff of the Western Electric CO. at New York, where lie has remained up to the present time. He has done some very remarkable work and for more than a year past has had direct charge of the television. A couple of weeks ago I learned that he was paying us another visit and accordingly took up with Mr. Moray the proposition of his spending some time on our mechanism while here. I know by reason of your knowledge of inventors, that you will fully appreciate the difficulties encountered in getting Moray to give Dr. Fletcher a chance to study and investigate his instrument. However, he did give his consent, and on Thursday a week ago Mr. Moray and Dr. Fletcher spent the afternoon in a detail study of the drawings demonstrating the circuits involved and the theory upon which the mechanism is based. This was as requested by Dr. Fletcher. On Tuesday last, Dr. Fletcher, myself and Mr. Jensen, another interested party went down to Morray's home. Dr. Fletcher was afforded the opportunity of studying the antenna, the ground and their respective connection with the machine. Moray then demonstrated that there was no life in any part of the machine, and explained to the Doctor what he was about to do. He then began his tuning in as you have seen him and in six minutes from the time of his commencement had sufficient power to light three one hundred watt lamps. Dr. Fletcher in observing the lamps stated that they were burning far above normal and that if they were to continue at that degree of radiancy they would soon burn out. While observing the lights various tests were made such as disconnecting the antenna and the ground. The lights were then screwed out quickly and a five hundred seventy five watt flat iron attached. This was heated to the "sizzling" point in about five minutes. After making such observations as were necessary to this test, the wire was disconnected and the lights again put on. After the lights had been burning for some little time, for some reason then unknown, they flickered a few minutes and then went out. The lights on the regular circuit in the house still going on. The globes were tested and found to be all right. *A later examination of the parts of the machine showed that one part of the detector, that piece of mechanism which is not yet "fool" proof, had slipped down out of place and in effect had disconnected that particular circuit. This happening pleased Dr. Fletcher and was considered by him a valuable part of the experiment. After the lights had gone out the mechanism was dismantled part by part and the Doctor given a chance to see that the mechanism was one intrical whole and no other connection than with the antenna and the ground.*

His conclusion was without further time or equipment with which to study the circuits, and the extent of them going through different parts of the machine, that the energy secured by the machine was what Mr. Moray contended for it or that Moray secured from his antenna and ground a force which set up in his tubes, the makeup of which were explained to the Doctor, some form of battery action which resulted in the electric current generated. He stated that if it were the latter however, the phenomenon was quit as remarkable as contended for by Moray, because in accomplishing what they did the tubes were far more powerful than anything known to science today.

His observation as to the possible weakness of the thing is it was some battery reaction in the tubes which were commenced and kept alive. by some form of energy from the atmosphere, was that the tubes would soon burn out and that it would be necessary to do further work with the tubes to give them long life. I told him that the tubes built two years ago last June had done services up to the last month when Moray, through their leaking on account of what he says is his crude way of making them, had had to make new ones. His answer to that was that if it is battery action the tiles might be used for some time then left idle that they would rebuild themselves and thus go on serving as the tubes mentioned had clone. He told its that an experiment that would be very helpful in determining what the energy was or the efficiency of the tubes would be to run the machine just as long as it would go, then determine what pact quit first and if it were the tubes make observation as to what happened. I didn't know just what Moray's response to that suggestion would be, but yesterday he dropped in to say that he was very anxious to make the test as soon as possible, and asked that I assist him in figuring out the proper personnel of a committee, seal the machine tip in some way after it was lighted, and then make frequent observations as to its continued operation for the full period of time it would run. I expect to work out such arrangements as soon as possible.

From this demonstration it is established, I should say absolutely, that what we have is something entirely new and very wonderful and that there is no possibility for doubt on any phase of this proposition. Dr. Fletcher left for New York by automobile yesterday morning. He told me that following the time that he had to sit down' and think out this matter a little, he would write us and try and make some suggestions for further development.

With kindest regards, I am
Yours respectively,

Original was signed .-by R. L. Judd,
Kearns Building, Salt Lake City, Utah

One outstanding example of how a discovery can be appropriated by others is in the "Moray Valve." During June of 1925, Moray's experimentation. in searching for a more stable detector for his Radiant Energy Device, blended certain substances which he had brought from Sweden in 1914 and had used in his Radiant Energy Device as a valve.

Moray failed in his search at that time, as far as getting a substance for the Radiant Energy detector, but discovered that by making "pellets" of a mixture of the Moray Lead, which withstands heat up to over 1800°F, and using pure germanium mixed with bismuth, iron sulphate triboluminescent zinc, and certain other impurities including the Moray fission Material, he obtained a substance that had wonderful properties as a detector or valve for radio signals. he made a specially constructed radio speaker, altho standard speakers also responded. With this germanium combination alloy used as a detector, it was found that radios would operate without batteries or tubes or any other source of power than that obtained from the radio transmitting station. His germanium valve, with a special radio circuit which he devised and a Special Moray constructed loud speaker, brought in radio signals which were loud and clear; the radio programs could be heard all over the building. Dr. Moray disclosed this fact to Atty. R. L. Judd and Atty. A. H. Nebeker witnessed Mr. Judd's signature on the 12th day of October 1925, describing how the valve was made to Attorney

Judd and showing them a drawing of the same which they signed in evidence. This valve and more data was also explained to Dr. Carl Eyring in the presence of Atty. R. L. Judd, also in 1925. This valve was fully explained to Dr. Murray O. Hayes in 1926 and at later dates. In October 1928 this Moray valve was explained in detail to Dr. Harvey Fletcher of the Bell Laboratories in the presence of Atty. R. L. Judd who wrote a detailed account of this disclosure. In July 1931, an application for patent was filed in this germanium valve as a detector and oscillator under serial #550622. "This valve and radio were explained and demonstrated to hundreds of people as late as June of 1938. Some of these gentlemen were — C. F. Clauson, J. C. Jensen, H. D. Snyder, Clive Gardner, W. Lewis Gardner, and many others who attested to these facts and signed documents.

In a letter to Mr. W. H. Lovesey describing this valve in action Dr. M. O. Hayes stated, "He connected his detector to a crystal set for receiving radio, in place of the crystal, and obtained better reception than with the Erla crystal, though the antenna was merely one of the bell type, in my home. He also took a lump of lead treated according to the process he has discovered and used it in place of the crystal, and got wonderful reception on a radio — loud enough in fact to operate an old fashioned horn speaker of the type put out by RCA about 1923."

From 1930 to 1938 Dr. Moray made tests at various times with scores of people present of his special radio. This radio, on several occasions received broadcasts from Little America, from Admiral Byrd and his party from the Antarctic. These broadcasts came in loud and clear on occasions when regular radio broadcasting stations reported that interference was so severe they could not receive Admiral Byrd's broadcasts because of weather conditions.

This special RE radio with a Germanium alloy valve was also demonstrated to Felix Frazer of the R. E. A. and be experimented with it during the months of March, April, and May of 1939.

As has been the case many times, the original discoverer of some great invention does not get the credit for having first made the discovery. This fact has been repeated in the case of the device now known as *the transistor*. This was first used by Dr. Moray in June of 1925 under the name of "Moray Valve" in many radios constructed and operated for many years. This is strongly documented in many references contained in the early records of the work of Dr. Moray by many witnesses.

(See Footnote also cut on patent papers)

EDITOR'S NOTE

Compiled from excerpts for the history of the T. Henry Moray research work on what he designated, at the time of it's discovery; as the Moray Valve. Details have later shown this valve to be the same as the discovery now known as the Transistor.

It was June 24, 1925, that T. Henry Moray discovered that by alloying Germanium with various substances he was able to make a valve for a radio receiver capable of reception of radio signals of considerable strength without the use of tubes, batteries or any conventional source of power. This germanium alloyed material he also used successfully in the amplification of radio signals for radios he constructed and used in his home and the home of his sister's family, with reception loud enough to be heard throughout the house. He devised a specially constructed loud speaker which worked better than the then standard permanent magnet type commercial speaker.

A schematic drawing of this radio hookup and the place where the germanium "compound" valve was used was shown to and described to Atty. Robt. L. Judd in the presence of Atty. A. H. Nebeker and this drawing was duly verified on the 12th day of October, 1925. The same drawing was later signed by C. Fred Schade, May 22, 1931, and by Dr. Murray O. Hayes, L. A. Thomsen, R. J. Chapman, D. L. Farnsworth and D. Thomsen, March 21, 1931. On the same day of March, 1931, the above six gentlemen were permitted to examine a set of six drawings showing uses of the compound germanium valve and the description of the materials used with the germanium and the method of forming this compound into pellets and why germanium works best when these "impurities" are introduced in the pellet.

On November 14, 1927, the germanium alloy material with another radio hookup was submitted and sworn to before R. Howard Allington, a notary of Salt Lake.

On September 17, 1928, Atty. Judd who had signed a drawing that he had had explained to him, the Moray germanium valve, on the 12th day of October, 1925, wrote a letter in which he stated among other things, the following "Dr. Fletcher spent the afternoon in a detail study of the drawings (plural) demonstrating the circuits involved and the theory upon which the mechanism is based. *This was as requested by Dr. Fletcher.*"

Application dated July 13, 1931.

This valve is indicated in the circuit shown on figures 1, 2 and 3 and will now be described in detail. The valve may consist of a metal case 135 to which pieces 136 of bismuth may be attached, the attachment being effected by fusing a portion of the surface of the bismuth and applying it to the case. A piece of iron sulphide may be attached to the bismuth by fusing, the said iron sulphide, however, being insulated from the case 135 at the point 138. It is also advisable to use, at the points 138 between 136, 137 and 139, portions of germanium which has some very unique properties in the functioning of the valve when used as a booster or amplifier. At 139, in the form of a rounded stone, is a small mineral body containing (material blanked out in this paper for security reasons but can say it describes the Moray fission material) triboluminescent zinc and germanium compressed into a hard, rounded stone. This rounded stone is delicately supported between the pieces of iron sulphide 137 and the upper piece of bismuth 136. The stone 139 has remarkable amplifying

and rectifying properties, is also remarkable for the maintainance of a higher temperature than exists in its surroundings, as well as for its radiation of alpha, beta and gamma rays which produce an ionic reaction. It is by reason of this later property that this stone readily ionizes gases. It will be understood, therefore, that this stone may well serve as a valve which allows energy waves to pass in only one direction at a time, that is to say, from the antenna capacitor into the various circuits or from the circuits into the antenna capacitor without necessarily changing from H.F. or A.C. to D.C.

Extending through the case 135 but insulated therefrom, is a metallic pin 140, this pin being connected to the antenna lead-in and carrying a piece of molybdenite (molybdenum sulphide or a molybdenum metal combination of Moray mixture of the germanium alloy). This later contacts the stone 139. A wire 142 connects the case of 135 with the various hookups hereinbefore mentioned. An arm 143 extends through the case 135 and furnishes a support for the wire 142 while at the same time it is provided with an upturned portion having a nut 144 threaded thereon for the purpose of securing a tight covered sealed plate over the otherwise open mouth of case 135. This, with variations and hookup shown in figure 10, as used for the rectification and amplification of radio or other high frequency signals without the application of any outside current other than the incoming radio or Cosmic signal and small pencil sized dry cell batteries. Certain hookups require no battery cells whatsoever.

*See photostat patent application #550611.

The following is a copy of one of the signed papers on the Moray germanium valve which anticipates the transistor. This tracing cloth document was signed as having been read and signed by the following on December 16, 1937: K. K. Steffensen, Johanna Solmon. Christ T. Clawsen, J. C. Jensen, H. G. Snyder, W. Louis Gardner, Clive D. Gardner, which reads as follows:

"This and more data was originally explained to Dr. Carl Eyring of the B.Y.U. with Atty. R. L. Judd present in my home (Morays) in 1925. It was later shown to Dr. Harvey Fletcher of Bell Laboratories in the Fall of 1928. Later to Dr. Murray O. Hayes and later this was incorporated in the RE patent application of July 13, 1931, serial number 550,611 (dates furnished on request). The Moray valve and circuits involved shown on the drawing 1, 2 and 3 were there described in more detail. The valve used a metal envelope shown at #135 to which bismuth was attached at 136 by fuzing. Iron sulphide was, or, one might say, may be added to the bismuth by fuzing. The sulphide being insulated (from case 135 at point 138, portions of germanium were used at point 138 between 136, 137 and 139. It has been found that germanium prepared by the Moray mixture, which was explained to Dr. Hayes, Messrs. Chapman, Thomson and others enough to establish dates in March, was the same as had been explained to Dr. Fletcher in 1928 in complete detail. All had been sworn not to describe what they saw, only to establish dates of data signed. Dr. Fletcher, according to Air. Judd's word to me, had, in the presence of Judd, been placed under oath at Moray's request that he, Dr. Fletcher, would keep sacred what I (Moray) was about to disclose to him. I often refer to a detector tube as a valve, hence this Moray valve. The "rounded stones" shown in the drawing are small Pellets containing (left blank on this copy but not on the tracing for security reasons) and germanium compressed into hard round pellets. Germanium may be mixed with other materials explained to Dr. Fletcher, Dr. Hayes and others. These pellets are supported, as shown in other drawings.

These combinations of materials are used in the various radio hookup-, which receive radio signals in good strength without conventional power supply. This Moray valve radio has been in operation at a home at 2505 So. 5th East. St. as also at 2484. So. 5th East St. as experimental research for several years (1928-1937). No ABC batteries or power source used. This was the radio valve used in the RE powered radio which scores of people heard, especially in bringing in Admiral Byrd from Little America (in the Anarctic). Molybdenum (molybdenum, sulphide or molybdenum metal germanium combination), wording changed somewhat to suit Dr. Hayes' wording as he wrote the patent application.

Impure germanium and Moray germanium compound mixture has some very unique properties in functioning in the Moray valve. Also used valves as boosters or amplifiers when several valves were connected in the circuit together as has been shown. (Part left out for security reasons) *See circuit diagram. For more complete information see other disclosures made after putting named parties under promise to tell no one. They were told all I was doing to establish date of conception of discovery and to maintain as much protection as I could by establishing these dates. The tracing is signed T. Henry Moray and then signed by the gentlemen named above, some on the 15th day of December 1937, some on the 16th day of December 1937, as shown on the linen tracing cloth drawing.

The Moray files' signed drawings, records and documents. together with scores of witnesses who heard the Moray radio operated by the Moray germanium valve, all prove that Moray discovered and experimentally operated the device now known as the transistor some twenty years prior to the time the Bell Laboratories did so. The records show this discovery was disclosed as early as 1925 to Dr. Eyring who was later with the Bell Laboratories and a cousin of Dr. Fletcher. Also that in 1928 it was shown to Dr. Harvey Fletcher who was the head of the division of the Bell Laboratories which came out with the transistor.

It is the opinion of the editors that it is certainly strange that two employees of Bell Laboratories came out with a germanium mixture that protyped the Moray valve. We doubt that the Bell Laboratories know the full story of this discovery as they being an honorable company would never have been a party to such an unethical action.

(Footnote Wood & Webber, Inc.)

Képaláírások:

- Photostate patent application #550611
- The Moray pocket radio 1 1/2 times actual size used Moray Germanium mixture. Moray valve now called Transistor
- Moray Valve Circuits
- Official U. S. Government picture taken by Dr. Frazer in April 1939 of the Moray radio using the special Germanium mixture valve. With special loud speaker by Moray that will work with Moray Valve. First discovered in 1925.

Wood and Weber

REPORT on MORAY IIADIANT ENERGY DEVICE

On April 7th and 8th, 1933, the writer in company with Dr. C. R. Bonzel and Mr. J. J. Jurgensen of Greeley, Colorado, visited Dr. T. H. Moray, at his laboratory, 2484 South Fifth Street East, Salt Lake City, Utah, and thoroughly discussed with him the device which was the particular object of this investigation, and other devices and products, of which Dr. Moray is the inventor.

We also talked with others in Salt Lake, who are or have been connected with Moray in the development of these inventions. We first met and talked with Mr. W. H. Lovesay, Purchasing Agent of the Utah Refining Co., of Salt Lake City, who has been closely associated with Dr. Moray in the development of this work, and who knows him intimately.

This is marked as it contains details of construction not deemed wise to publish.

I was impressed with the apparent honesty of Mr. Lovesay's opinion of the invention, and that he was wholly convinced of the integrity and honesty of Dr. Moray. At this conference Mr. Bringham, a business man of Salt Lake, was also present. He is secretary-treasurer of the Moray Products Co.

Mr. Lovesay described to us numerous demonstrations he had witnessed of the Radiant Ray apparatus, as well as other inventions and devices developed by Moray; and although he made no claim as understanding them, there was no question in his mind as to the honesty of purpose, integrity and ability of Dr. Moray. Some two hours were spent in going over various matters connected with the project, with Mr. Lovesay, who took the time out of a busy day at his own affairs to give its all possible help in our investigation. The balance of the first day and a part of the second was spent with Moray at the laboratory and in visiting others connected with the project.

I found that Dr. Moray was extremely open and frank in every way, and gave us every possible opportunity to investigate what we came for. He is, in my opinion, a man of marked ability in the line of research and invention, but needs assistance in developing it into a commercial business venture. I found no evidence of lack of integrity and honesty. He has evidently worked for many years in the investigations, and of course is thoroughly imbued with the nature and possibilities of the particular invention. The investigation convinced me that he has discovered something about the nature of energy which has not been known before, and which is not even now understood by anyone.

Certain theories have been advanced by him, and other scientists, to explain the phenomenon, but all that can be said about it is that certain results have been obtained that indicate unlimited possibilities for development along these lines, in the way of production of energy for all light, heat and power purposes.

I am thoroughly convinced that the device is not a hoax, or a fake, and that the results are not the results of induction from established power sources or batteries; but I do not pretend to understand the real nature of the source. This is something, that in my opinion, can only be determined by future research.

The device is not especially complicated, nor is it

This is masked as it contains details of construction deemed unwise to publish.

I talked with a number of reputable people who witnessed numerous demonstrations, and examined signed and sworn-to letters, describing the demonstrations. From all of this, and from the conferences with Moray, I am fully convinced that there is no hoax or fraud about the device. The commercial development at this time apparently hinges upon the construction of a vacuum tube especially invented for this purpose, which will eliminate

Masked, not for public information as it contains construction information

a tube, an which application has been made for a patent. He thinks it wise not to divulge the details until applications can be made for patents in foreign countries, and until sufficient capital is available to establish laboratory facilities, when the tubes can be perfected.

My conclusions are as follows:

- 1 — It is not a hoax or fraud in any sense.
- 2 — Dr. Moray has discovered a new principle in electrical energy that has not heretofore been known.
- 3 — That the nature of the energy is not fully known, but that Moray's theory of the world being surrounded by a sea of oscillating energy is as satisfactory as any.
- 4 — That energy that can be utilized for light, heat and power has and can be produced from the surrounding space by devices which Moray has developed, but which need perfecting.
- 5 — It would seem that any amount can be developed. That in effect we are surrounded by an unlimited reservoir of energy that can and some day will be utilized.
- 6 — That to demonstrate the commercial feasibility of the project, equipment and funds must be made available, under competent business administration.
- 7 — The results obtained so far indicate that such research undertaken in the proper spirit and under proper conditions, will result in the development of an unlimited source of energy that will revolutionize our whole industrial and economic life.

In addition to the radiant energy discoveries, Moray has developed other devices and products that should have widespread commercial value, if properly exploited. Among them is a simple radio device using neither tubes or battery, that can be manufactured inexpensively and widely marketed. Whether it is patentable or not remains to be seen, as no application has been made, but even with a very limited patent protection should have widespread commercial value.

I feel that if Moray is given the proper opportunity, under competent and sympathetic management, he will produce revolutionary results in many lines of research.

Respectfully submitted,
FRANKLIN P. HOOD
For Wood & Weber, Inc.

April 12, 1933

Képaláírás:

Official U. S. Government picture taken by Dr. Frazer in April 1939 of the Moray radio using the special Germanium mix. ture valve. With special loud speaker by Moray that will work with Moray Valve. First discovered in 1925.

Rossz minőségű fotókópia szövege:

MORAY SCIENTIFIC LABORATORIES
Dr. T. H. Moray
2484 South 5th East Street.
SALT LAKE CITY, UTAH

September 15, 1931.

To the Commissioner of Patents
Department of Commerce
United States Patent Office
Washington, D.C.

Dear Sir:

I, Thomas Henry Moray, a citizen of the United States, and President of the Moray Products Company, to whom the following patent was assigned:

#550,611 Radiant Energy Device Filed tiny 13, 1931

hereby revoke the power of attorney given to ?név1?, ?név2?, Karkan & Sutton, Attorneys, 700 - 10th Street, Washington, D. C., and until further advice, it is the desire that all communications and correspondence in connection with this patent shall be directed to the Moray Products Company at 2482 South 5th East Street, Salt Lake City, Utah.

Respectfully,
MORAY PRODUCT COMPANY

Accepted
SEP 17 1932

In a letter sworn to before a notary public on Oct. 29, 1928 and written Oct. 10, 1928, Dr. Murray O. Hayes states:

To Whom It May Concern:

Below is a report of my observation of the Moray cosmic energy device.

The aerial used is about two hundred feet long and is about eighty feet above the ground, the wire is a copper cable approximately a fourth inch in diameter, and well insulated. The ground is the water pipe in tile basement of Dr. Moray's home.

The device was assembled in a trunk through the sides of which were holes for the connections to ground and to the antenna and for observation; the said holes were about one-half inch in diameter. There were two boxes about ten by twenty by four inches, one on top of the other; both were closed and the covers fastened with screws. On the upper box was lying an insulated panel about an inch thick by fifteen inches long and three inches wide; it is of slate or hard rubber or some material of similar appearance. On this were two binding posts that were connectible by means of a small switch; also mounted on this panel is a body about two and one-half inches square, wrapped in friction tape, front which protrude two poles about one-fourth inch in diameter, apparently of soft iron. A double receptacle for light globes was connected in the circuit, in one of which was a twenty watt globe, and in the other a hundred watt globe.

E. G. Jensen, R. L. Judd, and I were present and examined the trunk to see if there were any connections other than the antenna and the ground, but found none. The small switch above mentioned was thrown several times, but without result; the connections to ground antenna were also removed, also without result.

Dr. Moray then took a magnet, which was a very broad, short limped U, and began to stroke one hole of it in the pole in the taped body; M. Jensen placed his fingers on the binding posts several times, and at last received a rather vigorous shock; Dr. Moray then threw the switch and the globes lighted. When the switch was opened the lights went off and came on again when the switch was closed. Removing either the ground or the antenna connection caused the lights to go out, but they came on again as soon as the connection was re-established. The time of excitation was ten minutes, and the lights came on at 7:59 a.m., October first.

The trunk was then closed and sealed with railroad car seals, and the numbers on the seals were recorded by Mr. Jensen. Each morning and night up to the morning of Oct. 4, I inspected the seals and observed that the lights were burning. About 10:30 on this date the detector was jarred out of adjustment by the felling of a heavy tree next to the house.

The evening of the same day Mr. Moray removed the detector in the presence of Mr. Jensen and me and in twenty minutes had it readjusted and reassembled ready to start. As soon as Mr. Judd arrived the stroking began and the lights came on in about ten minutes. The trunk was again sealed as before.

The device continued in operation until the morning of Oct. 8, and the trunk was opened in the presence of the three witnesses above mentioned after a run of eighty-four hours. The hundred watt lamp was removed and a standard 575 Hotpoint electric iron was plugged into its place; the iron was heated as quickly as though on the

usual house circuit. During this test a sixty watt globe was put in the place of the twenty, so that the total wattage was 635.

The antenna and ground connections were then removed until no current was delivered when the switch was closed, and five 100 watt globes were substituted for the iron, making a total power output of 560 watts. The lamps appeared to be as bright as when on the house circuit. It required four minutes of excitation to get it in operation again.

After again being disconnected until it ceased to operate it required but one minute of excitation to bring in the current.

While the test was in progress every test that could be thought of was applied to make sure that there were no hidden connections to the house circuit or to a battery; the house lights were turned on and then all main switches pulled, which turned off the house lights but did not in the least affect those in the test. After the run had terminated the trunk and table were examined for wires, but none were found except those to the antenna and to the ground.

As a further proof that the conversion of the energy was due to the mechanism in the box, Dr. Moray hit the table on which the trunk was standing, a moderate blow with a hammer whereupon the light flickered and went off, due to the detector being shaken out of adjustment.

It is to be noted that after a total run of 158 hours the device supplied 635 watts; inasmuch as a horsepower is but 746 watts this equals 0.878 of a horsepower or slightly more than 7/8 horsepower. This alone is sufficient to dispose of any suggestion of a battery.

In witness to the above I hereunto sign my name"

Signed, Murray O. Hayes
Duly verified and notarized.

During the early morning hours of September 3, 1926, Dr. Moray first successfully operated his sound detector device. After months of work in his laboratory, he was able to "pick up" conversation and music from thousands of feet away from his laboratory without instrument or wire connections to the point from which the conversations originated. Several days later the public was invited to listen to conversations originating in houses and from streets which were a considerable distance from the instrument in the laboratory.

In October 1929 a scientist from Russia, a Dr. A. A. Yakalov came to the Moray laboratory and witnessed tests of the Moray Radiant Energy equipment as well as listening to conversation brought in by the Moray Sound Pickup Device which was going on some five miles from the Moray laboratory i.e. in the Denver and Rio Grand R. R. Station, Salt Lake City.

By 1936 the Sound Detector Device had been improved to where it would operate radio loud speakers. Up until this time only radio head phones had been used. The signals were brought in loud and clear. A test of this equipment was given to a General Shinkle of the War Department and an accompanying Captain of the U. S. Army in December of 1936. These army gentlemen, with about eight civilians witnessed these experiments. The general said he was very much impressed and asked how the Sound Pickup Equipment might be obtained for the U. S. government. Dr. Moray told the general he would give it to the government free of charge, the only requirement being that the government give the device the Moray name. The general said he would report to his superiors. It was later reported to Dr. Moray and others by a U. S. Congressman that an official report had been filed in Washington, but that the government had not accepted the offer. This report was made by U. S. Representative Congressman Thomas Amlie.

Now for the question of induction.

As was suggested by Dr. Harvey Fletcher, Dr. Carl Eyring, who was head of the department of physics of Brigham Young University, saw a demonstration of the Moray device. In a statement dated Sept. 7, 1929 Robert L. Judd relates that a demonstration was given to Dr. Eyring in October of 1925. We quote:

Dr. Eyring was permitted to risk any questions he wished and after spending over an hour with the device in operation, he said that he could not find any fault with what he saw; that the current was not obtained from batteries or hidden wires so that his only conclusion was "induction," but that such induction was wonderful and unheard of before over such distance."

Dr. Eyring said that if the device would operate five miles from all power lines, he would be satisfied that it was not induction.

A demonstration was given in Emigration Canyon, there being no power lines in the canyon at that time, in the presence of Mr. Judd, Mr. O. W. Adams, and a Mr. Nebacker of the Judd law firm. A site was arbitrarily selected by Messrs Adams, Judd and Nebacker. Mr. Adams and Mr. Nebacker erected the ground and antenna. A single one-hundred watt lamp was lit for a period of one hour.

Some days later Dr. Eyring, who had not been present at this demonstration, met these men at Dr. Moray's laboratory. We quote from Mr. Judd's account of that meeting. "We spent the morning going over all the theory and hook-ups and examined the device and the Dr. asked questions continually. He made several drawings and sketches. Dr. Eyring congratulated Dr. Moray on what he termed as a wonderful work and said that what he had seen and heard was electrically, mathematically and scientifically sound and corrected.

A statement dated December 1929 quoted below was written by Dr. Eyring in his own handwriting.

"This discovery with its processes, mechanisms, and devices deals with and enables man to use the so called cosmic energy, acts energy radiated from the universe to operate any of the mechanical, electrical, magnetic, or optical devices for the utilization of energy or power.

"Cosmic energy as the term is here used, is energy which exists in the space surrounding the earth and which have or may have, its source in the natural processes and movements of the earth, in the earth itself, and includes its atmosphere and component parts or elements on celestial bodies. These cosmic rays are continually bombarding the earth.*

To further disprove the induction theory concerning the Moray device, let us consider another test.

On October 29, 1926 Dr. Moray, Atty. R. L. Judd, and Mr. E. G. Jensen loaded the equipment into Mr. Jensen's car and drove up Daniels Canyon into the Strawberry Valley. Mr. Jensen gives a very detailed description of the weather, the location, how the apparatus was set up and the subsequent successful demonstration. The speedometer of the car verified that they were fifty-two miles from the closest power line when the test was made.

In July of 1950 Mr. E. G. Jensen verified all of the statements made in his letter of 1926 concerning the Strawberry test and another letter dated October 1928 telling of the before mentioned endurance test.

Now let us consider the fourth objection made in 1925 to 1945 to the Radiant Energy device on the basis that there is no such source of power. The discoveries of recent years make this claim look increasingly out of line. However it might be interesting to examine a letter written by Dr. Moray and witnessed as correct by a prominent Salt Lake attorney who was present during the conversation referred to and from which we quote in part.

The engineer who came here was a Mr. Pearson employed by a Mr. McKee, a high official in the north-west for the Electric Bond and Share of New York. Mr. Davis said Mr. Pearson did not believe in the Radiant Energy Device, not because of any fault he could point out of any evidence of anything being wrong or evidence of fake, but on the grounds that he did not believe there was such an energy to be had. That the device acted contrary to all known electrical laws on the incoming or primary side; but worked standard electrical devices on the output on the secondary side. He proved no standard meter would give a true reading of the incoming current; that a milli-volt meter gave a lesser voltage reading than the reading on the five volt scale or in other words the greater reading was had on the meter requiring 5000 times as much voltage to operate it. He made tests with batteries and other methods to check the meter and proved it to be in perfect operation and correct when used with other currents. Mr. Pearson tested the tubes and said they were OK and that he was satisfied they were all Moray claimed them to be and perhaps even greater worth and value than Moray might realize. In spite of this acknowledgment about the tubes and his OK of them he would not accept the Radiant Energy Device, although the tubes are the heart of the Radiant Energy Device, and Moray pointed out to Mr. Davis, the real invention is in the tubes.

Moray was very much pleased with everything, all and all, and as Moray told Mr. Davis, Mr. Pearson really OK'd the whole thing. Being of the frame of mind that there is no natural source of electrical wave energy to which Moray could tune his device, he would not accept the Radiant Energy Device as lighting the lights, but he accepted the tubes as they operated on this same Radiant Energy. They operated the radio and produced music which he acknowledged the best he had ever heard, the purest and best radio music ever produced. Being so prejudiced against there being such a source of current, it would be impossible for him to accept the device or the demonstration, or with an open mind understand what he was seeing. Yet in that opposed frame of mind he had to acknowledge that the current on the primary side acted as an outlaw current doing things which, from the standpoint of known laws are unreasonable and contrary to electrical law. This he should have reasoned, proved the results he saw were not and could not be obtained from any known source of electrical current or it would have obeyed these laws. His objection that on the primary side it was an outlaw current while on the secondary side it was able to operate known electrical devices, is very satisfactory because this only goes to show that it can be controlled when the proper methods are used.

Saying that the tubes are of great value and OK is the same thing as acknowledgment that the Radiant Energy Device is OK because as Moray said, the tubes are the heart of the Radiant Energy Device.

In 1931, Dr. M. O. Hayes wrote about a Dr. Gunn, a civilian scientist of the Naval Research laboratory who had proved that the earth is generating 200,000,000 amperes of electrical current.

There are hundreds of letters on record of experimental tests made by the Radiant Energy Device written by those who witnessed these tests. These were made for the purpose of establishing the scientific soundness of the theory upon which the device operated. The purpose being to enable the inventor to progress toward the perfecting of his invention by testing the workability and soundness of his various ideas, changes, and additions made to the component parts of the invention.

* It will be noted that Dr. Eyring attributes the energy to induction or to Cosmic Rays. Dr. Fletcher to battery action kept alive by energy from the universe and yet Dr. Fletcher pronounced the current high frequency. Please note, battery action is always direct current and never high frequency current so it could not be battery action.

A partial record of these letters was compiled from the original documents by a U. S. government investigator Dr. Felix Frazer and the original was signed by him.

Before we leave the account of demonstration, let us consider just a few more letters concerning them.

On January 10, 1938 Mr. George R. Pyper wrote a letter from which we quote in part:

"To Whom It May Concern:

I have worked in electricity all my life, was with the Utah Power and Light Company for thirteen years and worked in all departments including sub-stations. I have been with the Kearns Corporation over seventeen years; and leave charge of all the electrical work for the Tribune and Telegram Publishing Company and in the Kearns and Tribune Buildings.

On December 23, 1937, I witnessed a demonstration at Dr. Moray's home at 2484, So. Fifth East of his electrical marvel box. He let me see inside this box and there was a transformer H. F., some of his cold tubes, and some condensers. Dr. Moray connected this box to an aerial and ground wire and lighted about thirty small 120-volt lamps. He then disconnected the ground wire from the outside and two of us held a counter poise antenna attached to glass insulators in the room and when he connected the box to this counter poise antenna I saw the same results.

During this demonstration and while the lamp and appliances were on I shorted the aerial and ground wires. There was no spark, it just turned off the power from the box. I then took hold of both these wires. There was no feeling and they were both cold."

Mr. Pyper continues with a further description of the demonstration and then concludes.

"I am satisfied myself from my experience in electricity that there was no fake of any kind or concealed batteries. Everything was in the open so I could see every operation."

Let us now consider a portion of a letter written in October of 1930 by Mr. W. H. Welling, then Secretary of State of the State of Utah. Mr. Welling described the device and the demonstration and told how he and Mr. Gaxiola, the Mexican Consul, tuned in the system as the inventor had done, closed the switch and brought in the full volume of lights. He continues, "In order to make sure that the lights connected with the house circuit were entirely separate from the lights produced through the Radiant Energy machine, repeated tests were made of disconnecting the entire house circuit in which event the house meter did not register at all. An electric iron was then connected with the house circuit which of course produced the ordinary reaction in the house meter. After the demonstration had been completed, the inventor raised the two boxes from the work bench on which they were located, showing that there was absolutely no connection by wires from below or from any place, save to the aerial and the ground wire.

At the conclusion of the demonstration, Moray dropped a stone weighing two or three pounds about two feet onto the work bench. The jar caused the lights to flicker a moment and go out. This simple demonstration itself seemed to show conclusively that the power derived was dependent wholly upon the machine and in no way upon the house circuit.

In a report of the Moray Radiant Energy Device, dated April of 1933, Mr. Franklin P. Wood of Wood and Weber, Inc. Engineers later of the U. S. government wrote in part:

"The balance of the first day and a part of the second was spent with Moray at the laboratory and in visiting others connected with the project.

I found that Dr. Moray was extremely open and frank in every way, and gave us every possible opportunity to investigate what we came for. He is, in my opinion, a man of marked ability in the line of research and invention, but needs assistance in developing it into a commercial business venture. I found no evidence of lack of integrity and honesty. He has evidently worked for many years in the investigation, and of course is thoroughly imbued with the nature and possibilities of the particular invention. The investigation convinced me that he has discovered something about the nature of energy which has not been known before, and which is not even now understood by anyone.

Certain theories have been advanced by him, and other scientists, to explain the phenomenon, but all that can be said about it is that certain results have been obtained that indicate unlimited possibilities for development along these lines, in the way of production of energy for all light, heat, and power purposes.

I am thoroughly convinced that the device is not a hoax, or a fake, and that the results are not the results of induction from established power sources or batteries; but I do not pretend to understand the real nature of the source. This is something that in my opinion, can only be determined by future research."

Now let us consider a letter written by Dr. Murray O. Hayes to Mr. W. H. Lovesy on October 24, 1929:

"Dear Mr. Lovesy

Pursuant to my promise to you at our recent discussion, I am writing to make of record the extent of my acquaintance with the construction and operating principles of the Moray device for utilizing cosmic energy.

You are already aware that I have seen many demonstrations of what this mechanism will do, and that I have seen the parts of which it is built. Recently Mr. Moray has shown to me the wiring diagram of the assembly, and I am free to say that I can find no inconsistencies in it, nor anything which does not appear to be logical and sound. While the hook-up appears to be very complicated, when looking at the machine, it is in reality very simple in essence, and based on recognized laws of electricity, when all is explained. There are many features which appear to be incidental, but they are in reality of basic importance.

He has also shown to me and explained the detector which he uses. In this he has applied a fundamental principle of electric circuits which, I believe, would not be noticed unless pointed out by him. This element of his device also, as above mentioned in respect to the circuits, has numerous features which appear incidental but are the heart of the matter and of first importance.

I was recently present when an electrical engineer representing a foreign government was given a demonstration of the energy machine. He at first said that amplification of radio waves accounted for what he saw, although it would be a real achievement to amplify such waves sufficiently to light six one hundred watt lights at one time, and also to heat a flat iron of the standard five hundred seventy five watt type; when he had seen the inside of the device he admitted that it could not have been what he had supposed. He remarked many times "It is very interesting."

This machine has been operated in my presence so many times, under so many different conditions of weather and of season that I am positively convinced that it is what its inventor claims it to be, and that its commercial adaptation is feasible. I believe that Mr. Moray has explained all to me without reservation, and I am sure that this is a revolutionary and epoch making invention."

Sincerely yours,
Murray O. Hayes

On an attached sheet dated Oct. 25, 1929 to Mr. Lovesy, Dr. Hayes lists his education record and qualifications as follows: "A. B. with major in physics under Dr. Harvey Fletcher; M. S. including graduate courses in physics and mathematics; Ph.D. in geology. Five years in examining corps, U. S. Patent office. Acting head of department of physics, Brigham Young University, 1922-23, vice Carl F. Eyring, was finishing work for doctorate. To take bar examination soon.

It is very interesting to go through these original letters and records of demonstrations and read the detailed accounts of how thoroughly Moray's Radiant Energy device was demonstrated, examined, and actually taken apart. It is even more interesting to read recent letters by men who saw these early demonstrations. Some of them stand steadfastly by their original statements, recounting with surprising accuracy what they saw. It is very puzzling to read letters from others who saw so much but have had no direct contact for many years. "I have no way of deciding whether or not the invention is genuine, simply because he (Moray) refuses to let anyone see it or build one like it," is the way one observer put it. Others follow along this same line of thought. What could they possibly say if confronted by their two letters written thirty to thirty five years apart. Have they forgotten how much they saw, or has their memory been tricked by steady outside pressures?

The Moray energy equipment has been thoroughly investigated and tested. It has been experimented with under all kinds of physical and weather conditions. It has been tested many miles from all power lines before capable and disinterested electrical men and distinguished scientists from all parts of the world who could find no answer other than that advanced by the discoverer.

The discovery of the natural principles and laws through which energy has been captured and made part of the great discovery has been brought about by years of intensive work with this one phase of energy in mind.

It should be just as easy to, accept the fact that a receiving set or electrical device has been constructed for the purpose of receiving the energy, waves from the universe as it is to accept a radio receiving set that receives "audio waves" transformed from electrical impulses as the radio does. One transposes electrical waves to mechanical while the other transposes energy waves into light, heat and power. The facts involved are the same in both the radio receiving set and this device. The radio receiving set receives man transmitted energy waves out of the air and transposes them into "audio waves," the Radiant Energy Device receives oscillations from the universe and transposes them into electrical energy. As in the reception the circuit radio waves, so in the case of the Moray device; the circuit is a tuned arrangement to respond to the particular wave frequency "oscillations" which it is desired to intercept. A "valve" used to prevent the return of the energy to the outer circuit and force it to go through the, power application circuit is a part of the invention.

The discovery reached the point where continued experimental demonstration produced no valued results as to proof of the device and each new experiment was becoming a rehashing of well documented facts. Dr. Moray has exhausted all suggested tests, all are on record and all are conclusive. Dr. Moray made so many experimental demonstrations and so many disclosures during the early years of Radiant Energy that he found he was putting his discovery into a position of jeopardy under the patent situation and the U. S. patent law of public use, Section 4886. This situation has led to the present strict attitude Dr. Moray has had to take on demonstration of

the Radiant Energy Device. He must be very careful in the perfection of the Radiant Energy discoveries not to invoke public use. He will not jeopardize those who are interested in Radiant Energy by giving demonstrations which would cause them and him to loose their ownership.

Sometimes it is very difficult for an inventor to secure patent protection, particularly if the discovery is controversial in any respect which Radiant Energy is. Most people think that getting a patent is a straight forward thing but the red tape connected with such a procedure in a new and basic discovery is almost unbelievable to one not familiar with the process. A patent application can drag on to the point where it is very difficult to finance and an inventor has to put a great deal of trust and responsibility upon the patent attorney handling the case. The complete mis-handling of the original patent application during the days of the Moray Products Company has taken years to straighten out.

To add upon all of the other difficulties involved, the patent office contested many of the points of the Radiant Energy application even though Dr. Murray O. Hayes wrote to Dr. Moray on August 7, 1937 from Washington, D.C. that he had examined every patent issued on devices for the reception of radiant energy. Most were obviously dissimilar and not a one shows even the remotest resemblance to the Radiant Energy machine. He also reported there were no patents like the oscillator tubes. Here are but two of the objections of the patent office. "Claims rejected as being drawn to an apparently inoperative device. It is thought it will not produce a sensible current because the cathodes are not heated to a point where they will emit an appreciable number of electrons" (such an objection is now obsolete.) And still another: "No natural source of electricity wave energy is known to the examiner and proof of the existence of such is requested." (This statement too is now obsolete.)

Another problem was brought to light in a letter from a Mr. John Y. Smith to Dr. Murray Hayes. We quote: "One of the parties interested formerly held a confidential position with the General Electric Co. and later with the Westinghouse Company. He nearly took my breath (Mr. Smith's) when I told him regarding Moray's fears that the proposition might be stolen from the patent office. He said it will just as sure as you sent it there. That the U. S. patent office is "honey combed" with employees of the General Electric, General Motors, and other large companies. *That he had helped steal valuable data from the patent office at the request of the above companies.* He said you were crazy if you sent a description of the device to Washington before you had plenty of money to follow through and influence enough to prevent a theft. So I confess after hearing him that I was in error scoffing at the fears of Moray."

In a court test, whether the use of an invention is "public use" which will act as a bar to securing a valid patent, or whether a particular use of the invention is merely an "experimental use" is a question of fact to be determined in each case by each individual judge. It is difficult to draw a sharp line between public and experimental uses. No one can venture a guess as to the attitude the courts will take on the question of public use. Dr. Moray will not throw Radiant Energy on the mercy of the courts. Ford Harris Jr. of the Los Angeles firm of Harris, Keith, Foster, and Harris cites a present trend toward stricter and narrower interpretation of patent laws. It seems reasonably certain that they will not become any more liberal in interpretation during the next few years.

It would be impossible to review in a paper such as this, all of the legal aspects and fine points which determine public usage of an invention. Instead let us consider just two opinions. Patent attorney Alwine of Washington, D.C. wrote: "Up to the time, and prior to the time you actually have on file all U. S. and foreign patent applications which it is desired to file, and sufficient technical data to complete patent applications to obtain full coverage, any demonstrations which are not experimental could endanger and cause you to lose all your patent rights to your invention — see Sec. 4886 U. S. patent law."

In 1939 when Dr. Moray was connected with the R. E. A., the Attorney General of the U. S. fully supported his views on demonstrations and the patent law. Dr. Moray must take a firm stand for the protection of future investors. There can be no more demonstrations until Radiant Energy is in the patent office with an allowable application.

Some scientific men have vigorously protested that Dr. Moray should make full disclosures of the principles connected with Radiant Energy to scientific men, publish full disclosures, and allow others to build full working models. Ordinarily in the case of new scientific theories this is the procedure. In these cases the theory often came years before the development of a practical application. But here we have a unique situation. We have an application developed along with the theory. We have an application which must be kept under responsible control. In the words of Franklin P. Wood, a United States R. E. A. Engineer, "If it is all he (Moray) thinks it is, (it) will more profoundly affect the human race than any other discovery in previous history."

Two of the more sensational efforts to put Radiant Energy before the public have been with a company known as the Moray Products Co., which was formed in 1931, and an association with the Rural Electrification Administration 1939-1941.

In 1931 the Moray Products Company was formed in Nevada as a stock company to finance the development of the Moray inventions. D. V. Farnsworth was President, C. Fred Schade was Vice-president, and Murray O. Hayes was Secretary treasurer. These men willfully and fraudulently deceived the court in stating their position

and power in the company. Dr. Moray gave these men his trust and confidence, particularly Dr. Murray O. Hayes. As had been seen in a previous letter, Dr. Hayes admitted that he had Moray's confidence and full disclosures. It was not long after the company was formed that Dr. Moray discovered that it was being used to further the dubious purposes of Messrs. Schade, Farnsworth, and Hayes. In 1932 Moray instigated court action and tried to save the company. In the words of Mr. John Belford, a Nevada attorney connected with the case, "The whole thing was an example of shiltness and bad faith on the part of officials of the company."

There have been men who worked their way into Moray's confidence. Mr. Murray Hayes was one of these who defrauded Moray by misissue of a company's finances which had been organized to forward Moray's invention. The Public Auditor's report, in our files, on these dealings, states in part: "With regard to the item of \$2,056.00, Murray O. Hayes took check #17 for \$56.00, check #30 for \$100.00 and =1,900.00 cash. There is on file a statement signed by Mr. Hayes listing expenditures of \$1,867.80 but no supporting invoices to cover the expenditures. There is a minute order setting aside \$2000.00 for patent expenses." The record shows all that can be accounted for in patent expenditures is \$110.80. Should I go into detail this picture would become even worse. Remember, Moray is the one who brought these matters to Court action in an effort to save the company.

Auditor's report further states "Of the total expenditures on company account of cash and checks amounting to \$7,521.20, we could definitely support by cancelled check \$3,272.50. For the \$3000.00 check issued Aug. 21, 1931, there is no statement on file as to how this money was spent." We could go on and on, but Moray at last could take it no longer and he took the matter to court. Murray O. Hayes and others were removed by Court Action but the company had had its funds depleted. However, Moray worked for five years for nothing trying to save the company but the damage done was too great. The Judgment and Decree read: "It is hereby Ordered, Adjudged and Decreed That D. V. Farnsworth, C. Fred Schade and Murray O. Hayes be and they are hereby removed as directors," etc. And further "It is further ordered, adjudged and decreed That petitioner shall have and recover his cost of suit." Moray did not get one this, these men had depleted the treasury. Remember the date of this Court order, June 11, 1932.

"Dear Sir:

This will acknowledge receipt of your letter of June 9th, and also your letter of June 28th which Judge Brown answered. I have just gotten back from Chicago and went over to see Rowsen today.

As stated to you in my letter of June 9th, Rowsen informed me that a meeting of the directors had been held and that the number of directors had been increased to seven. Since this was done while these men were directors, I saw no way of attacking its validity. However, he today informed me that what he said was that they had been considering increasing the board. This is not at all my understanding of our conversation, and if the facts are as he states them I can see no reason why I should have agreed with him to permit them representation on the new board. As Judge Brown wrote you, E. H. Hursh has been appointed a director.

In view of our understanding, it appears to me that the only thing Rowsen can decently do is to resign, but this he refuses to do. He asked me to delay any action until he could take up the matter with Farnsworth, Schade and Hayes, two of whom are in the east. I informed him that I intended to institute proceedings immediately, and if he could arrange matters in the meantime all well and good. I am exceedingly chagrined that matters have taken the course which they have, and am determined to force the matter to as speedy a conclusion as possible.

I am preparing and will file a motion to modify the decree hereinbefore entered, removing Hursh and substituting one of Morays nominees. The motion will be based on the ground of fraud and deceit, reciting the fact that Farnsworth, Schade, Hayes and Hursh at all times knew that there were four directors instead of three, and wilfully and fraudulently deceived the court. It is my personal opinion that Judge Curler will not look kindly upon these men playing ducks and drakes with his court.

I was sorry not to see you in Salt Lake, but was in a hurry both going and coming.

With kind personal regards, I remain"

Very truly your,
(Signed) John S. Belford

Some years ago Moray saw and handled one such incomplete set of unissued patent application papers in the hands of Lionel Cornwell which were let out to these who had no right to have such papers by the above mentioned Farnsworth and Hayes. This was a breach of the ethical code all patent attorneys observe. (Dr. Hayes was the patent attorney). Details, however, were missing in these papers by art oversight no doubt, for as Dr. Hayes, before he made patent application, one time wrote "He, (Moray) has also shown to me and explained the detector which he uses. In this he has applied a fundamental principle of electricity which I believe would not be noticed unless pointed out by him. This element of his device, also as above mentioned in respect to the circuits, has numerous features which appear incidental but are the heart of the matter and of first importance."

So the fact these papers got out of the application Dr. Hayes had prepared, did not do R. E. too much harm but the intent to harm is evident by such actions.

Now keeping the date June 11, 1932 still in mind, after these men were removed by Court order, we read from a sworn statement made by Air. Farnsworth and Dr. Hayes before the United States Patent Office:

"Wherefore your Petitioner (Murray O. Hayes and D. V. Farnsworth (signing this statement under oath) prays that the said Moray be excluded from access to said application; that he be given no information concerning it and that no action taken in respect thereto by said T. H. Moray be recognized or sanctioned by the patent office." This sworn statement made to the U. S. Patent Office, is slated "18th day of July, 1932." Made under oath it is signed in behalf of the Moray Product Co. by D. V. Farnsworth as its president and Murray O. Hayes as its secretary. Remember they were removed by Court Order dated June 11, 1932 and so recorded. Is this not perjury when they had been removed by Court Order June 11, 1932? Naturally when the, patent office learned the facts, this wrong was righted and Moray had his rights restored.

Again we read from a letter written by Murray O. Hayes under date of March 21, 1932, from Washington, D.C., "The Patent situation on the Moray inventions is very good." "Do not tell Moray what I have. told you, as we are trying to get hint to do certain things but he probably will not if he learns that things are going well here."

Reading again from a letter dated July 15, 1931, signed by Dr. Murray O. Hayes "There is a man working where I do (U. S. Navy Patent Division) who says he makes more from his private patent practice than his salary (from the Navy.) "He does it through an associate, but we intend to have an associate anyhow, so that is OK by us I will be right on the job looking after our stuff." Another quote from a Hayes letter "I spent most of a day searching on the radiant energy device and the oscillation tubes but did not find anything even remotely resembling either one." "Keep me posted on developments there and I will do the same from this end for you."

Murray O. Hayes testified on the witness stand in Reno, Nevada, that he and those associated with him had endeavored to put together a machine described by the patent papers and had failed. A public auditor's report showed a clear misuse of company finances. There were discrepancies on money set aside for certain purposes and the amount used. The expenditures were listed but not supporting invoices to cover them. For a \$3,000.00 check issued Aug. 21, 1931, there was no statement on file as to how the money was spent. The story gets worse with the telling — meetings of stockholders were not called as in accord with Nevada law, and stock certificates were not properly issued.

On June 11, 1932 Schade, Farnsworth, and Hayes were removed as directors of the company by court order. It was further decreed that Dr. Moray should recover his cost of suit, but the treasury was depleted.

EDITOR'S FOOTNOTE —

It is a source of amazement to the editors of this article that the principles of the Moray Products Co. were allowed to walk away. The three (Farnsworth, Schade, and Hayes) with their partner in what they were doing, Mr. Harsh seemed to be on the outside of the Law. Yet as far as we can tell none were ever charged by either the courts or stockholders of the company. On top of this Hayes was allowed to practice patent law after it was proven in court that he had used the confidences of Dr. Moray and given this information to others. It was also ignored that these three gentlemen purged themselves in the U. S. patent office and Hayes was still allowed to practice patent law.

When one knows Dr. Moray as I know him you can understand why, even if it is not good business on today's standards; he wishes no one evil and after going in debt to save the Moray Product Co. he himself would not sign the charges. The cost of the fight was borne by him alone and he was sick of the sound of it by the time it was done.

The fact that Moray was not responsible is a matter of all records, still he tried for another five years to save the company, but the damage was too great.

In July of 1932, more than a month after having been removed from office by court order, D. V. Farnsworth and Dr. Murray O. Hayes, in a sworn affidavit to the U. S. patent office as the legal officers of the Moray Products Company, tried to have Moray excluded from all records pertaining to his own invention. The patent office reversed this exclusion when legal proof was furnished as to the true situation.

Fortunately Dr. Hayes must have missed some of these details which had been pointed out to him, as he and his associates failed in their purpose to reproduce Radiant Energy.

Here were men who deliberately misrepresented their true purpose until they thought they could take over completely. No wonder Dr. Moray is cautious about letting himself and Radiant Energy be put in a position of jeopardy again.

When all legal action turned against these men, their attacks against Dr. Moray became of a personal nature. Perhaps we are not as far from the jungle as we would like to think.

Now let us consider the Rural Electrification Administration and its dealings with Dr. Moray. At the invitation of the government, in the summer of 1938, Dr. Moray made a trip to Washington, D.C. Another trip was made early in the year of 1939. We quote from a letter written by Dr. Moray to Mr. John M. Carmody, then administrator for the R. E. A. in Washington, dated March 17, 1939. Dear Mr. Carmody: "I wish to express my deep appreciation of the many courtesies shown to me by you and members of your staff during my recent trip to Washington.

I have now reported to my western associates, and have consulted with them concerning the proposal set forth in your letter dated February 25, as clarified by your letter dated March 3.

They are all extremely gratified by the interest which you have shown, and by the manifestation of your desire to help in the great work of preparing radiant energy for actual distribution to the people.

Nevertheless, as they analyze your proposal, it appears to accomplish little more than this: It gives me a few months work in merely repeating what I have already done before, and it gives me the opportunity to submit my radiant energy device to an exhaustive test by your staff but not the funds to do so, and it gives me the assistance of your recommendation to the Department of Justice that all necessary patents be issued.

My associates are fearful that your recommendation in regard to the patent would still leave much work to be done, and much money to be spent, which we do not have before the patent situation is in proper order. Also, they are not yet fully satisfied that the contemplated demonstration would not constitute a "public use," and that your whole proposal would not constitute a "sale" within the meaning of the present law. They are not yet prepared to take the step of abandoning our rights to patent protection, and the situation is sufficiently complex that they hesitate to bind ourselves to make a "public use" or "sale" within the immediate future.

In other words, although they greatly appreciate the helpful spirit shown by your proposal, they are fearful that it still leaves the great bulk of our problems unsolved, and that our acceptance of the proposal at this time might seriously embarrass some course of action which would give promise of putting us much further along the way."

However, after many more assurances of good faith and assistance in technical advice and help from the justice department in securing proper patent coverage, Dr. Moray decided to go along with the R. E. A. in the hope that here was a big enough source to help give radiant energy to the world in a safe and proper manner. The agreement with the R. E. A. was along the lines that they would furnish legal help in securing a proper

patent and technical help in the form of advisors and the loan of scientific instruments, these instruments to be returned to the government if the agreement should come to an end. Dr. Moray was put on the payroll of the R. E. A. as a consulting engineer at \$25.00 per diem. In return Dr. Moray was to make all possible efforts to bring radiant energy to a commercial level. Other financial backing was also promised by those who contacted the R. E. A. This never materialized.

Dr. Moray built a new twenty room laboratory with a loan from private parties who interested the R. E. A. which was all repaid with interest. Subsequently many of the bills incurred in the building of the laboratory were unpaid and it fell upon Dr. Moray to meet them. As stated after the agreement with R. E. A. came to an end because certain parties among them insisted Moray turn matters over to include Russia, Dr. Moray paid for the laboratory out of his own resources. It took until 1949 for Moray to rid himself of the debt that this episode cost him. Not one red cent of R. E. A. money went into building the Moray Laboratory.

It is not even suggested that Moray's differences of political views extended to all the R. E. A. officials in Washington as a whole or to the administrators. however, it was not long before Dr. Moray began to have doubts about some of his government associates. We quote from an account given by Dr. Moray. As early as February 1939 "I began to fear, from personal contact, that Washington had more radicals in it than I had the slightest idea of and it worried me. I expressed my fears to some of my associates in Salt Lake City upon my return from Washington in February 1939 and later so informed a Dr. Frazer whom the R. E. A. had called in as a scientific expert to consult with me on my work and as my body guard.

In answer to my letter expressing my fears that I lead gotten Radiant Energy mixed tip with liberals and radicals which I could not go along with, Dr. Frazer wrote me on March 27, 1939, "The only thing J. M. should not say or write is anything in connection with a threat. When he does that he is very wrong and should be told so, and in fact I have told him so upon many occasions. I realize that so-called "radicals" are feared out west, but the term is not feared here in the east except by a few reactionaries." So it was I seemed to be surrounded with radicals, liberals and what have you and their talks of "their daring plans" and "this man is one of us and that man is not."

Again we quote from Dr. Moray's notes. "Dr. Frazer came to Salt Lake City and began investigatitig Moray and Radiant Energy. The following copied from my notes made in April and May 1939: In April, 1939, a department of the United States Government on its own initiative, sent a gentleman to Salt Lake City who had been introduced to me as Dr. Frazer. I was told he was an electricl expert. This gentleman was in the Moray Laboratory for about a total of two months spending many hours each day making tests and taking pictures of the Moray Radiant Energy discoveries, especially the Radiant Energy powered radio, using the Moray germanium fission valve and gathering information for written reports to his superiors in Washington, D.C. After about two weeks he said it was necessary he go to Los Angeles, Calif. and it was their desire that I also go to California."

In California further conferences were held; Moray returned to Utah in about a week and Dr. Frazer came back in May of 1939 when he again continued tests and experiments. After weeks of these tests he said "I have tested and tested until I am fully satisfied and feel there are no tests left to make (he was also getting advice and suggestions as to tests from two scientists at Columbia University in New York). He also stated as long as I lave the device I will want to run tests, so I wish you would destroy the damn thing so I cannot ask for more tests."

"Dr. Frazer returned to California and I was again requested to follow him. All these trips were paid for by the U. S. government. While in California I mentioned the "Jensen" test where the R. E. current had been passed through a sheet of 1/4" plate glass and the device operated with no hinderance to the flow of current even when passed through the plate glass.

Dr. Frazer said if he could use the "glass" test that would be all anyone in the government could ever ask for. It was arranged that he make the glass test. The only requirement I made was that the government should furnish the glass for these tests so it could not be said I had "doctored" the glass. Twelve sheets of window glass were used and the current passed through this glass and the device operated as if the glass had not been in series in the circuit. Dr. Frazer said "that is enough, we will never ask for another test." He gave me several copies of pictures he had taken of the Radiant Energy Device used to power the R. E. radio. Dr. Frazer grabbed a hammer and smashed the R. E. device, before I could stop him saying "Now I cannot ask for any more tests."

At one time, just before Dr. Frazer left Salt Lake to go to Los Angeles, after swearing him to secrecy I showed my confidence in him by disclosing details of three of the Radiant Energy tubes to such an extent I permitted him to make detailed drawings of these tubes for patent purposes. As I wrote then "I think that speaks for itself as I have only permitted one other scientific man to ever get that far into details of the construction during my entire work with this research."

In April of 1940 Dr. Moray wrote: "One former high government official in writing me, trying to convert us to doing what Felix, Woods, and others from the REA wanted us to do — disregard all patent protection and patent laws, said "Two years ago I made the statement that Democracy had probably less than five years to run

in Europe and that the process of disintegration there was probably not more than five years further advanced than here."

In other words America would, in five years or so, be controlled by their so called "liberals" (to me communists) : therefore I should have no hope of my work succeeding except with them. I need put no confidence in the protection of the laws of the country as they have been.

I was told I lead better do as I was told so I could stay in the government employ because in a little while everyone would be working for the government.

They also brought representatives from Russia to talk with me and turned certain papers I had loaned the REA over to these men.

I later wrote: "I wish I could have someone come here from our government who believes in the strength of our laws, who believes that the government that Washington and Lincoln stood for is not going to perish from the earth; someone who believes in the continued strength and protection of our United States laws, including the patent laws, and with faith in the preservation of the principles of the spirit of '76; someone who will not have a pet hobby of, to quote, "Our daring plan" and who does not live for "the expected change in our national structure."

On Tuesday morning, December 2, 1941, on page 2 of the Salt Lake Tribune, one may read comments made by Rep. Thomas D. Winter on the REA that made me feel I had made no mistakes with the REA. Washington Dec. 1. (AP) Representative Thomas D. Winter (R) Kansas, Monday demanded an investigation of the rural electrification administration, which he asserted was "obstructing national defense as surely as a paid saboteur."

"The true friends of farce electrification," he said in the house, "may as well face that fact, may as well realize, that this federal agency has fallen into the hands of a gang of communists, fellow travelers and political second story workers who do not hesitate to sabotage the national defense program in the interests of preservation of their political theories and perpetuation of their payroll."

Again we quote Dr. Moray. "I was constantly being sent to California by the REA for many reasons including the investigation of spiritual seances, the REA paying for these trips. With all there was to do, including recovering from a serious bullet wound, (Dr. Moray was shot while in his laboratory on March 2, 1940) and with all their trying to convert me to being "one of them," together with the building of a new 20 room laboratory (paid for by Moray not the REA), there was little time in these short months to accomplish what one would like to accomplish in the work with R. E. Then too, how far would any scientific research of this magnitude be getting on \$25.00 per day plus the loan of a few scientific instruments."

After Moray was shot, things went from bad to worse. Dr. Moray would not be threatened into giving Radiant Energy to men whose motives he had every reason to question.

The association was ended in February of 1941 when the scientific equipment loaned to Dr. Moray was returned to the government.

On October 16, 1956 Dr. Robert Craig, a former deputy administrator for the REA, who did not follow those referred to by Rep. Winter and left the REA, wrote that the development of Radiant Energy has been a slow, laborious task, one of the greatest difficulties being that Moray has stood all alone. People who should have been interested were more concerned with immediate returns than with the important long range returns. Naturally during such a long period, many questions arise as to protection rights, interests, etc.

Again on Nov. 14th, 1959 Dr. Craig wrote, and we quote, "Permit me to say that I have known Dr. Moray now for about 20 years and have observed him single-handedly trying to get acceptance of some of his ideas and discoveries, particularly in the area of "radiant energy." Many of the now-accepted areas in atomic and nuclear physics were outlined by Dr. Moray as early as the middle 30's.

At one time or another I have endeavored to help him by bringing his work to the attention of people in the government without any great success. *Of course, no longer do they dispute the basis of his work.* However, to bring pure research to successful commercial application involves time and money, particularly the latter. While we can spend millions for missiles that are abortive and no one seems to mind, a few hundred thousand dollars available to this man would obviate, I believe, much of the need for missiles. Of course, this is my own idea in the matter but I do believe a helping hand now to Dr. Moray could do more towards solving world tension than the mere building of bigger and bigger armaments to protect us from the "have-nots."

"I can assure you from my personal knowledge of Dr. Moray that here is a unique mind and an ability which would be worthwhile developing."

There are hundreds of letters of record of experimental tests made of the Radiant Energy device written by those who witnessed these tests. These were made for the sole purpose to establish the scientific soundness of the theory upon which the device operates. The purpose being to enable the inventor to progress towards the perfecting of his invention by testing the workability and soundness of his various ideas, changes and additions made to the component parts of the invention.

In the following pages are a few of these letters taken at random and not edited along with a few photographs of the experiments.

Washington, D.C.

October 16, 1956

Dear Sir:

In reference to your letter of October 12 regarding Dr. Henry T. Moray of Salt Lake City, Utah, I would like to say that I have known Dr. Moray now for about sixteen years. During that time he has spent his own money upon research in the development of radiant energy and various other high frequency projects.

One of the difficulties that Dr. Moray has faced that I know of to my own knowledge is inadequate financing to bring to complete fruition some of his discoveries. Unfortunately, people who should be interested have seemed to be more concerned with the returns they would immediately get than the development of discoveries which would be of immense benefit to all concerned and upon their logical development repay many times over the investment needed to bring these discoveries from the laboratory stage to commercial application.

Because of the difficulties of the past in finding wholehearted contribution. Dr. Moray has stood all alone, earning from other researches and from laboratory job work sufficient funds to provide for his needs and advance the major program of his interest. Naturally this is a slow and laborious task and of course many questions arise during this period as to protection of rights, interests, etc. I know this, that generous support without strings attached which would be prohibitive would have the result of real achievement in the field of high frequency.

Sincerely yours,
ROBERT B. CRAIG

TO WHOM IT MAY CONCERN:

On March 16, 1929, I witnessed a demonstration of the apparatus invented by Dr. T. H. Moray by which he produces electrical energy. A report of that visit has already been made.

On December 13, 1930, I witnessed a second demonstration of the same set; only slight changes in the apparatus were noted although a great improvement was made in the performance. The condensers, coils and other parts noted at the previous test were now in one small box about 10"x10"x30". To start the set operating instead of stroking with the magnet, as formerly, now, two discs — one hard rubber, the other of iron — were rubbed together and produced an electric charge. The electric charge, on being discharged onto the act started the set operating and once it is operating, it will continue to charge itself.

The lamp rack which formerly held 6 100-watt lamps is now displaced by a larger rack which holds 32 50-watt lamps, 3 100-watt lamps and a receptacle to receive an extension plug and cord. On the other end of this cord was a 575-watt electric iron. During this test, all of the electric lamps were lighted at one time and were more brilliant than other lights in the room which were supplied from the house circuit. When the lights were oil bright — the electric iron was plugged in. There was no noticeable blinking or sudden diminution of lights as is usual in house lighting systems when an electric iron was on. The lights were as bright as before the iron was cut in. The iron heated quite rapidly slid in about 2 1/2 minutes was hot enough to be used for ironing.

I made a thorough and careful examination of the entire system to see if it were possible for the electricity to have been introduced on the system from some other source. Every part of the system was inspected — the antenna, the lead-in wire, the switch; the switch was removed and examined; the leads from the switch to the box containing the condensers and coils; the box itself was lifted and examined; the lead-, from the box to the, lamp rack; the lamp rack was lifted and examined and the ground wire from the switch to the water pipe on which it was grounded; not an inch of space was overlooked where it would be possible, to introduce any metal that would carry the power and I am prepared to say that no such connection existed from which power could be had from any other system.

A crystal radio set was cut in on the lead-in wire from the antenna on one side and to the ground wire on the other side and perfect reception was had. If there had been power from other sources on the antenna or lead-in, by connecting the radio set to the ground wire, reception would not have been possible but a loud, humming sound would be produced. This was demonstrated by connecting the radio set to the house lighting system. When the system was working, the lights were burning bright. The terminal attached to the antenna was disconnected. A vigorous arcing occurred and the sparks jumped over all air gap as much as six inches. This would indicate that the power was high voltage and the nature of the sparks indicated a high frequency.

I do not understand the principle by which Dr. Moray produces the electric energy. The condensers and the coils of wire are common. The two cylinders called "oscillators" and the small conical shell called the "detector" are the only filings not commonly known, but the system works. It produces electric power in abundance and does all that Dr. Moray claims for it.

I do not own any stock or interest in the company that is promoting this enterprise and my only purpose in issuing this statement is in the interest of the advancement of science. I consider this development a great advance in the science of producing electrical energy.

Very truly yours,

In witness to the above I hereunto sign my name.

THOMAS J. YATES, E.E., ME.

STATE OF UTAH
COUNTY OF SALT LAKE

Thos. J. Yates, being first duly sworn, deposes and says: That he has read the foregoing statement and acknowledges that he wrote and signed the same as above set up.

(Seal)

THOMAS J. YATES

Subscribed and sworn to before me this 18th day of December 1930 R. J. Chipman.

Notary Public — residing at Salt Lake City, Utah.

My commission expires May 7, 1934.

Washington, D.C.
November 14, 1958

Dear Mr. Anderson:

Your letter with reference to Dr. T. Henry Moray came during my absence from the city so I have been delayed in answering it.

Permit me to say that I have known Dr. Moray now for about 20 years and have observed him single-handedly trying to get acceptance of some of his ideas and discoveries, particularly in the area of "radiant energy." Many of the now-accepted areas in atomic and nuclear physics were outlined by Dr. Moray as early as the middle 30's.

At one time or another I have endeavored to help him by bringing his work to the attention of people in the Government but without any great success. *Of course, no longer do they dispute the basis of his work.* However, to bring pure research to successful commercial application involves time and money, particularly the latter. While we can spend millions for missiles that are abortive and no one seems to mind, a few hundred thousand dollars available to this man would obviate, I believe, much of the need for missiles. Of course, this is my own idea in the matter but I do believe a helping hand now to Dr. Moray could do more towards solving world tension than the mere building of bigger and bigger armaments to protect us from the "have-nots."

I can assure you from my personal knowledge of Dr. Moray that here is a unique mind and an ability which would be worthwhile developing.

Sincerely,
ROBERT B. CRAIG;

Dr. Craig was formerly a high U. S. Gov. Official, is Vice President of a large International Company and other companies.

(C o p y)

THE STATE OF UTAH
OFFICE OF THE SECRETARY OF STATE
SALT LAKE CITY,
October 8, 1930

M. H. WELLING
Secretary of State
GEO. A. SEAMAN
Deputy

TO WHOM IT MAY CONCERN:

I witnessed a demonstration of the Moray Radiant Energy machine, October 5, 1930. There were present Mr. Gaxiola, Mexican Consul General to the United States, J. R. Murdock, Mr. Buehner, Dr. M. O. Hayes, besides Dr. Moray and C. F. Schade and D. V. Farnsworth.

The essential parts of the machine were contained in two boxes, one directly on top of the other, each box about 14" wide and 4" by 24" long. On the top of the upper box was an electric switch on an insulating base. There was also attached to the upper box two soft iron poles wound with wire which in turn was covered with ordinary friction tape. Ten standard electric light globes, each of 100 watts, were connected to the interior of these boxes. A heavy copper wire led from one of the boxes to an outside aerial, a second similar wire connected the boxes with a water pipe going into the ground. Several members of the party took hold of both wires at the same time which showed there was no current in them before the demonstration began. Dr. Moray also put the terminals of the connections which led into the boxes in his mouth to prove that there was no current in the boxes.

After having connected these terminals with the outside aerial and with the ground wire, Moray then took a small magnet and stroked the soft iron pole pieces above mentioned, the windings of which were connected to the interior of the boxes. He explained that the stroking was necessary to set the device into an "electrical oscillation," and that when it was "oscillating" in tune with what he called "radiant energy" it would continue so to do and bring in this energy in a usable form when the switch was closed. After this stroking had continued for a few seconds less than five minutes, Moray closed the switch and the lights came on very brilliant. The lights gave off very much more heat than the ordinary electric lights of similar voltage attached to the house circuits which with the added brilliance clearly indicated that more than the usual voltage was going through these 100-watt lamps. This was clearly shown in another manner when the inventor took out one light and attached to this socket an ordinary Hotpoint electric flatiron of 575 watt capacity. There was no dimming of the nine remaining lights. The iron was heated with great rapidity and when in operation with the lights added was drawing from this machine 1475 watts of electrical energy. I am told that this is practically two horse power. After watching the demonstration for some thirty minutes, Moray disconnected the lead-in wire. The lights of course immediately went out and when connected they did not immediately return. Later on, both myself and Air. Gaxiola, the Mexican Consul tuned in the system as the inventor had done, closed the switch and brought in the full volume of lights.

In order to make sure that the lights connected with the house circuit were entirely separate from the lights produced through the radiant energy machine, repeated tests were made of disconnecting the house circuit in which event the house meter did not register at all. The iron was then connected with the house circuit which of course produced the ordinary reaction in the house meter. After the demonstration had been completed, the inventor raised the two boxes from the work bench on which they were located, showing that there was absolutely no connection by wires from below or from any place, save to the aerial and the ground wire.

At the conclusion of the demonstration, Moray dropped a stone weighing two or three pounds about two feet onto the work bench. The jar caused the light to flicker a moment and go out. Moray explained to us: "This was because the detector is not perfect, and one part slips when so heavily jarred, but this is all that remains to be done to make the device a practical commercial product. This simple demonstration itself seemed to show conclusively that the power derived was dependent wholly upon the machine and in no way upon the house circuit.

Before witnessing the demonstration I had read affidavits certifying to similar tests made in Emigration Canyon seven miles from a power line, and in Strawberry Valley, 26 miles from any power line, when the machine operated with the same degree of success that it did in Mr. Moray's laboratory.

The inventor explained that this astonishing exhibition when understood was a matter of ordinary physics and predicted that there could be developed from the energy all about us power and light and heat sufficient to take care of many times the present known needs of man.

Respectfully
M. H. WELLING

LETTER FROM DR. POLLY

Baltimore, Md.
November 8, 1936

TO WHOM IT MAY CONCERN:

On the occasion of a recent visit to Salt Lake City (Sept. 1936) I arranged, because of my own interest in various reports I had heard, to visit with Mr. T. H. Moray and discuss with him some of his experiments.

I was happy to find his laboratory well equipped with a number of costly electrical measuring instruments, and soon became convinced that he understood their uses.

His radiant energy device, as he calls it, seems to involve no mysterious circuit, altho the electrical valve upon which it depends is novel. The apparatus does not depend on any battery or other source of electricity than the antenna. In other words the power obtained is not derived thru the medium of a secondary power source — no feeble current is built up as in a radio set by vacuum tube amplifiers. However, no violation of the laws of thermodynamics is implied.

I saw no evidence that he was perpetrating a hoax and I gladly write this in appreciation for the time he spent with me.

O. L. POLLY

Dr. Polly received his degree PhD. in Physics from Baltimore, Md.

Dec. 21, 1931
Kansas City, Mo. (3231 Broadway)

Mr. T. H. Moray
2481 Smith Fifth East
Salt Lake City, Utah.

Dear Sir:

I have received many days ago your pamphlets related to your wonderful invention which I personally inspected in your home last year in the company of Hon. Milton H. Welling, Secretary of State there.

I am still interested in the future of this invention and its industrialization, and would like to know if you will

Blanked out, contains personal data.

Yours very sincerely,

C. W. GAXIOLA

Mexican Consul General of the United States

Since the R. E. A. episode, Dr. Moray has turned his energies to discoveries in many other fields in order to obtain funds but always with the purpose of pushing R. E. to the fullest extent of his resources and time.

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ATTACHED RESUME

Reference is made to the following publications:

1. — Whose Who in Engineering, years 1923-1924-25
2. — History of Utah, Published in 1932 by The American Historical Society, Inc., Chicago and New York
3. — Famous Utahns
4. — Utah's Distinguished Personalities

In 1905 began experiments with then so-called wireless and other electrical devices

1907 to the present time have experimented with alternating currents of High Potential and High Frequency and with rays beyond the light rays.

1922 discontinued commercial electrical engineering and turned wholly to scientific research.

1926 research was started with radiations from radioactive substances especially with high grade colnotite from southeastern Utah and Colorado, branching into the study of artificial radio activity and the artificial transformation of the nuclei of a number of elements and fission reactions. Research in the study of rays from 1.000 Angstroms to those of 10^{-5} Angstrom Units and beyond has been going on since 1939. This research has extended into the disintegration of the nuclei using our own special constructed tubes to cause bombardment by swift moving alpha particles and neutron bombardments to accomplish artificial transformations as stated above.

In this research we have found and AEC assay reports show "The sample appears to be fused uranium dioxide." The samples assayed as high as 85 per cent U^{235} equivalent. One material, the report stated, might be an artificial product.

This is a breeding or ageing process in which none of the waste material is removed.

CHAPTER SIX

TO SUMMARIZE

QUESTION: Is there any question about the PRACTICAL features resulting from further research and development, and about the FINAL OUTCOME of the Project?

HOW do we KNOW and HOW can we be CONVINCED that further development will ACTUALLY PRODUCE the conditions, as well as the PRACTICAL and sufficiently ECONOMICAL "Radiant - Energy" Units, devices and methods, leading to COMMERCIAL application of "RADIANT ENERGY?"

Is it a matter of SPECULATION or has Research and Development during the last 35 years, produced SUFFICIENTLY SOUND mid REALISTIC FOUNDATIONS which would ACTUALLY GUARANTEE the SUCCESSFUL OUTCOME?

ANSWER: The "FIRST STAGE" in almost any undertaking of consequence is in "BELIEVING" that a certain thing can be accomplished. All major and minor developments in all phases of progress, throughout the ages, have proven this fundamental truth. CREATIVE IMAGINATION, combined with the power of "BELIEVING," were responsible for even the most primitive discoveries and applications of common-place "FREE-TRANSFER" of energy such as, the action of the wheel, the lever and fulcrum, and the pulley.

Advancing tediously and gradually, always following the NATURAL TENDENCY of EVOLUTIONARY PROCESSES, which no-one and no power can retard, hinder or hamper with impunity, a few bold pioneers devised means and methods of utilizing the NATURAL POWER inherent in wood, coal and oil, to be followed by the process of harnessing electricity in its crudest form.

The application of "ALTERNATING CURRENT" which was widely opposed for wider and more economical use, succeeded the limited nature of "DIRECT CURRENT." The telephone was held back 60 years and radio 157 years after their discovery. With Radiant Energy we are continuing to advance, no matter what hinderance. We are gradually approaching the seemingly "LAST FRONTIER" in the recognition and application of an UNLIMITED UNIVERSAL POWER, termed, for lack of a better description.

RADIANT ENERGY:

"Nikola Tesla," the electrical wizard and discoverer of "Alternating-Current," said in 1904 (and reiterated the assertion in 1933 on his 77th birthday)

"Ere many generations pass, our machinery will be driven by *power obtainable at any point in the Universe*. Is this energy static or KINETIC? If static, our hopes are in vain; if KINETIC, and this we KNOW FOR CERTAIN, then it is a mere question of time when *man will succeed in attaching his machinery to the very WHEEL-WORK of NATURE.*"

Incidentally, Nikola Tesla was NOT referring to so-called "Atomic-Energy" or nuclear energy, but to the energy which is continually bombarding the earth from outer space.

SERIOUS, SANE and SYSTEMATIC Research, Development and EXPERIMENTATION, coupled with a high degree of perseverance, and willingness to make almost super-human sacrifices, will sooner or later lead to "DEFINITE KNOWLEDGE" and CONCRETE DEMONSTRATION of UNIVERSAL PRINCIPLES or POWERS involved, and the realistic application of them.

Thus, having arrived at the second stage, we do not have to "BELIEVE" anything with regards to essential issues at hand. We either "KNOW" or "DON'T KNOW." Knowing what we do, we say so and PROVE IT. Not knowing it, we say so too, and explain WHY we don't know. This is a matter of great consequence to us and to all those who concern themselves with such vital developments of world-wide significance.

We have been forced to give up the idea of "WISHFUL THINKING" a long time ago. Consequently, we are proceeding with the greatest degree of CERTAINTY and here is HOW and WHY:

In 1914 T. Henry Moray said, and it has since been reiterated several times in his copyrighted articles, "It is the belief of the writer that all space is saturated with energies which are doubtless electrical in their ultimate energies or very closely allied to electrical action. The relation of matter to energy and energy to matter then becomes the potential of the universe, one continuous series of oscillations, oscillating to and fro like a great pendulum across the universe." See *Scientific American*, May 1958 page 44, Feb. 1960, page 53, June 1960, page 64.

WHAT ARE THE REQUIREMENTS for further Development and Research:

(a) Parts: POWER TUBES, VALVES, OSCILLATORS, etc.

(b) Means and Methods (c) MEASURING INSTRUMENTS and METERS so that a PROTOTYPE for COMMERCIAL production can be produced? To bring it from a supersensitive laboratory instrument to a rugged commercial apparatus. There is ONLY ONE DOMINATING REQUIREMENT LEFT TO

ACCOMPLISH before "RADIANT ENERGY" UNITS are ready for COMMERCIAL PRODUCTION, viz., the *STANDARDIZATION* of the *POWER TUBES* and / or *VALVES* as well as *OSCILLATORS* in order to get POSITIVE, UNIFORM RESULTS from every tube made. This essential scientific development and engineering call only be accomplished with the use and application of *SPECIALLY DESIGNED* and *CONSTRUCTED MEASURING INSTRUMENTS* and *TUBE-TESTING* Equipment which is built and calibrated for use with the Energy from the Universe, just as in the measurement and utilization of *DIRECT* and *ALTERNATING* current circuits.

"RADIANT ENERGY" is of a nature that Instruments available for measuring present-day electric energies are of no value when used in testing *RADIANT ENERGY VALVES*, *OSCILLATORS* and other Modalities which are part of Radiant Energy Devices and Equipment.

It might be said that the major part of this please of research and development for the construction of "Radiant Energy" Units constitutes Engineering Techniques.

STANDARDIZATION of POWER TUBES and / or VALVES and OSCILLATORS:

It is absolutely essential to standardize the *POWER TUBES* in order to obtain UNIFIED RESULTS from every tube. At present, when 100 tubes were constructed in the laboratory, only perhaps ten or twenty of them, would meet requirements. The others failed to measure tip to the necessary standard. Sometimes only a few operated as required by the *CRITICAL* Balance and combined *SYNCHRONOUS* Resonance action called four to accelerate with the magnetic fields in the Universe. As a comparison with Radio Tubes, *RADIANT ENERGY POWER TUBES* must function as *VALVES*, and some as *OSCILLATORS*, and so on. Each tube must be in a certain position in the circuit, for they will not operate in any other position in the circuit. They also have to synchronize and balance perfectly one with the other, in their relation with each other.

COST (approximate) of RADIANT ENERGY POWER TUBES

A "Radiant Energy" Unit calls for a set of 29 Power Tubes, the cost of which, at this developing stage, is approximately \$500.00 for each tube. Standardization of function, type, nature and manufacturing methods of such Power Tubes will soon lead to a very economical cost in actual production, making it possible to be within the total cost of the finished Unit for Commercial use.

STANDARDIZED MEASURING INSTRUMENTS and METERS

Highly specialized Measuring Instruments and Meters, allowing TRUE READINGS of the Radiant Energy Power Tube's characteristics, are not available in Industry or Commerce at the present time. While special types of such Instruments have been designed and constructed by T. Henry Moray and Assistants, these have not been entirely satisfactory, not giving ABSOLUTE readings under the frequency and other energy characteristics. The further development of the Instruments by the Inventor and Assistants and noted Instrument Designers, is part of the project, prior to construction of the commercial prototype of the "Radiant Energy" Unit.

COST (approximate) of further Development and Construction of MEASURING INSTRUMENTS and Meters:

Estimates received from leading Instrument Designers, working in conjunction with the inventor and his Assistants, would place the initial cost of further development and construction of the first instrument as quoted some 20 years ago at about \$750,000.00. Further production from such prototypes would reduce the cost to be in line with other standard Measuring Instruments and Meters, used for similar purposes.

TIME FACTOR:

While it is almost impossible to determine the exact time required for the completion of those last phases of Development of Power Tubes, Valves and Measuring Instruments, leading to final preparation for commercial production of the Radiant Energy Units, it has conservatively been estimated for 24 months, or possibly less, after this final project is accomplished.

It is certain, however, that the combined efforts of the Scientists and Engineers taking advantage of Talent, Facilities and past Experience, their aim will be achieved in the shortest possible time, provided monetary means and ways are provided without interruption and interference as it is estimated R.E. development is 90% completed.

ESTIMATED TOTAL COST for COMPLETION OF FINAL PHASES of "RADIANT ENERGY" PROJECT: covering:

- (a). Development and Research for *STANDARDIZATION* of *POWER-TUBES*, *VALVES*, *OSCILLATORS* and other Modalities, as well as *MEASURING INSTRUMENTS* and *METERS*;
- (b) Other essential and incidental Scientific and Engineering work and activities:

- (c) Equipment and other facilities;
- (d) Overhead

all leading to the final construction of a COMMERCIAL PROTOTYPE, from which Engineering Plans may be developed for ACTUAL MANUFACTURE of this and similar "RADIANT ENERGY" Units — and also development and methods for application of this Universal Power for other Machinery, Equipment and Appliances. \$5,380,000 (*Five-Million, Three Hundred and Eighty Thousand Dollars*)

To summarize what has been accomplished Energy has been received by and through this apparatus. An 18 inch high frequency brush discharge was sustained and energy up to 50,000 Watts obtained from one unit. Another distinguishing feature is the whiteness of the lights as determined by the expert photographers. The characteristics of the current obtained determined by those who have witnessed experimental tests prove a new source of energy. All the facts establish something entirely new has been discovered. There is no possibility for doubt on any phase of this method of obtaining energy from the Cosmos.

The above shows that so much of this development has been accomplished, that so much is being offered for so little, as compared to other energy projects now under development.

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Applied Nuclear Physics by Pollard and Davidson — page 70

Astronomy by Dr. Robert Baker — page 303

In the release of energy, where is the seal of energy, whence it came

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Evolution of Forces by Dr. Gustave LeBon

Experiments with. A. C. Currents of High Potential and High Frequency Experiments by Dr. Nikola Tesla — 1904

Radiant Energy by Dr. Edgar L. Larkin — page 17

Sky and Telescope — July 1956, August 1956, March 1959, pages 241-243

Element formation in the Stars is also energy transformation in the Stars

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Foundations of the Universe by Dr. M. Luckiesh — pages 5, 14, 43

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Szerkeszti: Varsányi Péter (Pepe) E-mail: varsanyi@axelero.hu

Külön köszönet Tax Istvánnak <tixi58@yahoo.com> az OCR munkáért!

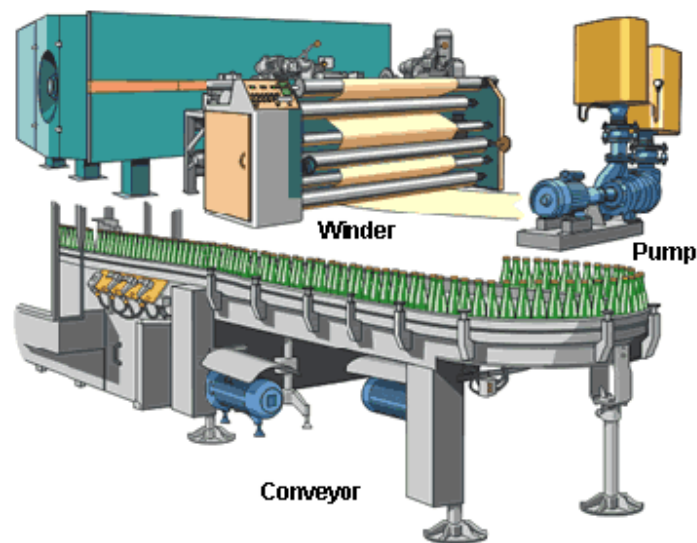
Baldors Motor and Drives Australia launch support for new superior energy saving incentive.



Right is Gerry Sutton a representative of the non profit organization panacea-bocaf accepting Baldors CEO Daniels support towards an environmental energy saving incentive.

Baldors motors and drives Australia <http://www.baldor.com.au/> are an electric motor manufacture company who has recently launched support towards the implementation of a 90% energy saver device which will help towards building our children an environmentally sustainable future.

Typically electrical motors supplied by a company such as Baldors motors and drives use electrical energy to produce mechanical motion. 1 to 2 horse power alternating current electrical one phase and three phase motors are typically used in many residential and industrial commercial utility applications, examples can be found in pumps or fans, winders, conveyers, mixers, lathes, drills, saws, pumps and grain grinders.



However what designers of electric motors for these industry intermittent use applications, such as a grinder, lathe, saw, drill or pump have not yet realized, is that by using a new method and discovery coined as the 'Roto- Verter or RV' will result in a far superior power management and save a significant 90!% energy in the motors idle state. Also this simple modification will allow a more efficient power on demand efficiency in the motors loaded states.

The 60 hertz RV motor modification is estimated to be up to a 90% percent energy saving device and can cut world wide emissions to a critically needed manageable level and result in a practical address towards future climate change.

Another world first advantage possible in running electrical motors by this discovery lies in the RV's solar co-generation applications. Using normal motors operated in an identical 1-2hp role you would typically require up to 10 solar panels for operation, in RV mode you only require 1 panel to run your solar shop lathe, drill or mill.

Never before has the opportunity been possible for an economically practical utilization of .8-1.13 Horse power motors in this solar cogeneration role. Baldors motor drives Australia have just sponsored an emerging environmental not for profit organization called panacea-bocaf ('bocaf' stands for building our children a future) to help disseminate this discovery and save the public money and energy! Normal Baldors motors now can raise their efficiency via the non profit orgs RV scientific discovery. The energy savings the RV can create is nothing to be taken lightly.

A normal one HP electric motor pictured below typically unloaded idles on 1.84 amps at 240 volts. When loaded uses 4.78 amps at 240 volts =1147 watts. This is at about an 80% + efficiency.



A normal one HP electric motor

Below is Panacea's replication of .8-1.13 1 HP (horse power) RV modified motor, if used in an identical role the motor will draw only 160 Watts when idling! And when loaded at 1HP, is estimated to be about at a 94+% constant efficiency.



Panacea's replication showing a BALDORS RV motor modified for energy saving applications.

The need for these energy savings and lowering emissions is becoming more and more critical today. Humans are stripping nature at an unprecedented rate and will need two planets worth of natural resources every year by 2050 based on current trends.

Populations of many species, from fish to mammals, had fallen by about a third from 1970 to 2003 largely because of human threats such as pollution, clearing of forests and over fishing.

Australia is living well beyond its means. The average Australian used 6.6 "global" hectares to support their developed lifestyle, ranking behind the United States and Canada, but ahead of the United Kingdom, Russia, China and Japan.

If the rest of the world led the kind of lifestyles we do here in Australia, we would require three-and-a-half planets to provide the resources we use and to absorb the waste.

The benefits of the energy savings which the RV will bring is critically needed to address such concern. Baldors motors and drives Australia is committed to helping meet this environmental integrity and is a supportive major sponsor of this essential Green technology.

Baldors motors and drives Australia has generously donated 2 motors free of charge to the non profit organization perusing this research to help further publicly disseminate this discovery and help raise awareness and valid premise towards mandating laws to upgrade the efficiency standards present in electric motors globally. The non profit organization also has a petition to sign which will make these efficiency figures count at the federal level. Please consult the web page mentioned below for further details.

Organizations such as NEMA who deal with enforcing efficiency standards in electric motors will now have a public responsibility based on this scientific discovery to further substantiate and apply this efficiency protocol towards 1-2hp electric motors to match the RV's energy savings figures.

Green local politicians and the public now have justified data and lab tested results to further support a public lobby at the federal level for support and security towards this scientific discovery.

Baldors motors and drives Australia are the first in the world to launch such an environmental project and support such an incentive for greener electric motor technology.



Baldors motors are located at <http://www.baldor.com.au/>

If you added up all the energy used in electric motors around the world at this very moment which are in the range of 1-2hp and use variable load applications or are in intermittent roles, you will find quite a significant energy savings figure contained in RV mode, especially by comparison of what motors waste when they idle compared to the RV.

Can the potential to saving 90%+ power that's usually wasted be denied? Can anyone justify the non usage of this discovery? With cost effective usage available from off the shelf motors and parts provided by Baldors motor drives it is not justifiable to exclude this discovery in favor of energy fuel wasting planet.

Currently the non profit <http://www.panacea-bocaf.org> organization is constructing a pilot scaled feasible model to be used in a solar or grid inputted RV drill for a public demonstration. Other applications are possible to show that the RV is the most efficient 1-2 hp electric motor in the world, and will not be out preformed in energy savings.

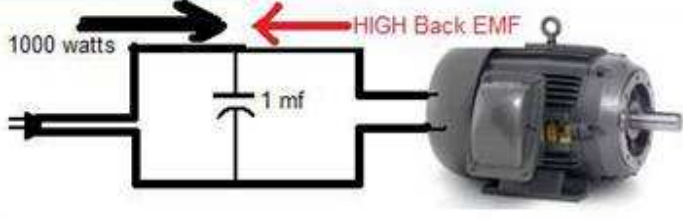
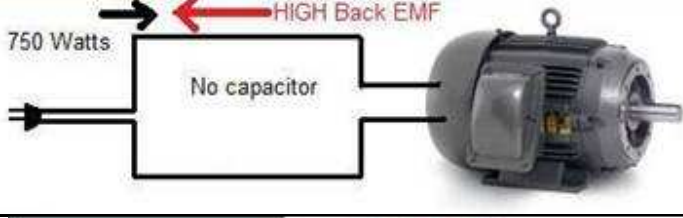
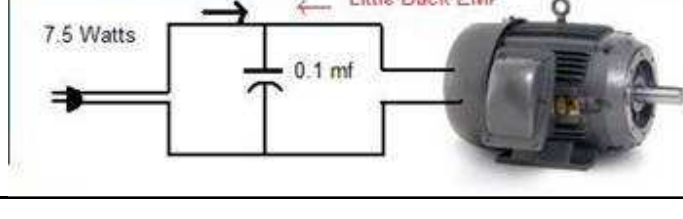
Panacea-bocaf currently has organization to launch various media appointments to help publicly disseminate this beneficial environmental discovery and is non proprietary in nature. The RV discovery is public knowledge, all revenue raised by a promotional aspect and or licensed connection goes back into the not for profit organizations environmental projects to help our kid's future.

Panacea will also submit this knowledge into a universities faculty curriculum to further ensure the security and public access of this environmentally sustainable discovery.

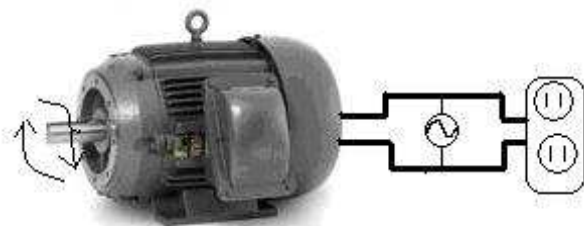
For further information and or support please consult the web page at <http://www.panacea-bocaf.org>. For a video introduction of the process please consult this page <http://www.panacea-bocaf.org/RotoVerter.htm>.

Operating Principles—Rotoverter

1. An electric motor wastes large amounts of energy by producing “Back EMF” that opposes the flow of electricity.
 - a. This back EMF can be cancelled out by using certain technologies t “tune” the motor.
 - b. It is thus simple to reduce power consumption by 90%.

	• Starting up: High current use. • A 750 watt motor may use 1000 watts of power. • A big starting capacitor is needed to help the motor
	• Running: Lower Current Use • No capacitor is generally used. • Current used is at the rating of the motor.
	• Tuned: Lowest Current Use • Small capacitor used • Only 10% of rated power required!

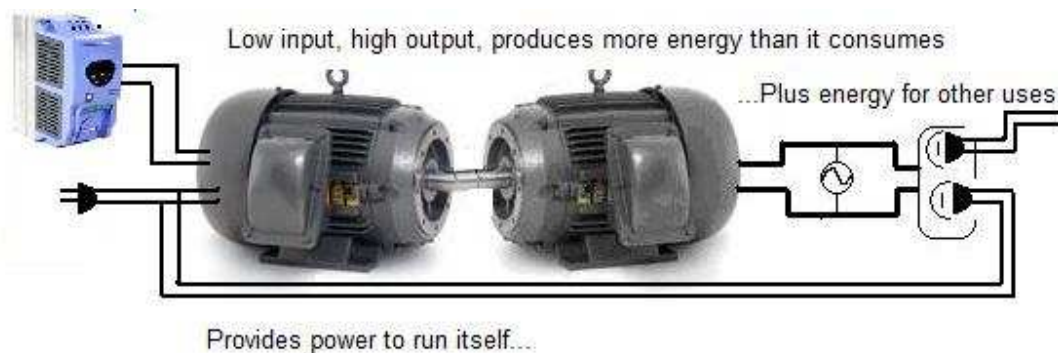
2. If the shaft of an electric motor is spun by another source (“prime mover”), the motor acts as a generator and produces electricity.



3. An electric motor can be controlled by certain electronic circuits in a way that produces many times the rated power of the motor. This can be done without a significant increase in the power use of the motor.



4. By coupling two electric motors, one acting as a motor (the prime mover), and the other acting as a generator, the power produced by the generator can be looped back to drive the prime mover motor. In this way, a low-power consumption motor can drive a generator and produce more power than is consumed.



5. Generators can also be modified to produce much more power than a typical generator. This allows much more efficient energy production from such sources as hydroelectric plants, mini-hydro, wind power, tidal power, etc.

Global Genius Energy has several more projects ready for production, which could be added to these projects at any time. Some examples are:

1. a stand-alone generator set which operates without fuel or energy input, producing up to 75 KW of energy on the footprint of a 5 KW standard genset. This uses a closed-loop tesla turbine that operates with Freon gas, powered with ambient energy.
2. Anti-gravity systems for propulsion and static use.
3. Protective force-field technologies.
4. Wireless, loss-less transmission of electrical energy, for power, as well as ultra-wide bandwidth for communications and information systems (internet) use.
5. Technologies which allow the growth of super-sized plants, vegetables and fruits, with high nutritional content, in almost any environment.

Trans-Verter research and development

Contents-

Introduction to the Trans-Verter is taken from Dans –RE-OU e-book.....	
Jinis' replication with group comments.....	
Latest extraction ideas and circuits.....	
Latest Inverter designs for experiments.....	
Credits.....	

Note for all pcb layouts, schematics etc, just copy them from this word document (right click then paste to your desktop) and enlarge them via windows picture and fax viewer

Introduction to the Trans-Verter is taken from –RE-OU 5.1 e-book

Transverter

Overview of Operation

Standard AC transformers can be pulsed to a measurable Over Unity transformation condition where conventionally the readings are not yet investigated or understood. These readings and efficiency states are achieved by taking the AC transformer into resonance. The power within the LC is interpreted from the inventor Hector as radiant in nature and provides a source of 'imaginary' potential within the shift of the resulting power factor. The research and development potential is to extract this potential in a condition that is non-linear and reflected to the source.

Theoretic background and scientific evaluation.

In a pure LC function the AMPERAGE reading is the important factor and is the same persona when attempting to tap a Radiant Energy potential. Both are the same and should be conceived and measured in an AMPERE LOAD, in RESONANCE the "R" is the anti node where the voltage value (in a perfect theoretical system) must be near 0 and the amperage maximal.

Ask yourself Why this system is's over unity when read from the input? (in an LC) Consider that the LC has a DECAY value in time, so the ONLY energy you need to supply is the one lost to DECAY as if system source where a negative inductor to LC (as is the case of RV alternator rotor; similar to a wet finger on a glass cup - cup decibel energy output exceeds finger input as glass molecules transform energy from their RESONANT STATE adding to input).

By an understanding where normal entropy decay is .618 of 1.618 as logarithmic time receding signal, a gain is also in entropic system of 1.618 where the frequency increase is And can be comprehended in octaves, this may increase amplification by a factor of

3.141592 where the spiral resonant circular projection can be expressed in a 12,000 4d polygon structure.

This visual picture can be similar to the structure of a double helix DNA structure, and is also considered why the human system is continuous by all definitions).

The logarithmic spirals orbital decay path in this case is understood as relative to gravity as a signal decay or gain is relative to the LC Q and parameters in a working ZPE system.

To prove this theory.

Surplus 3 PH transformers are good for these experiments, which are WYE-delta combinable 480/230/120VAC I/Os. Normal Universal transformers 480/360/240/120 I/O isolation 3KW 47-450-CPS are ok, but do require TUNING and a lot of work in vitro lab experience to GET the idea WERE OU is and WHAT RADIANT ENERGY is all About.

There is a lot that can be done with 3 phase transformers. A MAGNETOTRANSISTOR is just one of them. The transformer is superior to M.E.G (Tom Beardons motionless electromagnetic generator) as it does not need magnets to attain OU radiant energy states. Try rotating it first, to enclose the field within the transformer core. Resonate the side coils, vectoring DC plug to the center coil, drive in 3PH rotation (A,B,C) to create "MEMA" magnet-less Electro Magnetic Amplifier.

Splitting the transformer's center-tap, feeding POSITIVE across winding and SWITCHING the negative using a reverse DIODE in the transistor to capture and feed back counter EMP as the transistor switches off.

A schematic will be provided just find the right frequency and pulse-length to make the ferroxplana sing a song! As in NEWMAN coil, BIG CORES have nice CEMF EMP.

The Side lodes: $R/2 \text{ I} \times 2$ where centre amperage B phase $\times 2$ times. A,C phases current and A,B voltage is $V = V/2$ as A,B phases are 90° from centre C phase instead of 120 deg required in 3 phase relation; so being in phase relation is $(V1+V2+V3/3) \times 1.732 = VT$ in relation to V input (same applies to current-power relation). You need Q 12 to 15 to sustain rotation with near 0 field loss. Impedance is projected to infinity as fields open and goes wide banded with a projected M field out of the transformer (exteriorized field).

The solution is to co-phase A,B,C relation properly to create SELF impedance regulation within HI Q modes. Outside of the transformer this can become a POWER source as a SOLID EM AC EMF source if placed inside a coil. When you short a coil, the impedance decreases, and the Q increases. We need to see the 4rth dimensional picture in 3Phases of the whole construct in a given space.. Including Phases field projections interactions, and all the works! You must Go inside and out within that transformer, and understand that when there is an increase the "Q" Resonance gain Eff. goes up. This also

gives an interpretation and ideas on the postings related to Sweet VTA Magnetic latching and Resonance; revisit also the MEG.

Loading the sides of 3PH transformers A, C phase exteriorizes and projects FIELD outside transformer. If another LOOP is used it becomes a magneto-transistor. Experimentation is the key to obtain these effects. 3PH transformers can be used as Scalar WAVE EW EMP weapon. Work also harmonics. One frequency rotates in one direction the other counter rotates within; this is little known in power dynamics but is key to many OU states related to Magneto-atomic resonance. Maintain rotation, else EM field will leak out forming exterior projected field. This leaking is useful in other applications: put a coil outside the transformer and it will generate quite a good AC signal, as test to verify condition, this Broad bands LC as IMPEDANCE increases so Q goes down.

The trick is to Obtain HI Q at a given frequency, such resonance occurs. In your transformer case "ferroresonance", as in any circuit you must look for losses that reflect in lower Q and limit accumulative incremental resonance. Every transformer is Unique, not 2 are equal, as also no 2 capacitors are equal. Once attained a given Resonant Frequency, the Exiting Pulse can be shortened; at a given point where ring back OU effect is noticed, core magnetics porting energy to system, the requirements become minimal as per 1 Watt being able to maintain a HI Q kilowatt range resonance.

The problem will encountered where even a Clamp on Meter impedance detunes the LC, your BODY field changes the frequency as you get near it, the same where the MOON gravity Tidal force also detunes it. These aspects being very interesting to test in vitro (lab) as gravity influence is noticed under these conditions, Mass concentration becomes a Parameter in the operation of device.

For certain 3PH applications, 3 independent transformers are better as they are magnetically decoupled. The phase becomes more "malleable" to capacitor value influence. A triad Ultra looped system can be developed using SEIKE'S (a Japanese scientist) rotary transform theory (under resonance) self-inductive modes.

Bifilar inter-winding capacitance tends to correct power factor and creates de-phasing from resonance, but the SCALAR TENSOR provides the ability to allow the STANDING wave to be removed. Gray used AC the homopolar principle to do such transform, as long Radiant state TENSOR is maintained such tensor will manifest OU with a corresponding thermal pump effect. Quantifiable by Delta t transform (Thermopile effect), it's in reality simple but is LOST in the attempt to leave the Dual 0 states of resonance. POWER is not a "Unisex" force. The FORCES of the Universe are always manifested to fullest force when FEMALE & MALE forces interact "bipolar".

A Good toy to play with is a 2x 75 KW 3PH used for MEMA experiments. We (the inventor Hector) took it to resonance using a pulse driver driven with an AA 1.5 VDC volt battery where the 3W pulsar developed a 10KW ringing within the core.

Hector used Seike configuration Wye/Delta modes using pulses to maintain system rotary field ... 480/500VAC for Hi 208ACV delta low using 3x3 600VAC 22mF capacitor array. In a 75 KW 3PH hi efficiency transformer (FCC grade). The ringing varied in decay, frequency voltage increase from 1 cycle 1/10 sec pulse to 10KC 800V PP cut off end signal. A Ping with incremental voltage and frequency decay within a rotary LC triple-flux array. Even in a valance capacity-impedance array, the system tendency is to rotate clockwise under 1 phase pulsing A,B,C selected inputs. A 1.5VDC battery can power a 3W LC Driver, a Pulser can drive Joules into a big transformer; Exiting core to GIVE energy from thermal region (OU). Hidden somewhere Hector has the NASA rotary resonant transformer formulations, and they are nifty OU. All RF resonant coils are OU ... Stochastic resonance is the FIRST demonstration of OU.

If you listen to a Ferro-resonant transformer the core rings to the AC frequency at RESONANCE as electrical manifest into the mechanical ring frequency of the element being used as a core. This relation is considered UNWANTED noise, but for OU production like in VTA type latching you must put the Metglass to scream in agony on electron spin erotic delirium in order to attain certain energetic transfers from magneto atomic thermal regions to the electrical circuit ones (OU). If inverters TR cores were made to scream, they go OU but transistors & FETs usually fry as they are not designed for it (nor the circuits they are on).

You may need frequency and pulse length adjustments in normal DC to DC H network inverters. The up conversion to Hi voltage is adjusted as to EXCITE the ferroxplana to OU states charging the capacitors under sinusoidal logarithmic standing wave. The H network fires the capacitor charge as also frequency and pulse length adjust.

It goes "TUNG". That "Tung" is not 50 or 60CPS, but 10 harmonics up 0.5-0.6KCPS. As 50 or 60CPS feed the transformer, the power line frequency echoes of the fundamental & harmonics interact forming WAVITONS within the core by core natural "cyclo conversion" effect. Use an Equalizer Chart and see the so-called resonant PULSES are NOT in the fundamental frequency but in a multi octave broad banded in hyper modulated Waves across equalizer frequency range.

As the transformer is in Extreme LOW Q and its fundamental RESONANCE is WAY up from the power line one. This is what must be compressed into a rotating Hi Q phased COHERENT signal to attain EASER modes in the core. If you compare such a chart to one from a PUMPED laser rod you will see the simile, they ENHANCE this effect to Amplify light. Why not enhance it to amplify electric current, and let it acquire energy from ambient by stochastic amplification.

We have talked within the lines on this subject related to Easer modes: "seek the acoustic signature within LC resonance". "Ringing" as RV (The rotor verter) works is this state, it hums like a turbine (gravity and magnetism are not far apart). If a pulse of strong a magnitude is created countering a RELAXING iron mass, it can create an instant black hole (mass implosion) (used in X ray NSA-DOE lasers). That is what is called creating Wavitons within the core, like a LASER these electro-acoustic signals can be taken to

atomic fusion intensity; solid titanium as a resonator can help to deepen more into this phenomena (but is government restricted and expensive). So laminates and speaker metal end plates have to do it.

The fight has always been that if people want OU they must seek Hi perfection in the energy transformation mechanics. Resonant circuits are just tools to acquire states of Hi eff energy transformation. OU becomes a byproduct of such effort. Every time you experiment with resonance and Q aspects you can seek for the Sweet point, that Special condition where the combination of Reactive and capacitive components create the best Q, lowest loss condition.

MASS core materials make nice differences. Some commercial hi eff utility transformers go off the roof energetically speaking when resonated. Single-phase utility transformers have some magic in them also. Some give very HI Q transform as taken to Hi voltage resonance. I recommend resonating whatever you can find, some transformers will really suck, but others will sing to the tune of pure OU resonance.

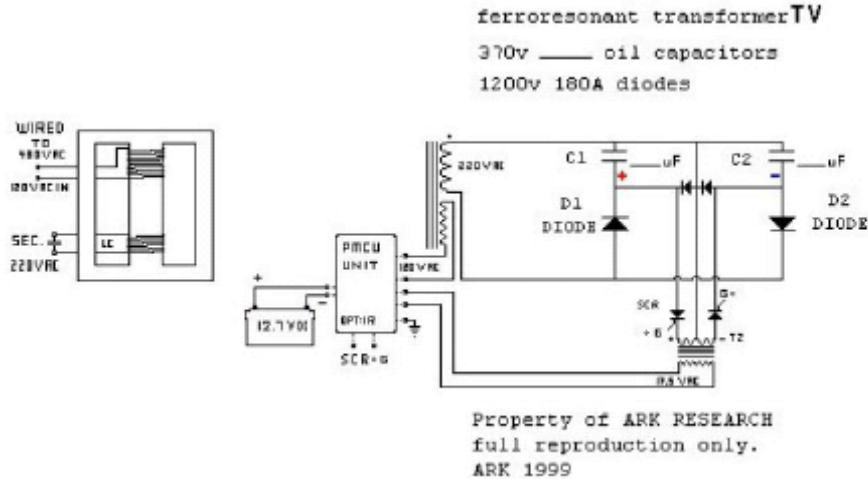
Relation: Core mass, coil turns, capacitance. Look for its Natural best resonating point, which is usually where the best Q is. Try harmonics; usually some transformers can resonate in harmonics this being ten fold in intensity to basic exiting frequency. In standard practice this is seen as loss, but if done intentional can be a source of energy multiplication.

The importance in OU design is CORE mass (its natural resonance), wire size and turn ratio as capacitor tensor relation across a diode as it charges it "logarithmic semi resonant curve". This is where HI gain & efficiency are leading to OU states.

Example

Take a DEC 10 power supply Ferro-resonant transformer (DEC 16-1491 rev D); use 1200v 22.5 uF capacitor in the resonant coil. AC primary input of 444.6W (117V 3.8A) with 3151.5W (573V 5.5A) circulating power in resonant coil. If diode plug is used as in plan with x2 capacity, each capacitor will become a half resonant Tank circuit becoming in a sense a VECTOR accumulator one negative and one positive "half" in "resonant" mode. If discharged in sequential pulse mode the power is awesome compared to the input. The ratio in this transformer circulating power was over 7:1. All this time we were forced to assume this was a POWER FACTOR phenomena and that this power was not EXTRACTABLE in any way. Well not any more with proper tuning and pulsing circuits or simple "Spartan" resonant direct connections it can be used. I hope you can find FR transformers or get a standard one 120/240/480V primary 120/240/480V sec. Turn the secondary into a resonant tank; the transformer will hum and if tuned right, will "drift" with input frequency "TUNE". No shunt needed since no core secondary current "regulation" is going to be used. After this first step try diode plug use x2 capacity. Note the circuit will not hum it will do a "punk" and input current will be a NO LOAD VALUE.

But be very careful: x2 voltages and x2 currents will be present at plug +/- terminals. Pulse-extract the power into resistor bank until the system goes resonant (hum), max "Q" if possible.

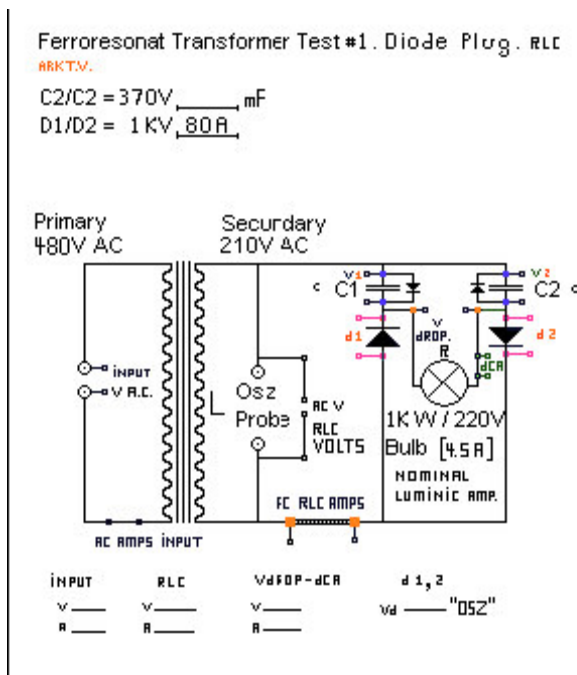


In a PM rotor the magnet translates as inductive VA-energy going into a capacitor (transform to VAR); the relation of L and C being RESONANT radiant ONE in half LC diode vectored tank the OPTO isolation circuit and BLANK energy firing non-reflective to source Stage is SECRET to EXTRACT ZPE energy.

So the trans verter circuit recovery approach is a 2-gunned device where there is no excuse for whatever energy resides within it or the core used to be converted into DC +/- vectors (poles). "Radiant" energy contributes to charge capacitor within Resonant circuit. Unit can be called in a sense a theoretical "Vovine feces" eliminator. If there is any (OU) this basic circuit will extract it from a coil at proper tuning parameters (RF tuning practices are the standard).

Try to replicate the FR RC effect and use the diode plug system; this simple device make many obsolete by all terms. This is simpler and cheaper than the roto verter 3PH systems. Suppose we take a trafo (transformer) 480V to 220V and feed it with 120VAC and resonate the secondary (pure LC, not diode plug). You need to raise Q, loss decreases to a point it self sustains like VTA configuration, as "reactor core" it self amplifies. In order to get the losses become negative to reach "self sustain", the Stochastic resonance comes to play, transfer of H Heat to Electrical current. As Einstein-bose condensate is created: certain resonance conditions create hyper-conductivity, cooling at magneto-atomic resonance level where natural superconductivity exist, like GENESIS device (UFO engine) it freezes to absolute 0 as it works to max potential. This at extremes as condition can be exothermic were the Burn out occurs (usually were BROADBANDING and signal annihilation occurs) as the Ferro-resonance papers stated. (To make the Genesis device working, the core material.

Natural resonance must be determined as to determine C and L values. An ACUSTIC physical NOISE like the TRANSFORMER Ferro-resonance is heard when such state is attained.) LC needs to be Optimized (No loss) no welds, no shorts, no sinks (Like RV alternator taken to highest Level, but with difference it stays on and does not shut down). Resonance can make an ELEMENT a SUPER conductor (why you think they call it COLD electricity?) (Note that Metglass magic is in kilohertz –megahertz range) About resonant Electrolysis, the Sonofusion water frequency is 23 to 24.5 Khz and its harmonics up to WATER boiling 2.45GHZ (microwave oven magnetron) and down to 2.45 Hz where the gas action separation is increased ten fold You can experiment with the transverter as vectored resonant electrolyser. In the first picture above, the R load is the electrolytic cells. The coils cores and capacitor need to be tailored to a specific frequency, where they match the best gas production of the electrodes or plates in the gas chamber (requires lab work).



Jinis replication

For updates please visit jinis site at [Link](#)

Transverter Replication

With respect to work of Hector D Perez Torres

001 - 11.11.2005 We have found an old transformer, which could be probably used for trans verter project. We were told; this transformer worked in an Russian server for handling keypunch cards.

Some photos of the transformer:



[Photo001-1](#)



[Photo001-2](#)



[Photo001-3](#)



[Photo001-4](#)



[Photo001-5](#)



[Photo001-6](#)



[Photo001-7](#)

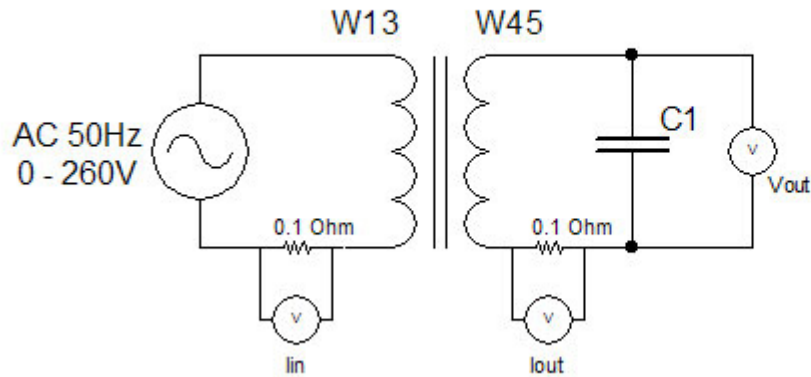


[Photo001-8](#)

002 - 18.11.2005 We have taken the coil W13 (660 windings x 0.74mm) as transformer primary and the coil W45 (390 windings x 1.16mm) as transformer secondary with parallel cap 69.8uF according to circuit 002-1. We measured output voltage, output current, and input current while increasing the input voltage from 0 to 260 Volt. We tried to find out the optimal value of input voltage for finding out the resonance on the secondary transformer winding.

Following electrical circuit has been used:

Circuit 002-1



W13 - 660 windings x 0.74mm
W45 - 390 windings x 1.16mm
 $W13/W45 = 660/390 = 1.692$

Characteristic curve, C1=69.8 µF

Overview characteristic curve, Uin AC increasing

Uin, V	Iin, A	Uout, V	Iout, A
0,00		0,00	0,00
20,00		21,55	0,46
40,00		45,50	0,98
60,00		73,80	1,60
80,00		111,00	2,39
92,50		143,50	3,07
95,00		237,20	5,33
100,00		276,30	5,34
120,00		282,00	5,36
140,00		285,00	5,37
160,00		288,40	5,36
180,00		291,20	5,35
200,00		293,40	5,34
220,00		295,30	5,28
240,00		297,00	5,29
260,00		299,00	5,29

Detail characteristic, Uin AC increasing*

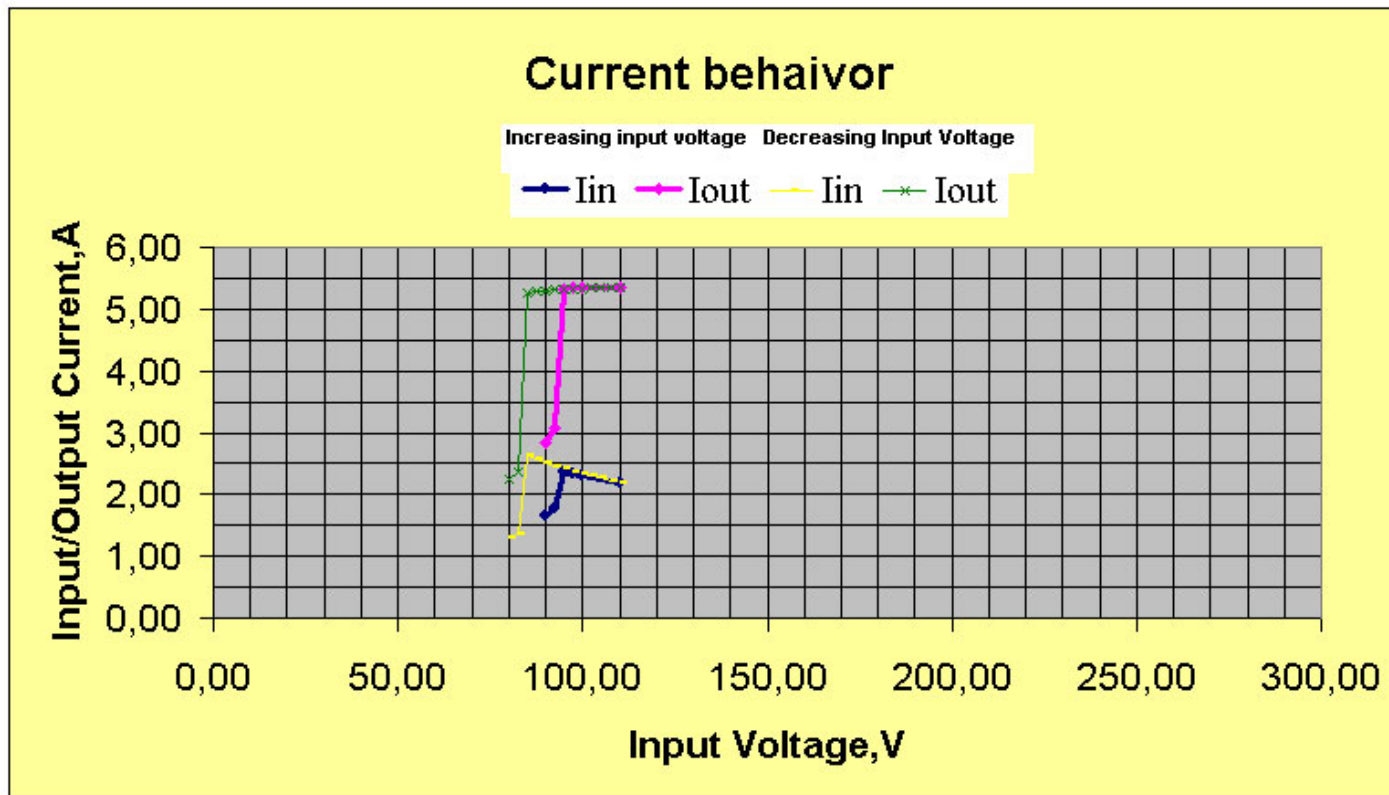
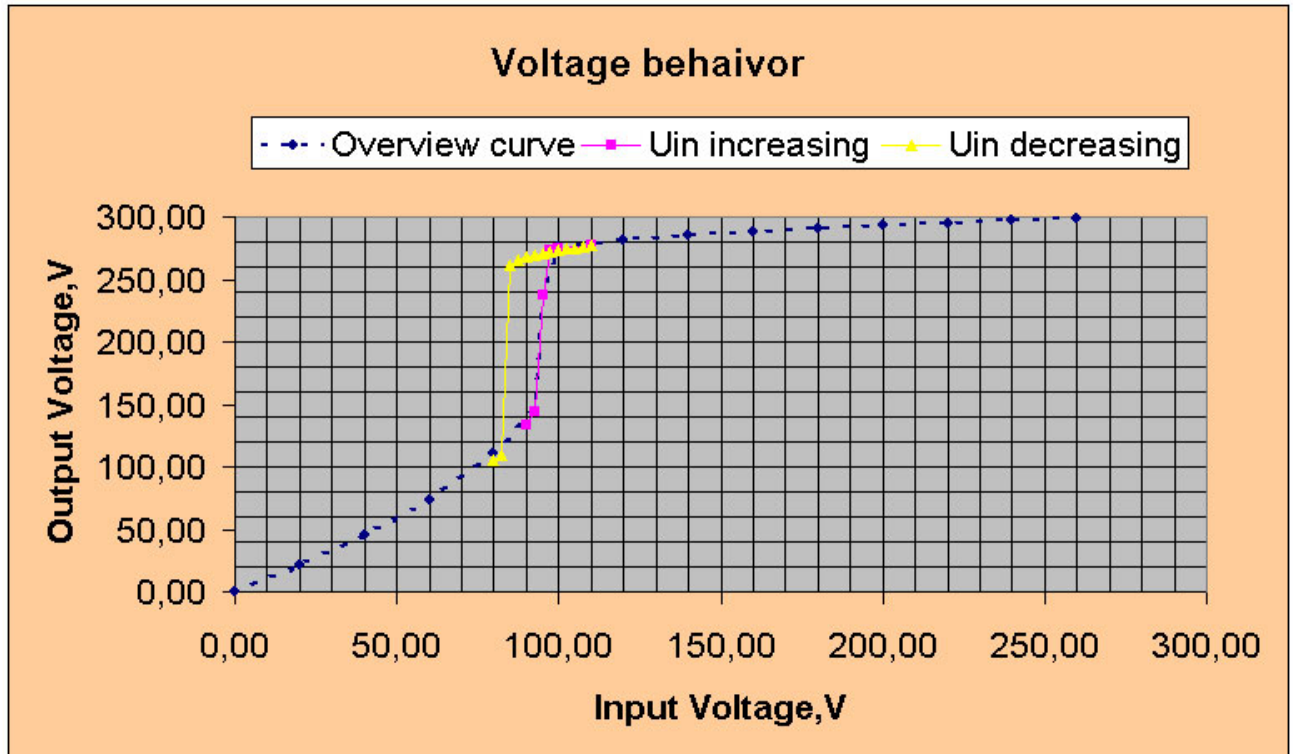
Uin, V	Iin, A	Uout, V	Iout, A
90,00	1,66	134,00	2,85
92,50	1,77	143,50	3,07
95,00	2,36	237,20	5,33
97,50	2,33	274,00	5,34
100,00	2,30	275,00	5,35
110,00	2,20	277,40	5,35

Detail characteristic, Uin AC decreasing**

Uin, V	Iin, A	Uout, V	Iout, A
110,00	2,20	277,00	5,35
107,50	2,23	276,40	5,35
105,00	2,27	275,30	5,34
102,50	2,31	274,50	5,34
100,00	2,34	273,30	5,33
97,50	2,36	272,20	5,33
95,00	2,41	270,80	5,32
92,50	2,44	269,50	5,31
90,00	2,50	267,50	5,30
87,50	2,56	264,90	5,28
85,00	2,63	261,50	5,25
82,50	1,37	110,00	2,37
80,00	1,30	104,80	2,25

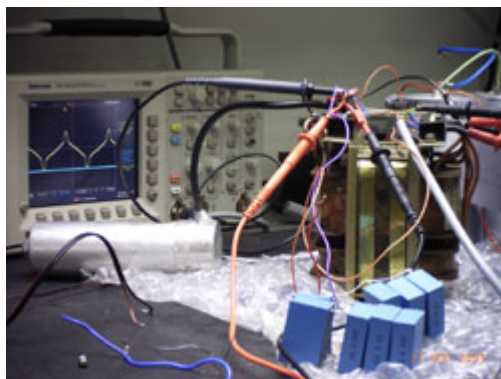
* - reading performed with increasing input AC voltage

** - reading performed with decreasing input AC voltage





[Photo002-5](#)



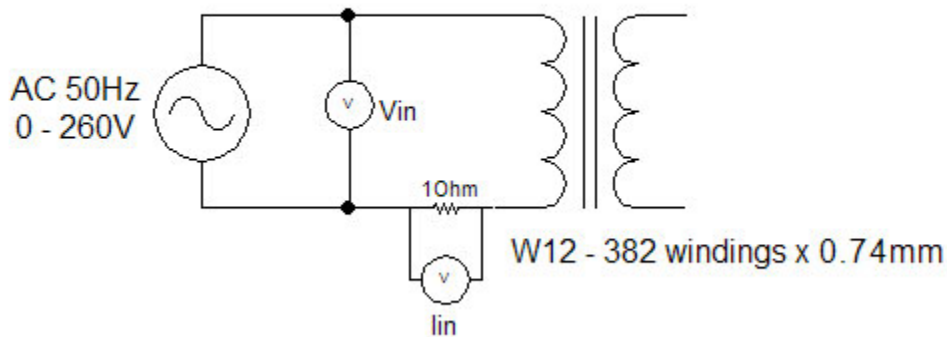
[Photo002-6](#)



[Photo002-7](#)

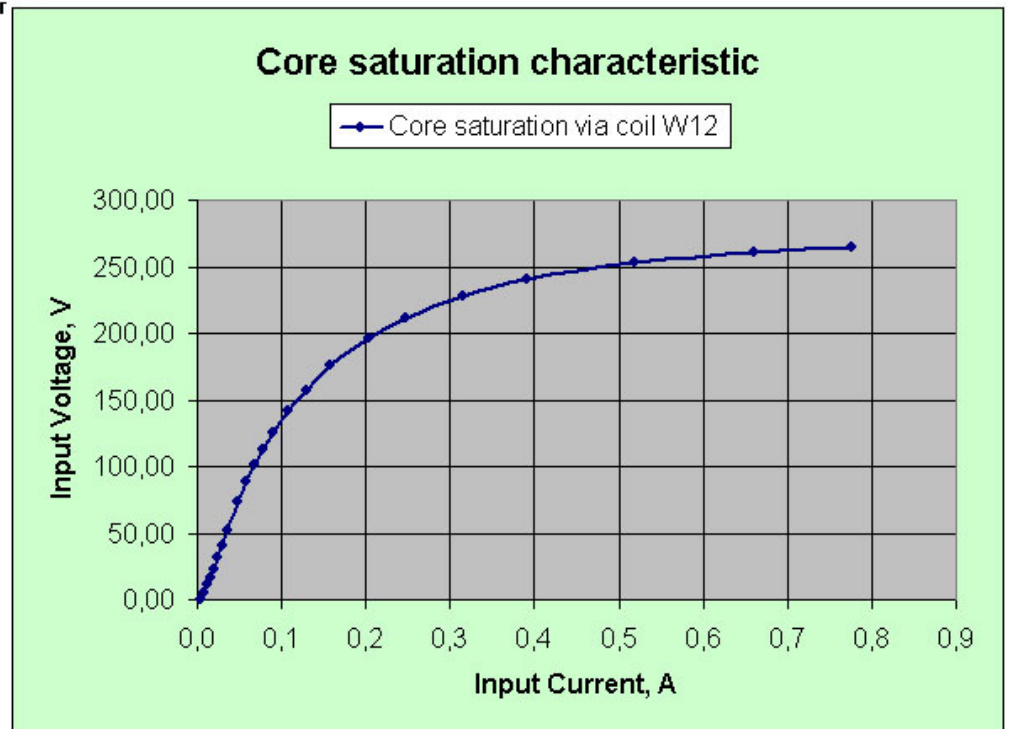
003 - 21.11.2005 We took the coil W12 (382 windings x 0.74mm), which is part of the primary winding W13, and measured input current to analyse the core saturation values.

Circuit 003-1



Measurements of core saturation
using coil W12 with 382 windings
measured on 10hm resistor

U _{in} , V	I _{lin} , A
0,00	0,004
5,09	0,008
11,01	0,012
16,80	0,015
23,16	0,019
31,20	0,023
41,00	0,029
52,20	0,035
72,80	0,047
88,80	0,058
101,00	0,067
112,60	0,077
125,80	0,090
141,80	0,107
157,30	0,129
175,50	0,158
195,80	0,203
210,80	0,247
227,70	0,316
240,90	0,391
253,30	0,519
260,90	0,661
264,20	0,776



to be continued ...

Comments from Hector on the replication

NOW YOU GOT INTERESTING FIGURES !! definitely showing some aspects on resonance and ZPE in normal standard HARDWARE . Lets say you try preparing a transformer were you can WIND the turns you want with the WIRE you want lets say it is multi stranded hi frequency RF wire 12 ,8, 6 Gage, wire your Core to a point is in the

highest Q at a frequency were the NATURAL core metal resonates " fundamental ferroresonance in this case " is taken TO an EXTREME Q AND ELEVATED RESONANT STATES WITH PROPER MATCHING NETWORK AND FEEDBACK, as SUCH the reactor BECOMES SELF SUSTAINING by transferring Electron energy to the system Core and coils whilst becoming COLD and superconductive, only when the system becomes self incremental to a given point of maximal energy saturation and resonance valance.

That is the secret of MEG VTA and Hendershot * Kohler device & others also apply .. The basic gain is 1.618 over isotropic (virtual dipole) X the core Q multiplication factor that is the ability to latch magnetically and gain energy from its Electro atomic components.

I have stated before that if its able to wind an Iron kitchen sink and resonate it properly in its natural resonance regions resonance you can extract energy from it in OU states! Like tesla stated hundred years ago, all you need to create this potential is a SINK were the energy flows and is transformed.

Try a Hi Q resonance state at 90 deg phases. Compensate the frequency drift using a a variable frequency source, the aim is to Compensate the LC time signal compression By USING A PULSELENGTH control of input signal (square) modified sine wave, You must then split and match the input impedance which is needed to drive with rotary the phase angle and defines the power input as a phase difference (reflected power to line correct input PF and note the differences.)

Further- To get minimal sustaining input the following needs to be done.

Keep optimal Wire turn parameters to the core & capacitor relation That is, try to create best and highest hyper Q LC tank Oscillation parameters. Have a variable frequency Variable amplitude (voltage) and pulse length adjustable source. Intent is to adjust frequency as Voltage is lowered to maintain synchronization and proper co phasing.

Energy input then is measured as phase Angle within an impedance matching of 2 nodal points within coupled systems.

As a Core is maintained in Hi Q hyper saturated modes Input voltage variations produce frequency drift creating beat harmonics increasing loading to source, synchronizing hyper signal becomes an art as voltage is LOWERED frequency needs to be compensated to keep proper rotary angle and mitigate parasitic beat harmonics, the co phasing of signals as stated before is measured in angle of rotation relative to power input and LC minimal sustaining power required to maintain resonance .

Comments from Jinis-

I would like to continue research work but I got stuck after the step with the diode plug. After putting the load into the diode plug on the secondary transformer winding the resonance almost stops or becomes very dumped, on the load I have pulsating

voltage, but it looks like ohm value of load doesn't really match correctly to the resonance condition (it was about 800W). I have in the circuit to many parameters to play with like ohmic load, C value, input voltage, input frequency, and I need to know how to calculate all values matching to each other.

In other words I have in the secondary winding of transformer so about 1.5kW apparent power where voltage and current are 90deg to each other but I don't have any working circuit for extract it into active power. Every engineer from a classic physic school would say the power with $PF=0$ is not usable, but I know that IT COULD BE USED some how :)

Hectors Answer

In plug to match lone cap its $C/2$ in farads (mF) to get OU P extracted its total C capacity in joules $Cj/1.618 /1.618$ then have main C and 2 diode plugged capacitors in parallel C to get a RESONANT POWER split without killing resonance effect.

This DIODE plug can self trigger using resistor and switching diode with small cap .005 and 6.8 K variable adjust neon trigger... can use lamp dimmer SCR circuit alike but tailored to switch on at C crest charge (self triggering) EV gray used spark gaps ... in HV as to brainteaser simile.

Further ideas

Another possibility would be to use opto electronic circuit for controlled discharging of caps into load. Even if I have seen in the doc the circuits with opto SCR s, I could not find the trigger circuit for discharging... Raivo can supply some of his, he still needs to solve jitter and secondary triggering ringing from load (damping needed)

In RF at the C node a capacitor charge is maximal, so you have a JOULE potential as a PURE DC in this capacitor. RECAPITULATE on past information (contained In Dans RE-OUI e-book) .

In a PM generator a magnet saturates shorted coil. This is WERE VOLTAGE is 0 and AMPERAGE is MAXIMAL at a 0 POINT energy CURRENT node, then at PEAK the coil is OPENED and this POTENTIAL DUMPS into a C were C is tailored TO equal in pure resonance of a hyper q value to get a FULL charge from the L across a diode until the amperage = 's 0 current and the C equals the maximal joule stored in the potential at 0 point energy transfer.

Its simple, I have given this in a hundred ways, Kone had created this condition in the lab. The M field charging a coil in an optimal core ampere turn to core mass relation of a hyper Q half shorted tank is were the pure L is taken to a saturation in a PURE current node to a hyper Q state were the OU will transform.

This is, at the field collapse where energy transfer to capacitor Coil then

Cools down transferring its magneto-thermal energy to the C.

All the RV and trans verter experiments are tailored to get the experimenter face to face with the REAL 0 point energy where it can be by replication it can confirmed and measured that the ZPE state exist as at citation where at pure resonance in a VOLTAGE node we have a 0 current and in a Current node we have a 0 voltage.

We then vector this energy as I have explained a zillion times and kone head demonstrated another zillion in the lab into a capacitor. Who says you cant drive something with it? even at 0 power factor? If its a DC potential stored in a capacitor its no bullshit DC. Like the RV it takes apparently years to get into the collective mind but I insist it is a matter of time un till someone loops a MEG ,a VTA , A Muller /RV or replicates a Hendershot generator with it .

It will then have taken 7 years of publishing the TRUE no bullshit secret of OU and a true ZPE meaning. The Key point here is a pulse can saturate a coil to maximal magnetic force .

In a given transformer the laminate as opposed to the best ampere turn to core match is essential , That is the Pulse and COIL ampere turn must be optimal as to transfer MAGNETIC SATURATING potential into CORE fundamental natural resonance.

Look into jinis charts and experiments, its quite demonstrated a minor input sustains a mayor energy circulation (OU) were ambient energy is transformed and sustained within Here is his site - <http://www.m-primus.com/www/de/data/tv/tv.html>

There is RADIANT ENERGY behaving like RF , at low potentials more manageable for low cost experimentation. The importance is learning to pulse Cores to OU states and CAPTURING this with the Plugs to split feedback power for self sustaining and transferring extra power to other device LOAD. More is possible using REACTORS pure switched L networks cascading in thyroidal transformer networks in infinite loop. Think 3 phase transformers in a 3x3 configuration.

Latest extraction ideas and circuits

Feedback- I found some weeks ago interesting patent with very easy possibility to convert the reactive power in the secondary TV into active power! We need probably to try to adjust such patent to the TV and test in vitro.

The idea of patent was to use transformer which is using RIBBON instead the wire on the primary winding. This RIBBON is actually CAPACITOR acting as inductance and producing REAL MAGNTEIC FLUX in the core. According to the inventor or patent holder Pavel Imris such transformer is able to convert 90% of reactive power into the active power. It looks very easy to build such ribbon transformer and sounds for logically that it could work... Just properly configure for resonance frequency matching C and L value in this ribbon construction.

Patent Link of Pavel Imris: [Link](#)

What do u think about such extracting in the TV? You told once you know 16 methods for using such reactive power, that's correct?

Feedback contd..

A ribbon or wire wound in a coil will exhibit resistance and capacitance or inductance depending upon the frequency. The EEs call this $R \pm jx$. Unless you understand why impedance changes from

- * resistance to
- *resistance plus capacitance or
- *resistance plus inductance

And why the dot moves around in multiple circles on the Smith Chart as the frequency changes, then you will have trouble understanding AC circuits, which are vastly different than DC circuits.

This RIBBON is actually CAPACITOR acting as inductance and producing REAL MAGNETIC FLUX in the core. I have trouble digesting this sentence.

Ribbons have their place in winding transformers, but I tend to prefer Litze over ribbons and wires, once entering the 10 to 20 kHz region. It is amazing, but true, that parallel wires twisted (Litze) together offer advantages over solid wire above a certain frequency, but that paralleled ribbons do ****NOT****.

Last Word from hector

Radiant Energy effects in electrets are to create latching junctions in a polymeric structure, the memory effect leads to the overheating in some of them and failure. Other materials are contrary, and hold charge better where the latching becomes stronger. That is why of the Transverter plug, the RF radiant effect is one way to force remnant Memory charge into the Forward energy component of the electrets and is intended as a recharge cycle, by any ways is OU, Hutchinson battery falls in this category the same as the Testatica. This is being interpreted from the posting on EVGRAY relating to the postings on Quantum diodes Electrets and ZPE, including Phil's postings on capacitors, that I refer to Quantum electron tunneling diode effect in old postings and it is in some of the compilations .

The Joule charge in a capacitor does not have a power factor. That is Volt ampere discharged in x time in a load. This is also stated in a Book rule quantifiable and simple , if the joule pulses exceed the input average energy your device is OU. The only barrier I see which would amount to being hard to understand here is the understanding and

interpretation of a proper averaging and TIME constants figure. Some hi level (engineering required) combined with the LAB work.

Raivo, Jinis and Dan's R and D

Ferroresonant (FR) transformer

In normal transformers, you wind the secondary on top of the primary. In FRs, you wind the primary on bottom half of transformer, and secondary on top half, with a magnetic shunt in between. This magnetic shunt is nothing else than simply the same laminate really shortcircuiting the magnetic path of the secondary. The thickness of this shunt is less than half of the transformer core thickness, else all flux would be 'shunted'. So you could see this transformer as containing 2 separate magnetic paths with a limited coupling between them.

The conventional reason of using a FR is because any change in the primary voltage will not translate into changes in the saturated secondary voltage, and voltage regulation results. Normally, core saturation in a transformer results in distortion of the sine wave shape, and the FR is no exception. To combat this side effect, FRs have an auxiliary secondary winding paralleled with one or more capacitors, forming a resonant circuit tuned to the power supply frequency. This "tank circuit" serves as a filter to reject harmonics created by the core saturation, and provides the added benefit of storing energy in the form of AC oscillations, which is available for sustaining output winding voltage for brief periods of input voltage loss (milliseconds' worth of time, but certainly better than nothing). In addition to blocking harmonics created by the saturated core, this resonant circuit also "filters out" harmonic frequencies generated by nonlinear (switching) loads in the secondary winding circuit and any harmonics present in the source voltage, providing "clean" power to the load.

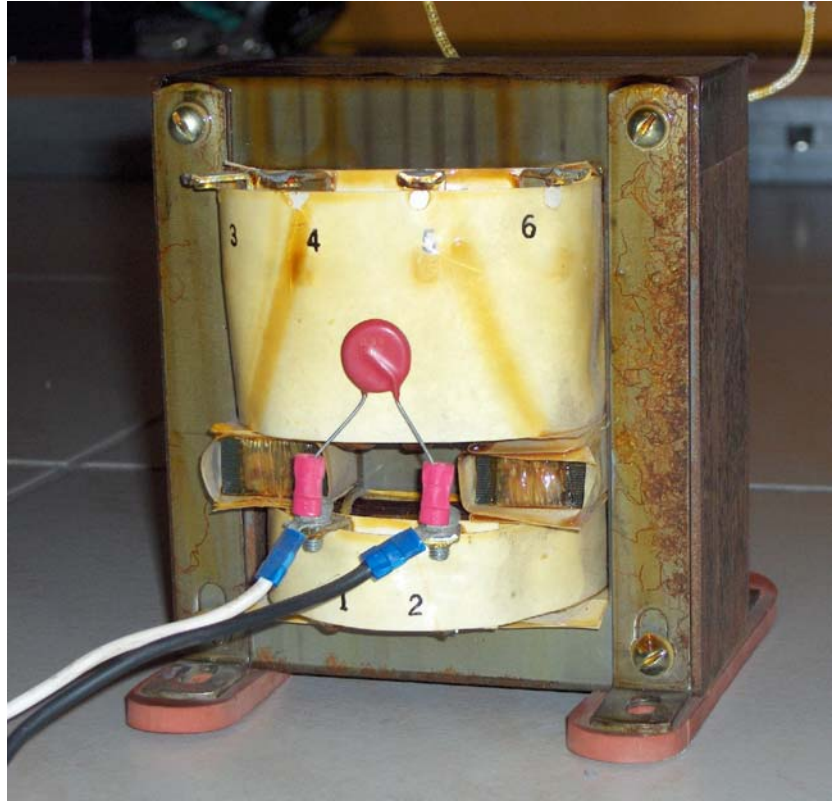
When a "ferro" is fully loaded, meaning that it is having maximum current drawn from it, the output voltage wave form approaches that of a sine wave. On the other hand, when the load is light, the wave form takes on more of a quasi square wave. This is a result of the transformer's effort to keep the output voltage as constant as possible, which is the very essence of the ferroresonant design. So far a conventional FR use.... end of "classic" education... ;)

Now the interesting thing....

We DON'T use it for voltage regulation nor with the auxiliary winding (just with the primary and main secondary), but purely for resonance creation (with high Q) without impact to primary. You can resonate the secondary (so creating high current and voltage). In a normal transfo, this will impact total flux and as such also the primary. In an FR, because of the shunt, this resonance and as a consequence the saturation remains within the secondary magnetic loop (because of the laminate shunt). So you can get the ferroresonance effect in the secondary without impacting the primary.

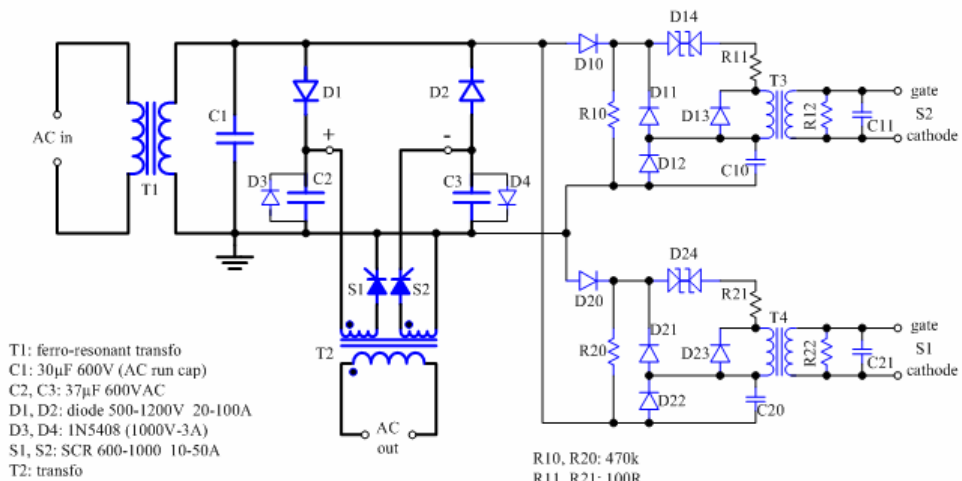
In fact you can see the primary winding as RV prime mover and the secondary winding as alternator, but all in 1PH. So the FR is more advanced than the RV prime mover+alt (simpler & no rotating parts), but the drawback is the single phase only. (unless you can make a 3PH FR, but I don't know if that even exists).

To the right is a pic of my FR. The bottom is the primary of 230V (connection 1-2). The top is the secondary of 50V with connection 3-6 (there are also some other connections to the same winding with lower voltage). This secondary has very thick wire, so good for high resonant current. There is an auxiliary winding (white small wires at the back), but not needed for my purposes. See the magnetic shunt between the windings.



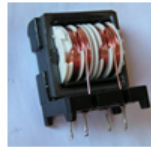
Now as I found that my LC is resonating to 3rd grid harmonic (150Hz), I'll use our 'infamous' SG inverter to feed the FR with about 150Hz, and make it "squeal like pigs". Then the new diode plug....So this is next step.

Transverter v1



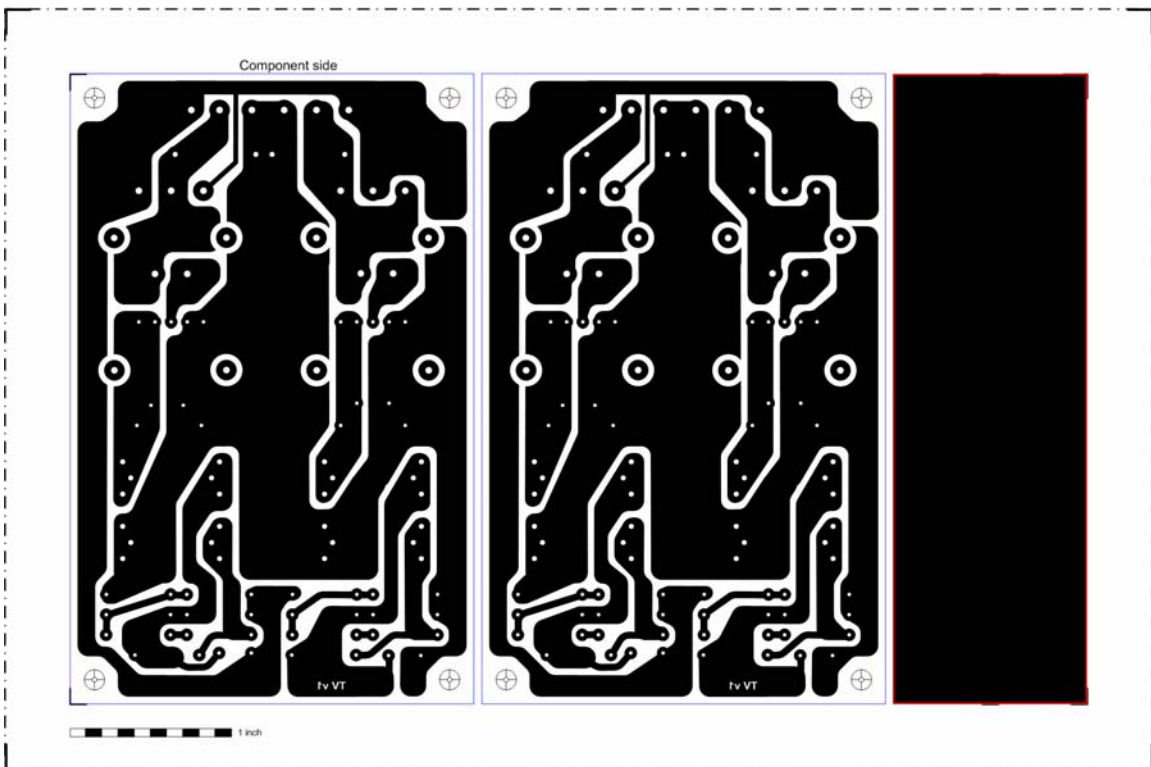
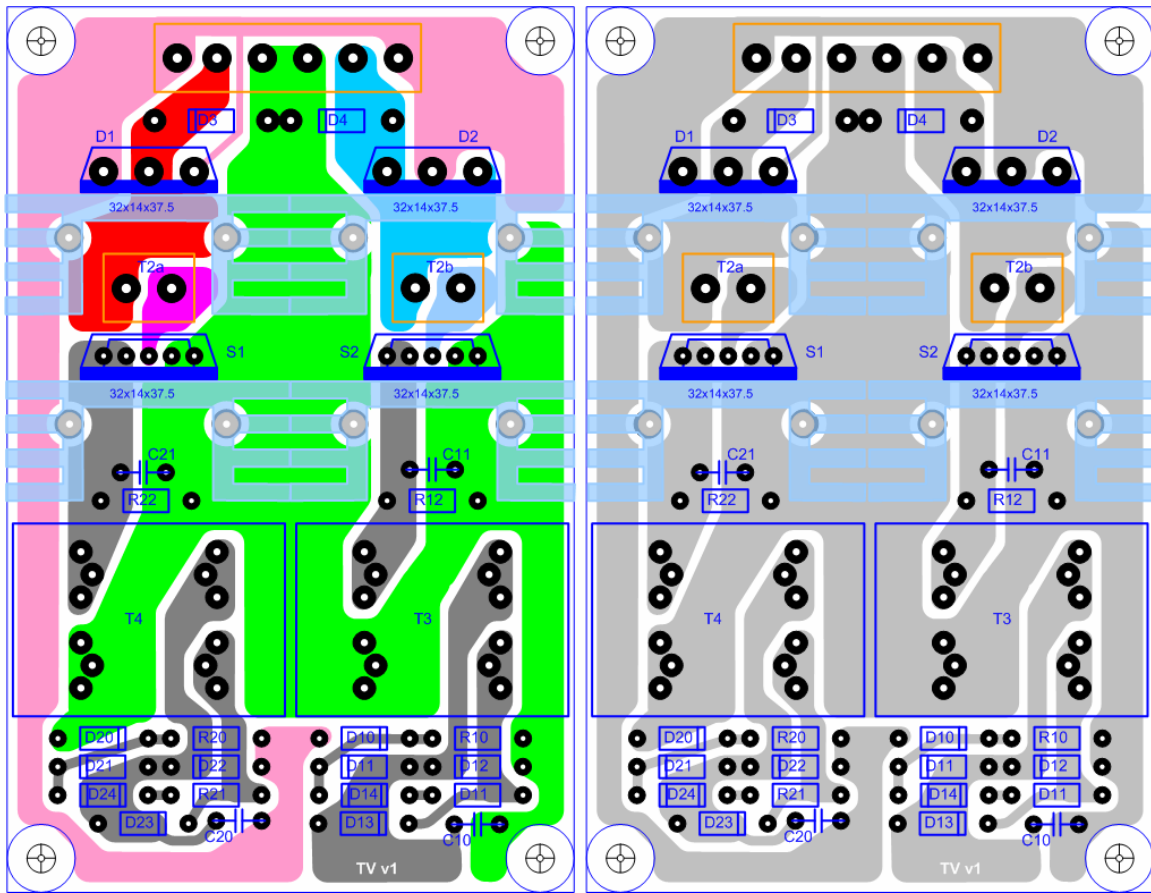
NOTES

- * C1, C2, C3: At optimised resonance, there is a 1.618 gain (multiplied by the Q factor), just extract the .618 and leave the 1.0. Adjust your cap values, so that:
 $C2 \leq 2 * 0.618 * C1$ ($C2 = C3$).
 C1 maintains the resonance, and extract from C2/C3. As such overextraction is not possible, as such no impact on resonance and power input.
 - * C5, C3: recommended to use AC run capacitor; use electrolytic only for short term use;
 - * S1, S2 example: TIC126M (600V-12A); 30TPS12 (1200V-30A); TYN412 (400V 12A)
 - * D1, D2 example: SKR45/12 (1200V-50A) or reverse diode of IRFP460 (standard recovery diodes are OK because of low frequency)
 - * D3 & D4 (both optional): power reversing blocking diode
- R10, R20: 470k
 R11, R21: 100R
 R12, R22: 470R
 C10, C20: 10nF 500V
 C11, C21: 100nF
 D10, D20, D11, D21, D12, D22, D13, D23: 1N4007 or MUR160
 D14, D24: DB3 28V diac
 T3, T4: pulsetransfo - see picture

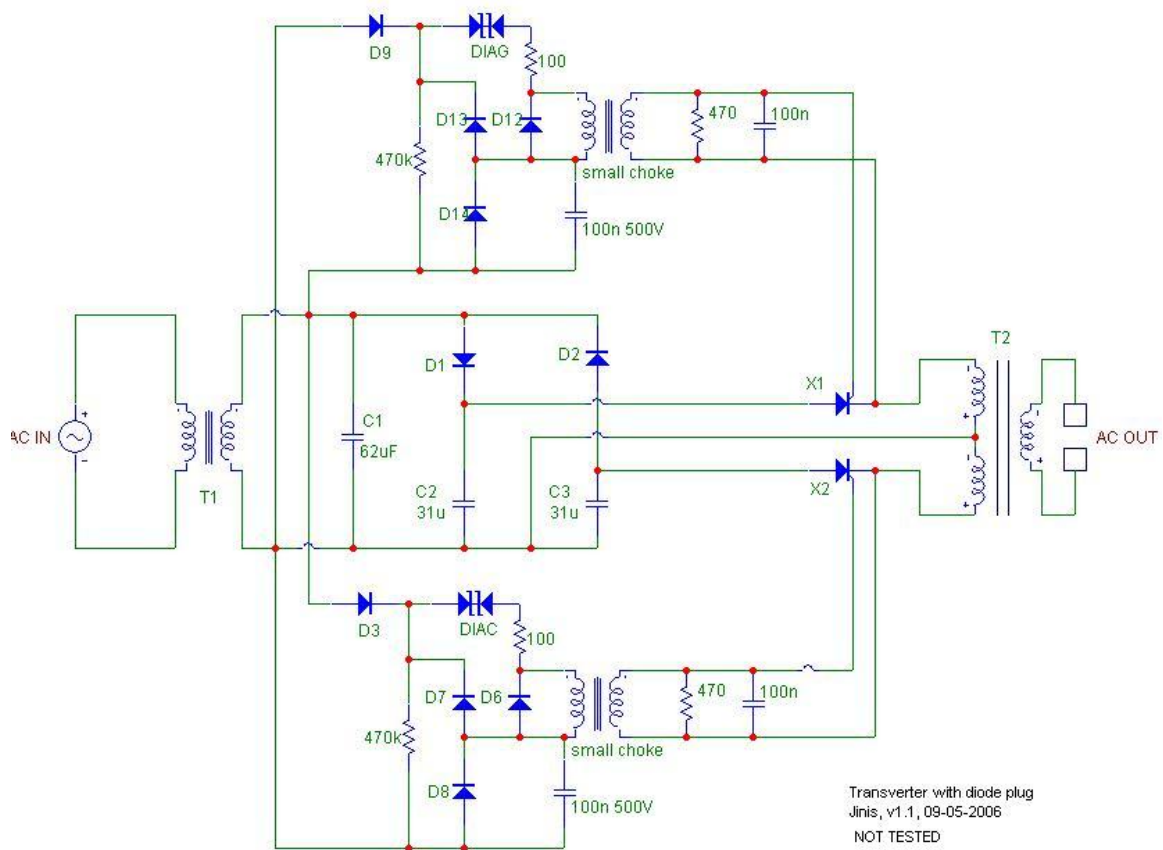


Dan & Raivo - July 2006
 (with credit to Jinis)

PCB layouts



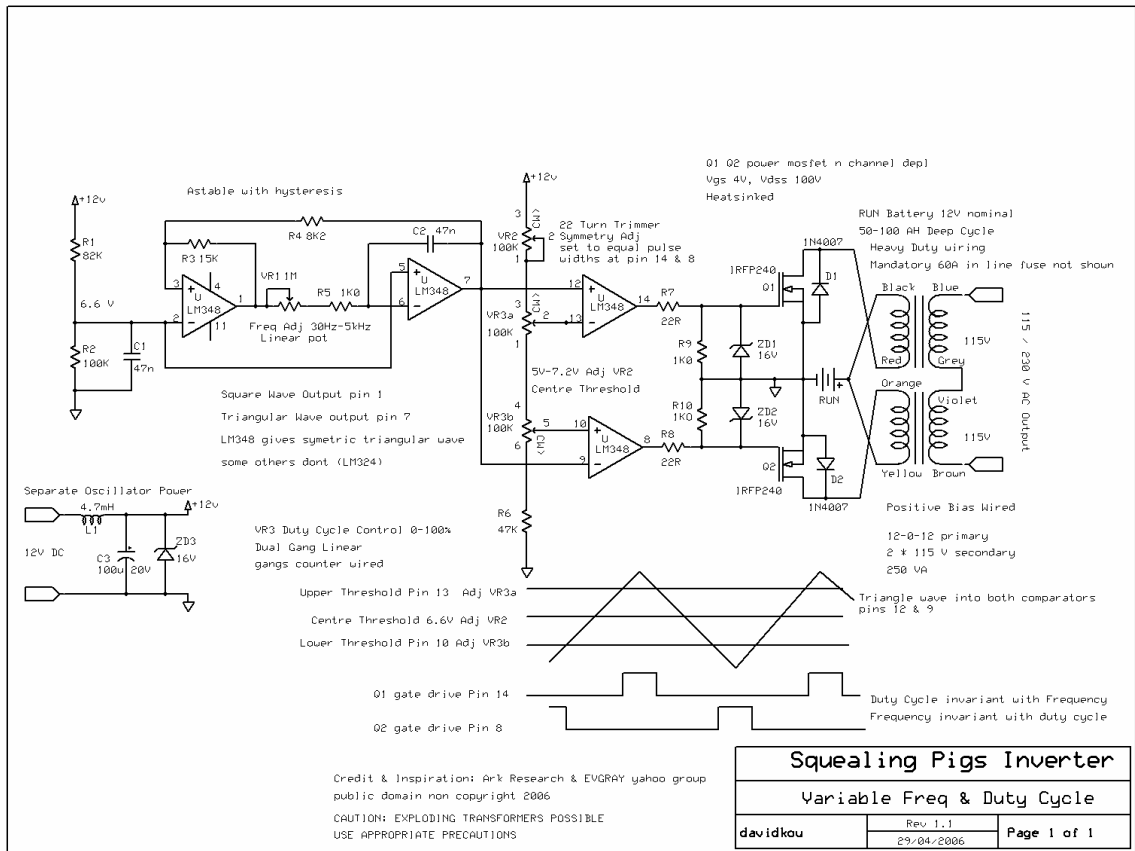
Jinis's First schematic



To be updated and continued...

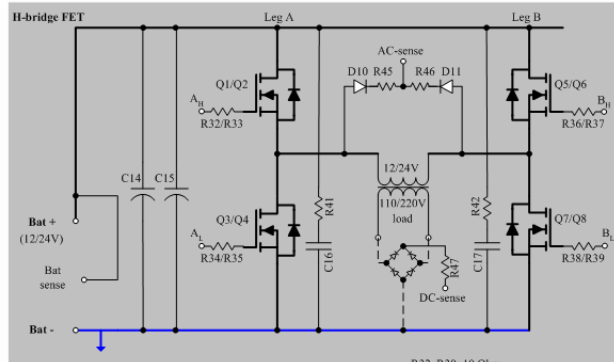
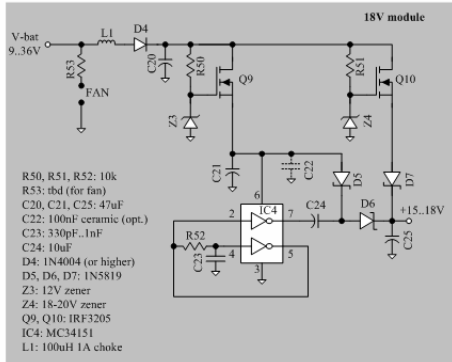
Latest Inverter designs for experiments

Squealing pig

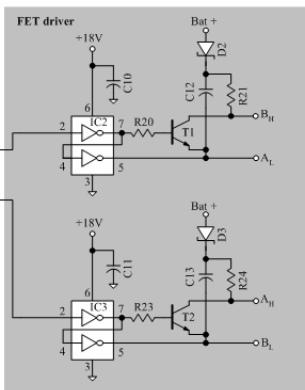
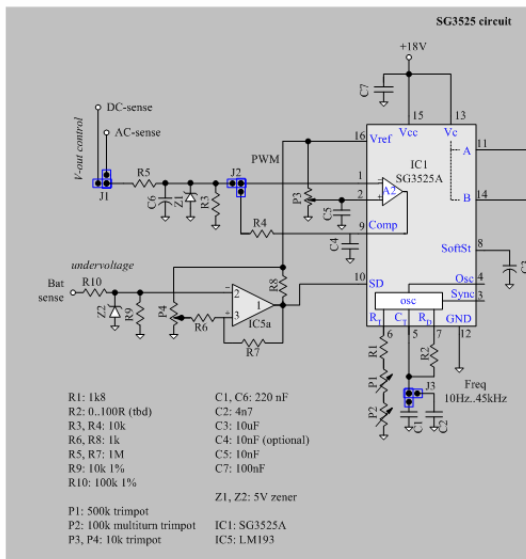


12-24V SG inverter

12-24V H-bridge inverter v3.3



R32..R39: 10 Ohm
R45, R46, R47: 10k
C14, C15: 2200..10000uF
(to support short peaks)
D10, D11: 1N4007
Q1..Q8: IRF3205
C16/R41 and C17/R42:
lump damper snubber (values tbd)



R20, R23: 4k7
R21, R24: 2k2
C10, C11: 4.7uF
C12, C13: 1uF
D2, D3: 1N5819
T1, T2: BC546A
IC2, IC3: MC34151

NOTES (READ CAREFULLY):

SG3525 circuit

* Oscillator frequency is set with R1-P1-P2-C1-C2 ($f = 1 / C_1(0.7R_1 + 3R_2)$):

R1 limits frequency to maximum about 100kHz

P1 for coarse tuning

P2 for fine tuning

use J3 to connect to C1 for frequency range 20Hz..3kHz,

or to connect to C2 for frequency range 1kHz..100kHz

(note: output freq at A & B is half of oscillator freq)

* Softstart controlled with C3 (for about 50% duty: $t = 2C/50uA$) - 10uF for about 0.4s

* PWM adjustable with P3

- connect J2 to pin 9 (Comp) for manual PWM control (short R4 if not used)

- connect J2 to R3 for automatic PWM control based on output voltage

- select with J1 either DC-sense or AC-sense

* Battery undervoltage protection: set with P4

The output of the comparator goes H in case of undervoltage, which goes into SD pin to shut down PW

* PW outputs at pin 11 and 14

FET driver

* IC2 & IC3 circuit is to pulse drive the fets according to the pattern in the schematic below

* the high side has a voltage boost (circuit around T1/T2)

FET H-bridge

* Q1..Q8 are double for high current

* use J4..J7 to enable individual legs and/or high/low Fet

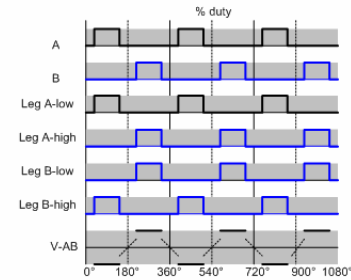
(by default all set vertically - see red marks on PCB design)

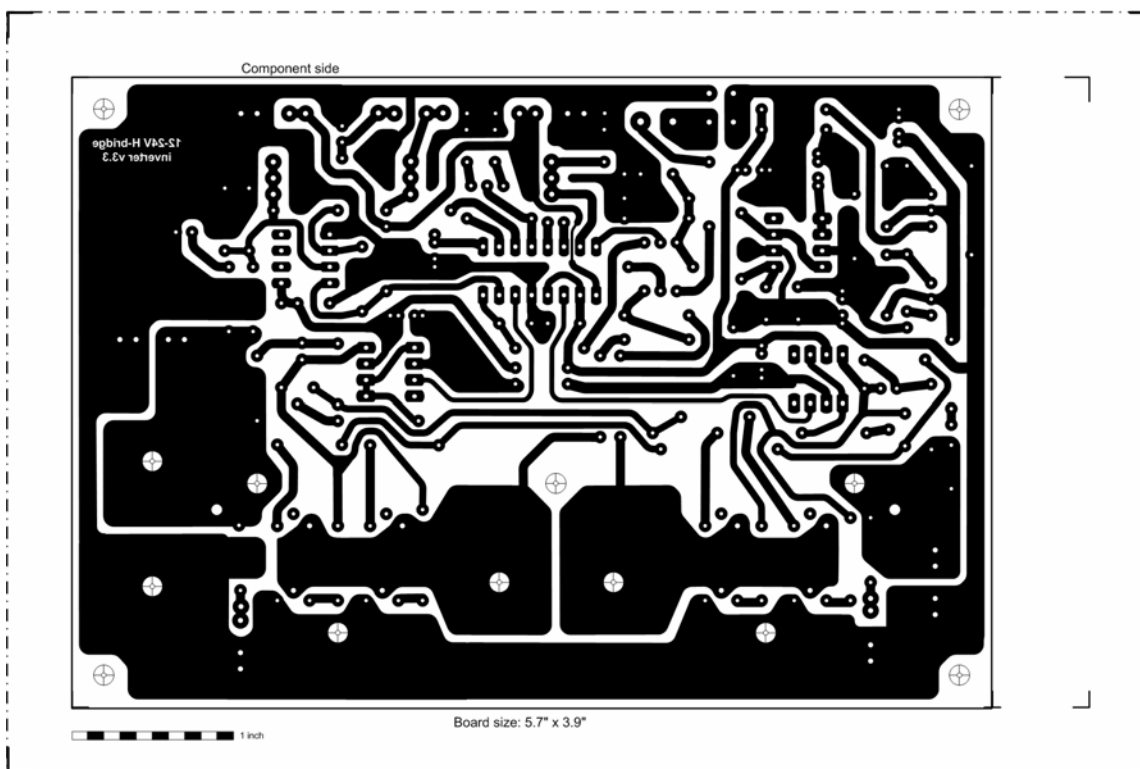
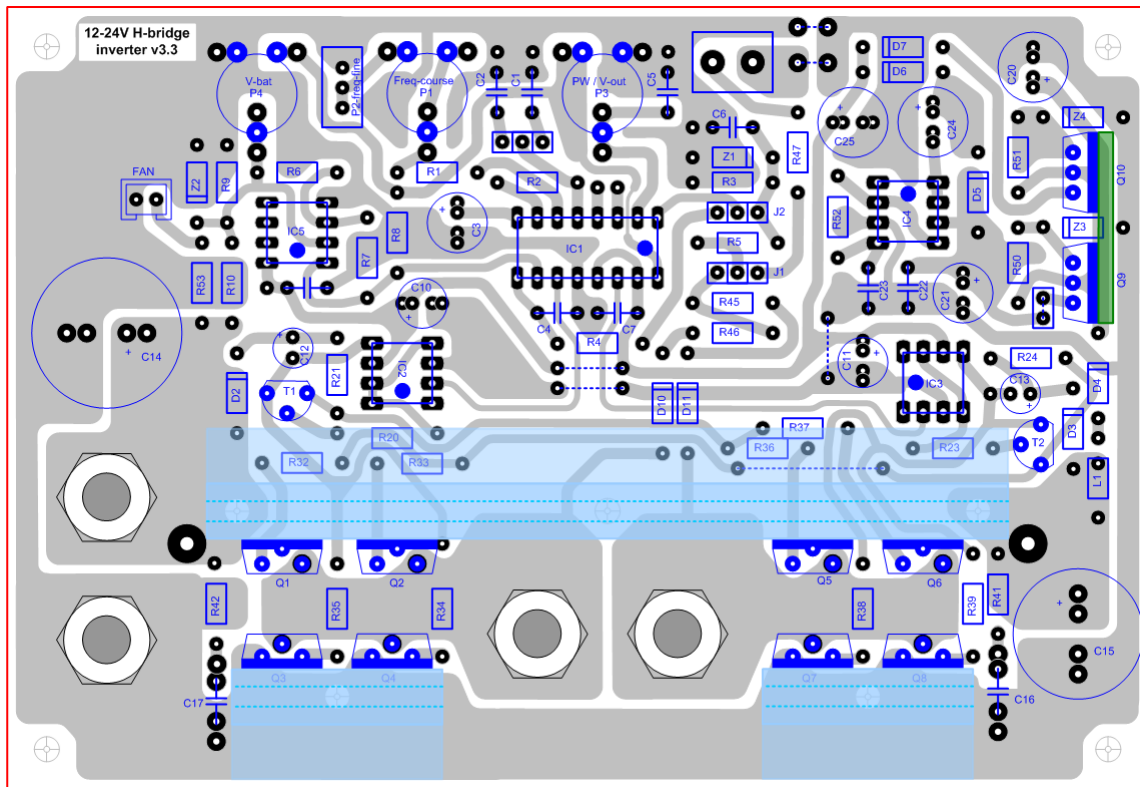
* R41..42 and C16..C17 offer space for a snubber network

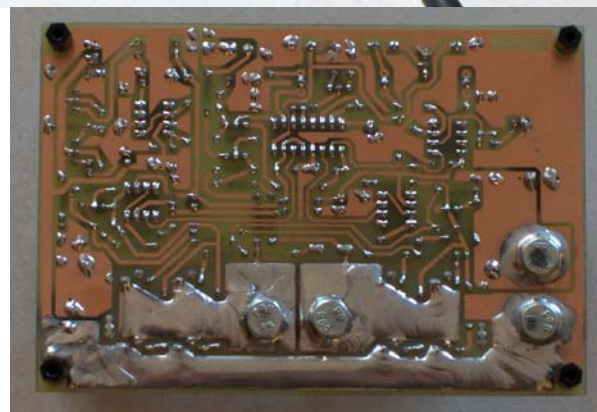
(not recommended for use, unless slower turn-off dV/dt is required)

* transformer should have dual primary and secondary winding (2x12v prim - 2x110V sec)

put either in series or parallel, depending on battery voltage and required output

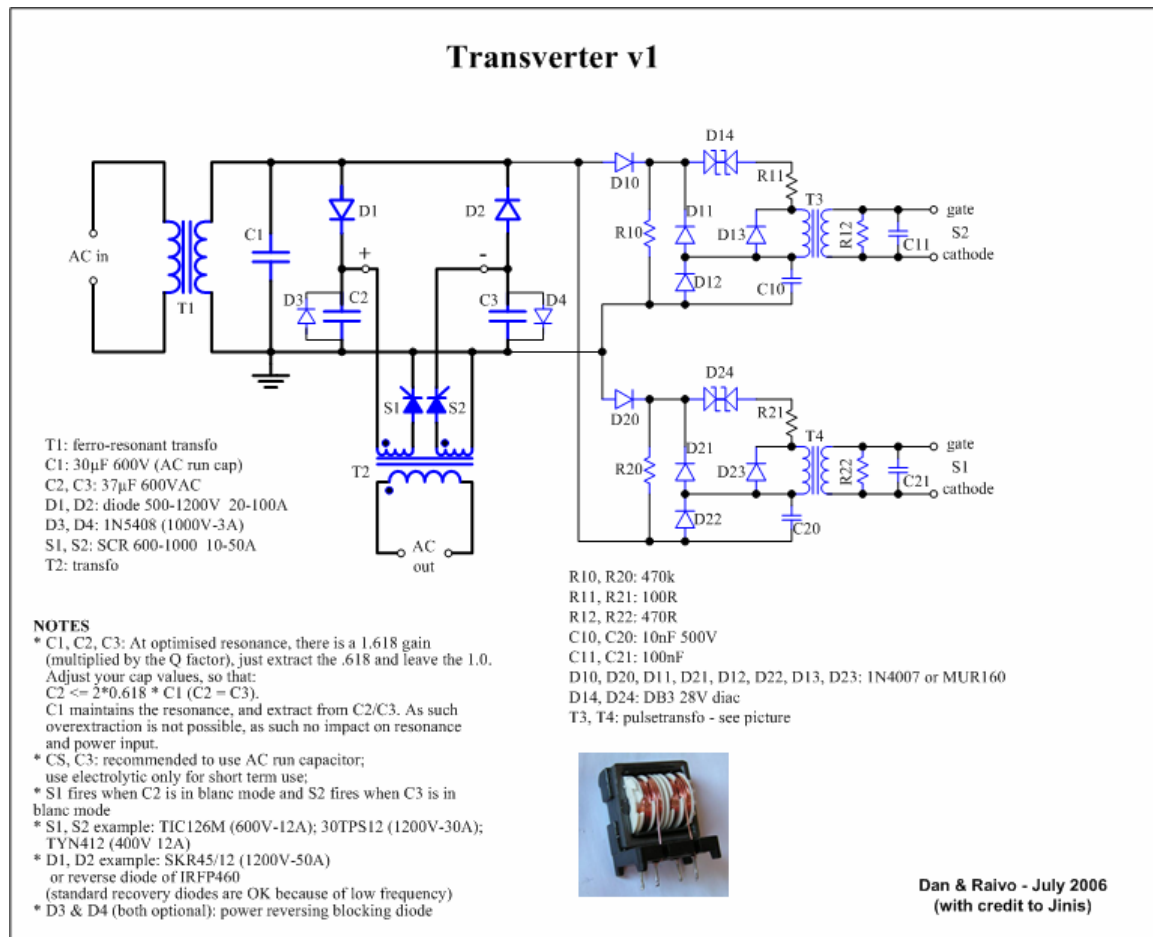






To find the Natural Ferro resonance of your Trafo core

One way to test is pulsing it with a short pulse & read the way it resonates; there you can find the natural Ferro resonance of your Trafo core. If you see jinis page scope shots you see some spikes, those spikes are the natural resonance harmonics of the transformer, the resonant slope indicates also its resonant point is on a sub harmonic as spike is very



The problem with driving an RV (or any motor) is that when you reduce the frequency of the inverter (so to have the motor running slower), the motor at that time works as a generator (because of its “over speed” and inertia).

The energy generated can be quite high, trying to find a way back through the inverter into the battery. (the current flows in reverse direction through the anti-parallel diodes build into the fets of the H-bridge). You can measure this energy recuperation. This works OK.

BUT when you reduce the frequency too fast, the energy pulse back from the motor is so high, that the voltage peaks exceed the fet values... blue smoke...fets burned....

Simple is to put some high-Joule varistors (rated about 40V for the SG inverter) in parallel to the load which will short-cut the peaks and let the rest go back via the H-bridge. Well build (thick solder and heat sinks), the SG inverter can go to 75 Amps (12 or 24V), with limited peaks to 150 Amps. Put a step-up transformer in the output to have higher voltage.

Recent tests from Gustavo Roveran

CIRCUIT DESCRIPTION

Vcc = 20 Volts

Pwm circuit:

Voltage comparator lm339 ([Link](#) Improved Circuit)

Mosfet Driver IR2110

Mosfet IRF510

Trafo: Two Coils wired around toroid 1:1 relation.

MY Introduction:

The idea is to find the resonance of the system.

I have considered three (3) types of systems:

- 1) Trafo's primary between Vcc and IRF510 Drain (without load at secondary)
- 2) Trafo's primary between Vcc and IRF510's Drain (with different caps as load at secondary)
- 3) Trafo's primary between Vcc and IRF510's Drain with 1 ohm in series AND with different caps as load AND 1 ohm in series with secondary coil.

EXPERIMENT (resonance search)

System 1) I have detected the resonance of the system, using the same process that you can see in [Link](#) site.

In the system (1) there is no cap, but there are parasite caps in primary, secondary, transistor output and board.

Resonance frequency is near 1 MHz (Note!!: for example if you change the mosfet for another model you will have different resonance frequency. In IRF510 -> $F_{res}=1,25\text{MHz}$, In IRFZ44-> $F_{res}=900\text{Khz}$)

System 2) The resonance frequency will depend on the capacitor load at secondary.

System 3) The resonance frequency will depend on the capacitor load at secondary. But in this case I said that I have put 1 ohm resistance in series with Coil in primary, and another series 1 ohm resistance in secondary Coil.

EXPERIMENT (ferro – resonance search)

BUT from the readings, we have to look for ferro-resonance, so we have to add something else to these experiments, and here is when PWM takes place.

Playing with the pulse width I make the core enter into saturation at the resonance frequency I found for each system, so it is ferro-resonance. (Search information on ferro-resonance in internet. I found a document called “ect190.pdf” at Groupe Shneider site)

CONCLUSION

1) In the system (1), I have found the resonance of the parasite caps and transformer. When I tried to load secondary with caps, the system go out from resonance and began to consume more current. This is because the parasite cap is very small, and you will not find a cap at secondary that let you to achieve a system plug diode at the secondary to recover some energy.

2) Ferro resonance is achieved by finding resonance frequency of the System BUT making the core enter into saturation zone.

Answer from Hector: *Pulses are intended to excite a resonant condition (ZPE) loaded as a tensor to an energy transfer system.*

QUESTIONS

What would be the better way to know how deep must be the saturation of core? I means, for example, In a B-H curve.

3) The core will make noise only when the frequency of resonance you use, is in the audible band frequencies. (More saturation more noise)

Does any body make noise with the core using frequencies greater than 20KHz?

Answer from H- lower harmonics induced within non audible create noise ... (as in MRA) also "beat tones" create audiles.

4) It is possible to have more dissipation power in the resistance at secondary than resistance at primary (thermal difference). System (3).

Answer from H: yes that is the idea.... law is voltage must be same ... sample 12 V in 12V out.

BUT the total power that enters into the system (IC, Resistances, etc) is bigger than the power at the secondary This means more power at secondary than primary. or not?

Answer from H- voltage referred to resistance is what the deferential in heat is about if I input 1000V across a 50Ohms resistor to feed a 1000 V AC primary transformer and use the 120VAC output to feed identical 50ohms resistor at the load end I will burn the output resistor but not the input one. Its the VA relation.

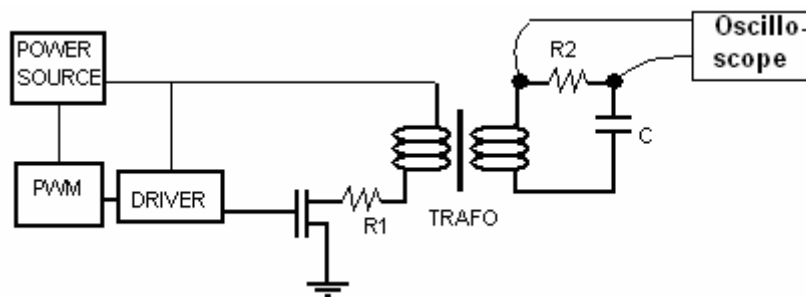
5) I will do another experiment that consist in putting a serial cap (as barium titanite piezo) with primary coil. (similar to the “ A technical Schematic of the MRA principle courtesy of Jerry Decker's KeelyNet” at [Link](#) And will be another system to test....

6) Does the ferrite core of this type off toroids be a good material to test. Or Fe-Si cores of common transformers are better?

Mini TransVerter Tests

(Mini TransVerter test with different wired transformers using the same type of core.)

Circuit:



$R1=R2= 1 \text{ ohm}$

The test was done with three different transformers (T1, T2 y T3), 1:1 each of them, but with different number of turns.

(Less turns) $T1 < T2 < T3$ (more turns)

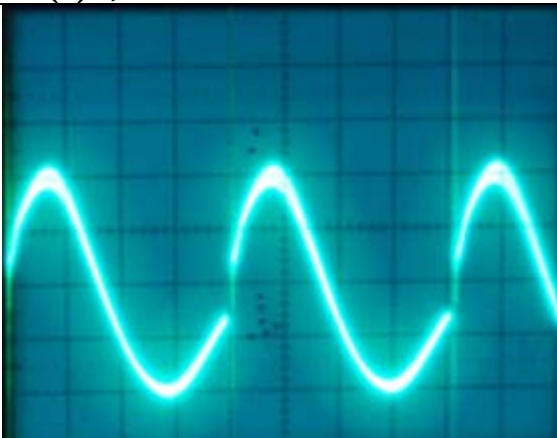
I use the same capacity (C) at load side for all tests.

I measure for two different pulse width for each transformer. And adjust the frequency to consume less power as possible for the overall circuit.

	freq at resonance	Source V	Source I	PWM %	C microF	PtP at R2
T1 (a)	12,5 Khz	20	0,29 amp	5	2,6	3.1
T2 (a)	5,26 Khz	20	0,29 amp	36.8	2,6	2.65
T3 (a)	1,96 Khz	20	0,29 amp	58.8	2,6	2.5
T1 (b)	14 Khz	20	0,10 amp	0.98	2,6	0.6
T2 (b)	5,43 Khz	20	0,11 amp	2.1	2,6	0.7
T3 (b)	2,38 Khz	20	0,10 amp	2.9	2,6	0.84

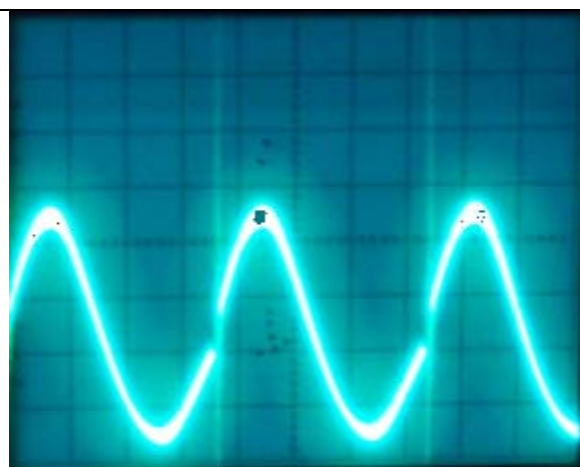
Note: PtP at R2 = means quasi sinusoidal wave peak to peak voltage over the R2 load.

Oscilloscope Photograph (R2 voltage for each case)

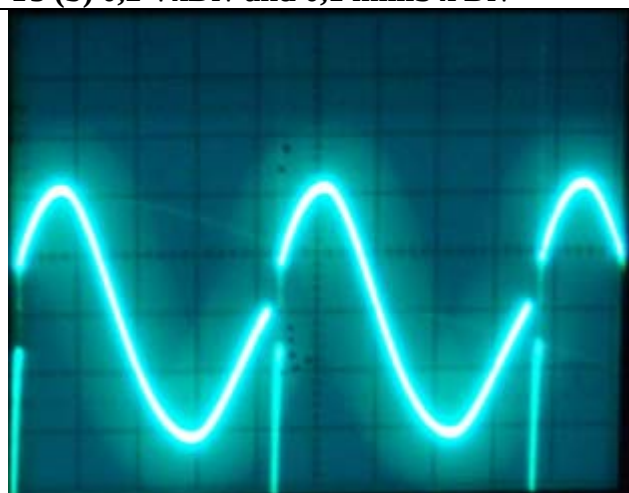
T1 (a) 0,5 VxDiv and 20 microS x Div	T1 (b) 0,2 VxDiv and 20 microS x Div
	
T2 (a) 0,5 VxDiv and 50 microS x Div	T2 (b) 0,2 VxDiv and 50 microS x Div



T3 (a) 0,5 VxDiv and 0,1 milliS x Div



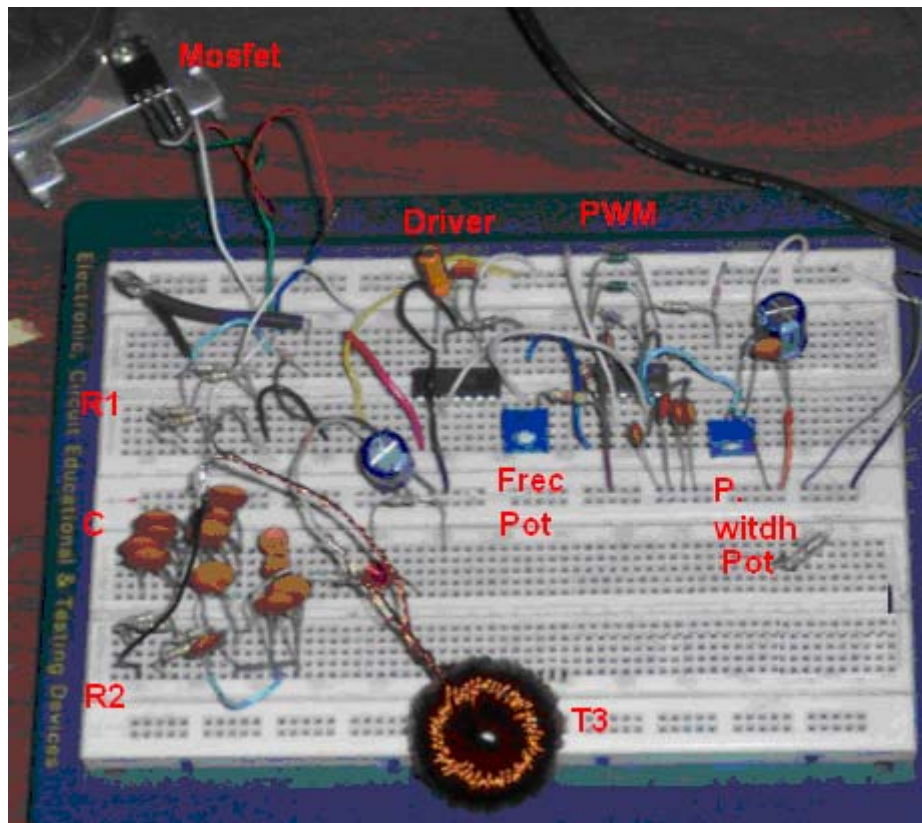
T3 (b) 0,2 VxDiv and 0,1 milliS x Div



Trafos photographs



Circuit Photograph with T3 transformer



As you can see, for each measure I have to find the resonance frequency and then modify the pulse width to achieve the different measures.

When I worked with a pulse width that make the circuit consume more current, the best performance was for the T1 transformer. But when I worked with a pulse width that make the circuit consume less current, the best performance was for the T3 transformer

Best performance means more voltage over load R2 for same current at overall circuit input.

Some notes:

I have choose a capacitance at load that let me work with a resonance frequency in the audible bandwidth.

When i achieve the resonance frequency for each test, could heard the noise of that frequency. BUT I realized that the noise did not come from the core. It came from the capacitors at load side, and in the **T3 case** i could heard the T3 noise, but it seems to come from the wire and not from the core.

The circuit consumption without mosfet activity (no current through Drain-Source), is about **0,06 amperes**.

In all the test, I can feel that the R2 is hotter than R1.

But for example,

Case T1(a)

$$\begin{aligned}\text{Power at R2} &= \frac{1}{2} * V_p * V_p / R2 && //\text{considering sinusoidal wave} \\ &= \frac{1}{2} * 1,55 * 1,55 / 1 = \mathbf{1,20 \text{ watts}}\end{aligned}$$

$$\text{Power Overall circuit} = 20 \text{ Volts} * 0,29 = \mathbf{5,8 \text{ watts}}$$

$$\text{Power logic circuit} = 20 \text{ Volts} * 0,06 = \mathbf{1,2 \text{ Watts}}$$

$$\text{Effi} = 1,2 / (5,8 - 1,2) = \mathbf{0,26}$$

Case T3(b)

$$\begin{aligned}\text{Power at R2} &= \frac{1}{2} * V_p * V_p / R2 && //\text{considering sinusoidal wave} \\ &= \frac{1}{2} * 0,42 * 0,42 / 1 = \mathbf{0,086 \text{ watts}}\end{aligned}$$

$$\text{Power Overall circuit} = 20 \text{ Volts} * 0,10 = \mathbf{2 \text{ watts}}$$

$$\text{Power logic circuit} = 20 \text{ Volts} * 0,06 = \mathbf{1,2 \text{ Watts}}$$

$$\text{Effi} = 0,088 / (2 - 1,2) = \mathbf{0,11}$$

It is clear that I could not achieve energy from the ambient,

or I am wasting power in mosfet (it is not warm) or the transformer (it is warm).

Conclusions

It is possible to achieve resonance with pulse width modulation.

It is possible to modified the frequency for different pulse width for least overall circuit current consumption.

I could see that I can carry the system to the saturation point BUT i could not see the point where can really achieve a kind of ferroresonance to extract ambient energy.

So, if I could achieve resonance and could achieve core saturation then

¿What is the step I am doing bad?

¿How the wave form over R2 would be?

¿What else I have to do to extract more power?

From the experiment seems that I will have more efficiency for less turns of wire ¿Do I have to work with transformers with less turns of wire?

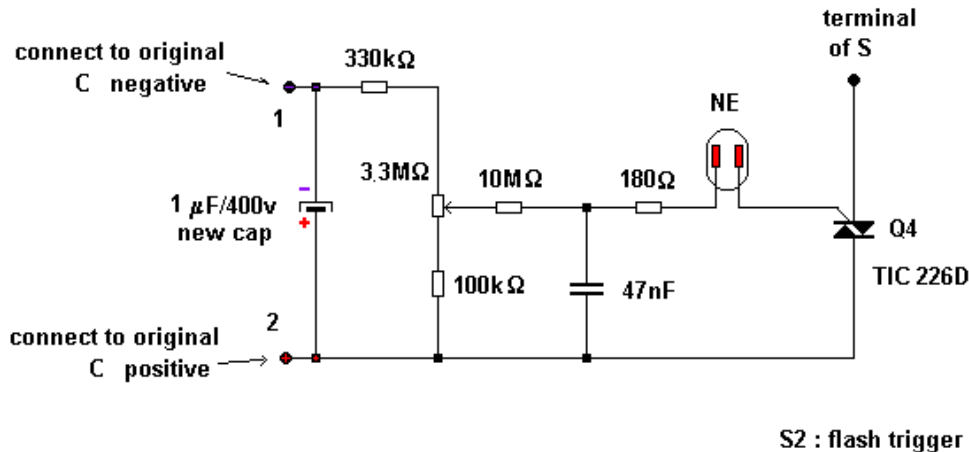
Help is really needed.

Regards,

Gustavo

Additional information provided By Dan.

ADDITIONAL CIRCUIT FOR TRIGGER CONTROL



Important Note: remember photoflash capacitor C must be removed and contacts 1 and 2 must be soldered instead.

From Hector:

This circuit is for 350VDC to 400VDC range, resistor values can be lowered or raised to fit application. On a TransVerter plug a pair of this circuits are used as self triggering ,c2,c3 dischargers or basic fundamental x2 plug non reflective to source discharge units. check other circuits related to RV and TV plug within the files section or refer to compilation script.

Then you go into frequency drive power management ,there is were the real savings can be seen and the technology starts to enter in the ZPE energy management region.

Read Vassilatos' book on Tesla and It vindicates me totally in that Radiant energy is RF ,still book errs in the statement RADIANT energy requires pulses to be created (quite misleading). RV alternator looked at the proper way and the way light bulbs are lighted using a single wire from its potential, it can be confirmed ...or may I say (Its already confirmed) is pure ac radiant energy at pure resonance (lab tested) EVLF extremely very low frequency radion (radio) RF waves.

Book clearly mentions Tesla used pure voltage (Voltage node of RF wave to create the alleged "radiant energy" (RF)) and use pulses to create it in one way direction SB (sideband),(no other thing that aether density pulses) capacitive waves = RF waves of type similar to earthquake acoustic propagation waves .

READ EARTHQUAKE wave propagation dynamics (Its same laws applied to RF there you will clearly see what I refer to (S & P waves) as a hint! add wave polarization to the equation thinking like I once stated in 4rt dimensional projection .

Analyzed in lab is the same stuff RF and sound respond to, same LAWS of physics.

The Super luminal is EASY, 2 waves conjugated at an angle create a faster wave at junction point (waviton) conjugating LASER waves into wavitons create faster than light hypersignal (this is kid stuff) can be made in any well equipped lab .

Reread my posting on the hose in pool with the traveling balloon from end to end ... creating waves in the pool but the balloon is still held in the hose (electrons) the pool water where waves are created is the "AETHER" medium. refer to electron density postings .

In modern electronics study single sideband radio engineering design it helps understand the directional pulse stuff. The effects is where acoustics meet the electrical, refer to old postings where I mention a ZILLION (annoying) times that all waves respond to acoustical mechanics as well as electrical ones. Remember this when you make OU coils "squeal" like pigs! check Jini's page experiment interpret the scope readings there is more to those readings than what you may think possible, its direct look into ZPE guts! Some "octaves" up. Tip (the big power spike in center with the big power "surge"!

That is when radiant wave RF meets acoustical realm ,then we have to work in IRON CORE crystal lattice matrix as well as its electrical character because HERE is where the extra energy is acquired by means of transformation from the ambient, The iron becomes a TRANSPONDER -"transformer" element of the ZPE available components specific to the area is located on, electron spin energy, electro atomic ambient noise, aether density in the medium, gravitic compression signature and other components in the ambient direct sea of energy including ambient thermal ones.

Radiant energy is CREATED in pure AC mode within the RV alternator electro-mechanical > AMPLITRON < (read radar theoretic, (amplitrons & magnetron theory) "its simple ...

Recent correspondence

To be more exact, i am working with toroidal cores that you can find within pc power supply. "I normally use a classic E-I transformer, as there is lots of iron laminate in it, which is really necessary for OU operation." It is better iron than ferrite? What type of trafo do you use exactly?

Not really, as ferrite is also based on iron. However ferrite works in HF, whilst with laminate you work in low freq range, which is much easier to handle, until you become an expert in the matter.

I use a ferro-resonant transformer But a normal trafo will also do (eg. 220-12V trafo).

In any case the tests must be done with unloaded secondary. The only load is the scope. Any load will change the result." And "The ferro-resonance of a given core-coil combination is fixed. Change core or coil parameters and you change the resonance freq."

I did what you say. I looked for the resonance frequency with unloaded secondary. So in that case I found frequencies near 1 Mhz. After I found this info. i decided to resonate the trafo. putting a cap at secondary trafo side to achieve the resonance.

But i could realize that the resonance with unloaded secondary worked with capacitances between wire turns, then when I put a cap at secondary to achieve the resonance, the Ferro resonance change to less frequency than the first one found with unloaded secondary. Finally my "conclusion" is that the capacitance is one of the elements that participate in ferroresoance frequency.

Every value of capacitance I put at the unloaded secondary will add to the capacitance between wire turns then will change the ferroresonance frequency.

Sure the load detunes the resonance frequency. This is normal. But the reason to test unloaded, is to be sure you find the core frequency (or very close to it), and not one of the harmonics. Then when you load, it detunes, so change freq until you get best resonance again. So you did exactly the good thing.

The IDEAL case is where you can also change the coil parameters (less or more windings) so to ba back again at the same core freq as when unloaded. This is th super best case, as you LC is then at the same freq as the core. But I didn't do that yet, as is not needed for our start. It's only when you master the technology, that you start doing that and pour more out of the beast...

The IRFZ44 is a good choice as the R-ds-on is low. Another good choice is IRF3205, IRF540, IRF2907, BUZ341. Thanks for fet you advise me... Personally I use the IRF3205 and IRF2907, as both have extremely low R-ds-on. Kick them hard with 18V on the gate, and they switch perfectly!

"No, as it has to do with phaseshift between current and voltage, and possibly standing waves you have at resonance. Remember that an R can turn into an L at resonance."
So, How can you detect that your circuit is in the OU zone ?

I found that measuring voltage over resistor is not accurate due to the phaseshift in resonance, so false hope of OU. However measuring in a non-resonant primary is not a problem. Example: battery and series resistor (used to measure current, so indication of power-in) into inverter (or PWM generator). This is OK. At resonant secondary: extract power into FWBR and cap. Only there you can measure over R.

Ah, now I see you use ferrite, as this is the reason of the high-freq resonance. Try first playing with an E-I iron laminate transformer, as the circuits are easier to play with, lower freq, very low stray capacitance & inductance... much less influence and variables to play with. Once you master an iron-laminate core, you can go to ferrite as you will then understand why it can behave different to due other influenced variables. I begun with these little cores because are cheaper (for me) and can work with very little voltages. However, Please tell me what would be the exact best trafo to test, and to achieve OU. Try any grid trafo you can get. The larger the better (>500W)

If you need a power H-bridge PWM circuit, let me know and I can send you all the schematics. It's one I made a year ago and works very well. Yes please, send it to me as soon as possible, hope I can find the ic's you use in your circuit within my Country. (However I was thinking to do this type of circuit with two ir2110 (a bit expensive IC's) and 4 fet for the little cores)

Back to your experiments, I notice you have very high frequency. This is normally due to the type of transformer used. You mention toroid. Is this a high-frequency toroid, or just at the grid-frequency. Those at grid-freq are tape-wound, and still can go to high frequency, but max out at around 2kHz. I normally use a classic E-I transformer, as there is lots of iron laminate in it, which is really necessary for OU operation.

In anycase the tests must be done with unloaded secondary. The only load is the scope. Any load will change the result. The reason why you have different results with different fets, is that each type of fet has it's own characteristics. However if you select a fet type close to another, the results should be very close though, except at higher frequency. The IRFZ44 is a good choice as the R_{ds-on} is low. Another good choice is IRF3205, IRF540, IRF2907, BUZ341.

Good you use a fet driver, as the PWM circuit cannot deliver enough current to get the fet switched on properly. You know that fets are voltage devices, however during switch on & off, you first need to punch through the gate capacitance (which requires current !) before the fet properly conducts. At high speed, this current can be up to 1 Amp or more!

> QUESTIONS

> What would be the better way to know how deep must be the saturation of core? I means, for example, In a B-H curve.

You don't need to be that deep in the curve. Slightly over the "knee" is OK.

> 3) The core will make noise only when the frequency of resonance you use, is in the audible band frequencies. (More saturation more noise)

> QUESTION

> Does any body make noise with the core using frequencies greater than 20 KHz?

Depends on which core is used: ferrite or iron laminate. Iron laminate is in audio range. Ferrite is not audible range. I only use iron laminate currently for my tests. The ferro-resonance of a given core-coil combination is fixed. Change core or coil parameters, and you change the resonance freq.

> 4) It is possible to have more dissipation power in the resistance at secondary than resistance at primary (thermal difference). System (3). BUT the total power that enter into the system (IC, Resistances, etc) is bigger than the power at the secondary

➤ QUESTION This means more power at secondary than primary. or not?

No, as it has to do with phase shift between current and voltage, and possibly standing waves you have at resonance. Remember that an R can turn into an L at resonance.

> 5) I will do another experiment that consist in putting a serial cap (as barium titanite piezo) with primary coil. (similar to the “ A technical Schematic of > the MRA principle courtesy of Jerry Decker's KeelyNet” at <http://www.panacea-ocaf.org/MRAEVGray.htm>
> And will be another system to test....

That will be an interesting test, as you add a crystal device into the circuit to create also resonance effect in the primary!

> 6) Does the ferrite core of this type off toroids be a good material to test. Or Fe-Si cores of common transformers are better ¿???

Ah, now I see you use ferrite, as this is the reason of the high-freq resonance. Try first playing with an E-I iron laminate transformer, as the circuits are easier to play with, lower freq, very low stray capacitance & inductance... much less influence and variables to play with. Once you master an iron-laminate core, you can go to ferrite as you will then understand why it can behave different to due other influenced variables.

If you need a power H-bridge PWM circuit, let me know and I can send you all the schematics. It's one I made a year ago and works very well.

To be updated and continued

Credits

EVGRAY/RVreplication yahoo groups

Chapter 7

Resonance and Impedance Matching

Many common circuits make use of inductors and capacitors in different ways to achieve their functionality. Filters, impedance matching circuits, resonators, and chokes are common examples. We study these circuits in detail and in particular we shall focus on the desirable properties of the passive components in such circuits.

7.1 Resonance

We begin with the textbook discussion of resonance of RLC circuits. These circuits are simple enough to allow full analysis, and yet rich enough to form the basis for most of the circuits we will study in this chapter.

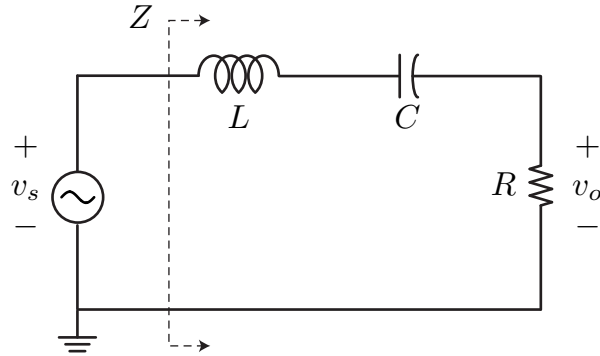
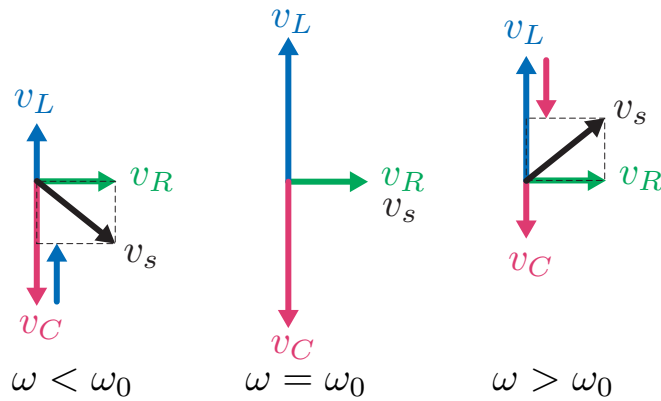
Incidentally simple second-order resonant circuit can also model a wide array of physical phenomena, such as pendulums, mass-spring mechanical resonators, molecular resonance, microwave cavities, sections of transmission lines, and even large scale structures such as bridges. Understanding these circuits will afford a wide perspective into many physical situations.

Series RLC Circuits

The RLC circuit shown in Fig. 7.1 is deceptively simple. The impedance seen by the source is simply given by

$$Z = j\omega L + \frac{1}{j\omega C} + R = R + j\omega L \left(1 - \frac{1}{\omega^2 LC}\right) \quad (7.1)$$

The impedance is purely real at the *resonant frequency* when $\Im(Z) = 0$, or $\omega = \pm \frac{1}{\sqrt{LC}}$. At resonance the impedance takes on a minimal value. It's worthwhile to investigate the cause of resonance, or the cancellation of the reactive components due to the inductor and

Figure 7.1: A series RLC circuit.Figure 7.2: The phasor diagram of voltages in the series RLC circuit (a) below resonance, (b) at resonance, and (c) beyond resonance.

capacitor. Since the inductor and capacitor voltages are always 180° out of phase, and one reactance is dropping while the other is increasing, there is clearly always a frequency when the magnitudes are equal. Thus resonance occurs when $\omega L = \frac{1}{\omega C}$. A phasor diagram, shown in Fig. 7.2, shows this in detail.

So what's the magic about this circuit? The first observation is that at resonance, the voltage across the reactances can be larger, in fact much larger, than the voltage across the resistors R . In other words, this circuit has voltage gain. Of course it does not have power gain, for it is a passive circuit. The voltage across the inductor is given by

$$v_L = j\omega_0 L i = j\omega_0 L \frac{v_s}{Z(j\omega_0)} = j\omega_0 L \frac{v_s}{R} = jQ \times v_s \quad (7.2)$$

where we have defined a circuit Q factor at resonance as

$$Q = \frac{\omega_0 L}{R} \quad (7.3)$$

It's easy to show that the same voltage multiplication occurs across the capacitor

$$v_C = \frac{1}{j\omega_0 C} i = \frac{1}{j\omega_0 C} \frac{v_s}{Z(j\omega_0)} = \frac{1}{j\omega_0 C} \frac{v_s}{R} = -jQ \times v_s \quad (7.4)$$

This voltage multiplication property is the key feature of the circuit that allows it to be used as an impedance transformer.

It's important to distinguish this Q factor from the intrinsic Q of the inductor and capacitor. For now, we assume the inductor and capacitor are ideal. We can re-write the Q factor in several equivalent forms owing to the equality of the reactances at resonance

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 C} \frac{1}{R} = \frac{\sqrt{LC}}{C} \frac{1}{R} = \sqrt{\frac{L}{C}} \frac{1}{R} = \frac{Z_0}{R} \quad (7.5)$$

where we have defined the $Z_0 = \sqrt{\frac{L}{C}}$ as the characteristic impedance of the circuit.

Circuit Transfer Function

Let's now examine the transfer function of the circuit

$$H(j\omega) = \frac{v_o}{v_s} = \frac{R}{j\omega L + \frac{1}{j\omega C} + R} \quad (7.6)$$

$$H(j\omega) = \frac{j\omega RC}{1 - \omega^2 LC + j\omega RC} \quad (7.7)$$

Obviously, the circuit cannot conduct DC current, so there is a zero in the transfer function. The denominator is a quadratic polynomial. It's worthwhile to put it into a standard form that quickly reveals important circuit parameters

$$H(j\omega) = \frac{j\omega \frac{R}{L}}{\frac{1}{LC} + (j\omega)^2 + j\omega \frac{R}{L}} \quad (7.8)$$

Using the definition of Q and ω_0 for the circuit

$$H(j\omega) = \frac{j\omega \frac{\omega_0}{Q}}{\omega_0^2 + (j\omega)^2 + j\omega \frac{\omega_0}{Q}} \quad (7.9)$$

Factoring the denominator with the assumption that $Q > \frac{1}{2}$ gives us the complex poles of the circuit

$$s^\pm = -\frac{\omega_0}{2Q} \pm j\omega_0 \sqrt{1 - \frac{1}{4Q^2}} \quad (7.10)$$

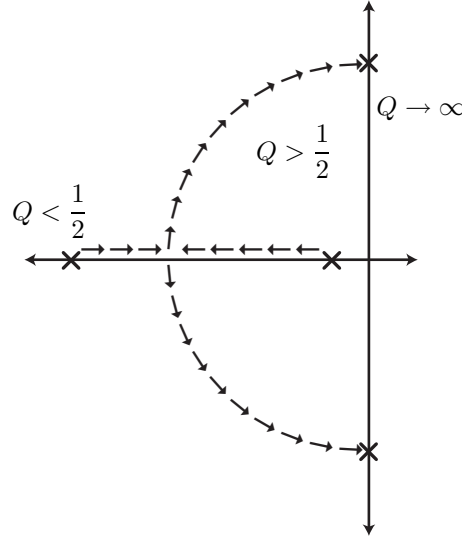


Figure 7.3: The root locus of the poles for a second-order transfer function as a function of Q . The poles begin on the real axis for $Q < \frac{1}{2}$ and become complex, tracing a semi-circle for increasing Q .

The poles have a constant magnitude equal to the resonant frequency

$$|s| = \sqrt{\frac{\omega_0^2}{4Q^2} + \omega_0^2 \left(1 - \frac{1}{4Q^2}\right)} = \omega_0 \quad (7.11)$$

A root-locus plot of the poles as a function of Q appears in Fig. 7.3. As $Q \rightarrow \infty$, the poles move to the imaginary axis. In fact, the real part of the poles is inversely related to the Q factor.

Circuit Bandwidth

As shown in Fig. 7.4, when we plot the magnitude of the transfer function, we see that the selectivity of the circuit is also related inversely to the Q factor. In the limit that $Q \rightarrow \infty$, the circuit is infinitely selective and only allows signals at resonance ω_0 to travel to the load. Note that the peak gain in the circuit is always unity, regardless of Q , since at resonance the L and C together disappear and effectively all the source voltage appears across the load.

The selectivity of the circuit lends itself well to filter applications (Sec. 7.5). To characterize the peakiness, let's compute the frequency when the magnitude squared of the transfer

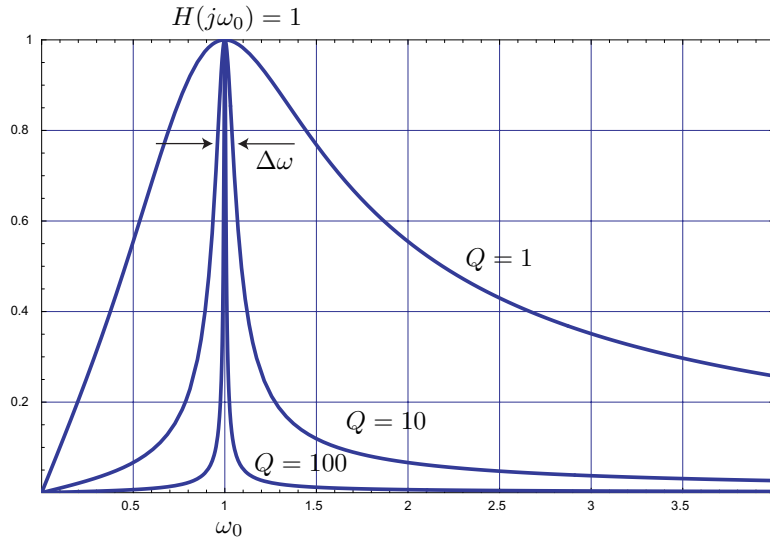


Figure 7.4: The transfer function of a series RLC circuit. The output voltage is taken at the resistor terminals. Increasing Q leads to a more peaky response.

function drops by half

$$|H(j\omega)|^2 = \frac{\left(\omega \frac{\omega_0}{Q}\right)^2}{(\omega_0^2 - \omega^2)^2 + \left(\omega \frac{\omega_0}{Q}\right)^2} = \frac{1}{2} \quad (7.12)$$

This happens when

$$\left(\frac{\omega_0^2 - \omega^2}{\omega_0 \omega / Q}\right)^2 = 1 \quad (7.13)$$

Solving the above equation yields four solutions, corresponding to two positive and two negative frequencies. The peakiness is characterized by the difference between these frequencies, or the bandwidth, given by

$$\Delta\omega = \omega_+ - \omega_- = \frac{\omega_0}{Q} \quad (7.14)$$

which shows that the normalized bandwidth is inversely proportional to the circuit Q

$$\frac{\Delta\omega}{\omega_0} = \frac{1}{Q} \quad (7.15)$$

You can also show that the resonance frequency is the geometric mean frequency of the 3 dB frequencies

$$\omega_0 = \sqrt{\omega_+ \omega_-} \quad (7.16)$$

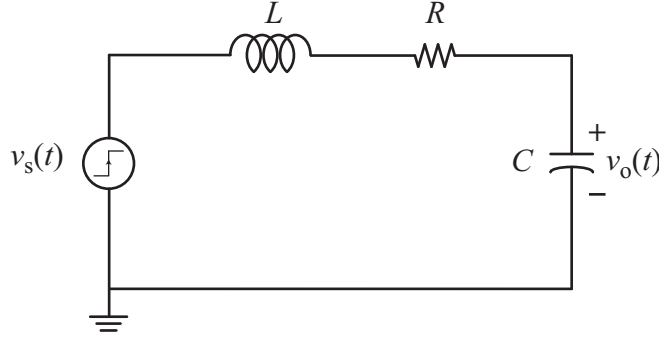


Figure 7.5: A step function applied to a series RLC circuit with output taken across the capacitor.

Circuit Damping Factor

So far we have characterized the second order series RLC circuit by its frequency response, leading to the concept of the resonant frequency ω_0 and quality factor Q . An equivalent characterization involves the time domain response, particularly the step response of the circuit. This shall lead to the concept of the damping factor. As shown in Fig. 7.5, we shall now consider the output as the voltage across the capacitor. This corresponds to the common situation in digital circuits, where the “load” is a capacitive reactance of a gate.

First let’s recall the familiar step response of an RC circuit, or the limit as $L \rightarrow 0$ in the series RLC circuit, the circuit response to a step function is a rising exponential function that asymptotes towards the source voltage with a time scale $\tau = 1/RC$.

When the circuit has inductance, it’s described by a second order differential equation. Applying KVL we can write an equation for the voltage $v_C(t)$

$$v_s(t) = v_C(t) + RC \frac{dv_C}{dt} + LC \frac{d^2 v_C}{dt^2} \quad (7.17)$$

with initial conditions

$$v_0(t) = v_C(t) = 0V \quad (7.18)$$

and

$$i(0) = i_L(0) = 0A \quad (7.19)$$

For $t > 0$, the source voltage switches to V_{dd} . Thus Eq. 7.17 has a constant source for $t > 0$

$$V_{dd} = v_C(t) + RC \frac{dv_C}{dt} + LC \frac{d^2 v_C}{dt^2} \quad (7.20)$$

In steady-state, $\frac{d}{dt} \rightarrow 0$, leading to

$$V_{dd} = v_C(\infty) \quad (7.21)$$

which implies that the entire voltage of the source appears across the capacitor, driving the current in the circuit to zero. Subtracting this steady-state voltage from the solution, we can simplify our differential equation

$$v_C(t) = V_{dd} + v(t) \quad (7.22)$$

$$V_{dd} = V_{dd} + v(t) + RC \frac{dv}{dt} + LC \frac{d^2v}{dt^2} \quad (7.23)$$

or more simply, the homogeneous equation

$$0 = v(t) + RC \frac{dv}{dt} + LC \frac{d^2v}{dt^2} \quad (7.24)$$

The solution of which is nothing but a complex exponential $v(t) = Ae^{st}$, leading to the characteristic equation

$$0 = 1 + RCs + LCs^2 = 1 + (s\tau)2\zeta + (s\tau)^2 \quad (7.25)$$

where we have defined

$$\tau = \frac{1}{\omega_0} \quad (7.26)$$

and

$$\zeta = \frac{1}{2Q} \quad (7.27)$$

which has solutions

$$s\tau = -\zeta \pm \sqrt{\zeta^2 - 1} \quad (7.28)$$

This equation can be characterized by the value ζ , leading to the following three important cases

$$\begin{aligned} \zeta < 1 & \text{ Underdamped} \\ \zeta = 1 & \text{ Critically Damped} \\ \zeta > 1 & \text{ Overdamped} \end{aligned} \quad (7.29)$$

The terminology “damped” will become obvious momentarily. When we plot the general time-domain solution, we have

$$v_C(t) = V_{dd} + A \exp(s_1 t) + B \exp(s_2 t) \quad (7.30)$$

which must satisfy the following boundary conditions

$$v_C(0) = V_{dd} + A + B = 0 \quad (7.31)$$

and

$$i(0) = C \frac{dv_C(t)}{dt} \Big|_{t=0} = 0 \quad (7.32)$$

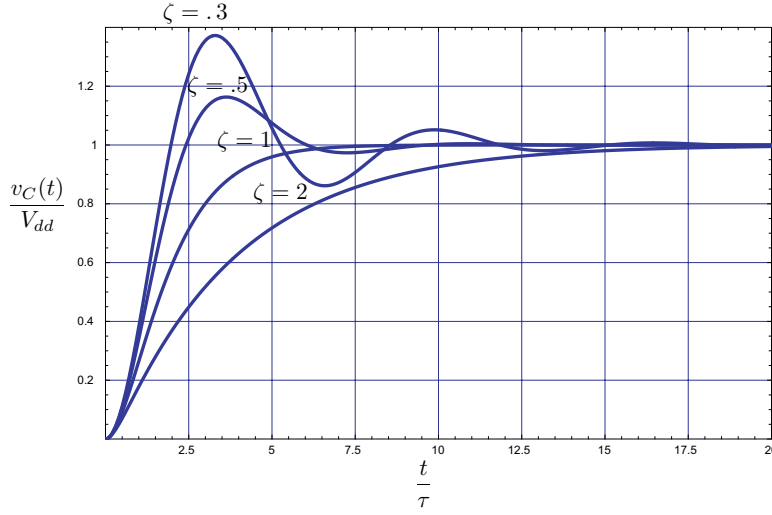


Figure 7.6: The normalized step response of an RLC circuit. The damping factor ζ is varied to cover three important regions, an overdamped response with $\zeta > 1$, a critically damped response with $\zeta = 1$, and an underdamped response with $\zeta < 1$.

or the following set of equations

$$As_1 + Bs_2 = 0 \quad (7.33)$$

$$A + B = -V_{dd} \quad (7.34)$$

which has the following solution

$$A = \frac{-V_{dd}}{1 - \sigma} \quad (7.35)$$

$$B = \frac{\sigma V_{dd}}{1 - \sigma} \quad (7.36)$$

where $\sigma = \frac{s_1}{s_2}$. So we have the following equation

$$v_C(t) = V_{dd} \left(1 - \frac{1}{1 - \sigma} (e^{s_1 t} - \sigma e^{s_2 t}) \right) \quad (7.37)$$

If the circuit is overdamped, $\zeta > 1$, the poles are real and negative

$$s = \frac{1}{\tau} (-\zeta \pm \sqrt{\zeta^2 - 1}) = \begin{cases} s_1 \\ s_2 \end{cases} < 0 \quad (7.38)$$

The normalized response, with $\zeta = 2, 1, 0.5, 0.3$, is shown in Fig. 7.6. Qualitatively we see that the $\zeta = 2$ circuit response resembles the familiar RC circuit. This is true until

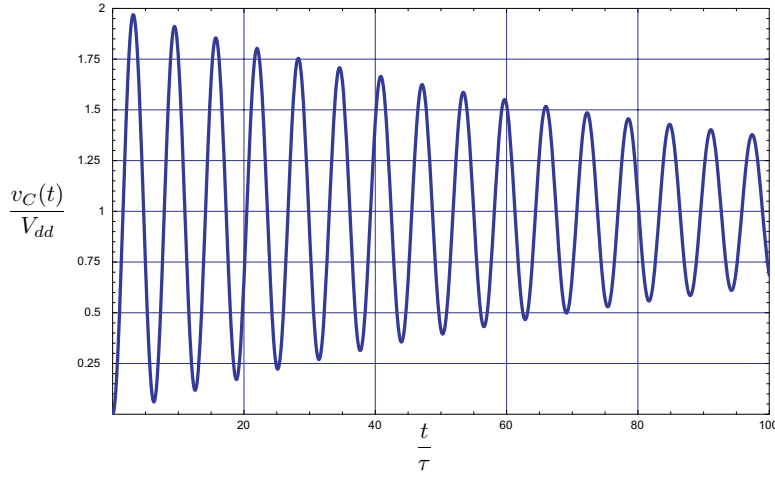


Figure 7.7: The step response of an RLC circuit with low damping ($\zeta = .01$).

$\zeta = 1$, at which point the circuit is said to be *critically damped*. The circuit has two equal poles at

$$s = \frac{1}{\tau}(-\zeta \pm \sqrt{\zeta^2 - 1}) = -\frac{1}{\tau} \quad (7.39)$$

In which case the time response is given by

$$\lim_{\zeta \rightarrow 1} v_C(t) = V_{dd} \left(1 - e^{-t/\tau} - \frac{t}{\tau} e^{-t/\tau} \right) \quad (7.40)$$

As seen in Fig. 7.6, the circuit step response is faster with increasing $\zeta \leq 1$, but still similar to the RC circuit. The *underdamped* case, $\zeta < 1$, is the most interesting case here, as the response is now markedly different. The circuit *overshoots* the mark and settles down to the steady-state value after oscillating. The amount of oscillation increases as the damping factor ζ is reduced. The response with very low damping, $\zeta = .01$ is shown in Fig. 7.7.

The underdamped case is characterized by two complex conjugate poles

$$s\tau = -\zeta \pm j\sqrt{1 - \zeta^2} = a \pm jb \quad (7.41)$$

Note the complex conjugate of the A coefficient is simply

$$A^* = \frac{-V_{dd}}{1 - \sigma^*} = \frac{V_{dd}}{\sigma^{-1} - 1} = \frac{\sigma V_{dd}}{1 - \sigma} = B \quad (7.42)$$

which allows us to write the voltage across the capacitor as

$$v_C(t) = V_{dd} + e^{at/\tau} (Ae^{jbt\tau} + A^*e^{-jbt\tau}) \quad (7.43)$$

or more simply

$$v_C(t) = V_{dd} + e^{at/\tau} 2|A| \cos(\omega t + \phi) \quad (7.44)$$

where

$$|A| = \frac{V_{dd}}{|1 + \sigma|} \quad (7.45)$$

and

$$\phi = \angle \frac{V_{dd}}{1 + \sigma} \quad (7.46)$$

The oscillating frequency is determined by the imaginary part of the poles, $\omega = b/\tau = \omega_0 \sqrt{1 - \zeta^2}$, which approaches the natural resonance frequency as the damping is reduced. The decay per period, or the envelope damping of the waveform, is determined by a , which equals $\zeta\omega_0$. This is why the damping factor controls the amount of overshoot and oscillation in the waveform.

Energy Storage in *RLC* “Tank”

Let’s compute the ebb and flow of the energy at resonance. To begin, let’s assume that there is negligible loss in the circuit. The energy across the inductor is given by

$$w_L = \frac{1}{2} L i^2(t) = \frac{1}{2} L I_M^2 \cos^2 \omega_0 t \quad (7.47)$$

Likewise, the energy stored in the capacitor is given by

$$w_C = \frac{1}{2} C v_C^2(t) = \frac{1}{2} C \left(\frac{1}{C} \int i(\tau) d\tau \right)^2 \quad (7.48)$$

Performing the integral leads to

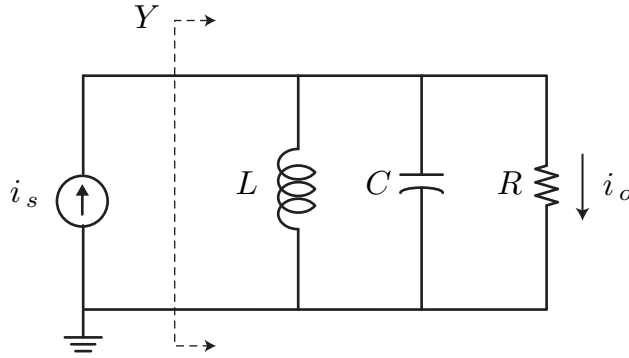
$$w_C = \frac{1}{2} \frac{I_M^2}{\omega_0^2 C} \sin^2 \omega_0 t \quad (7.49)$$

The total energy *stored* in the circuit is the sum of these terms

$$w_s = w_L + w_C = \frac{1}{2} I_M^2 \left(L \cos^2 \omega_0 t + \frac{1}{\omega_0^2 C} \sin^2 \omega_0 t \right) = \frac{1}{2} I_M^2 L \quad (7.50)$$

which is a constant! This means that the reactive stored energy in the circuit does not change and simply moves between capacitive energy and inductive energy. When the current is maximum across the inductor, all the energy is in fact stored in the inductor

$$w_{L,\max} = w_s = \frac{1}{2} I_M^2 L \quad (7.51)$$

Figure 7.8: A parallel RLC circuit.

Likewise, the peak energy in the capacitor occurs when the current in the circuit drops to zero

$$w_{C,\max} = w_s = \frac{1}{2} V_M^2 C \quad (7.52)$$

Now let's re-introduce loss in the circuit. In each cycle, a resistor R will dissipate energy

$$w_d = P \cdot T = \frac{1}{2} I_M^2 R \cdot \frac{2\pi}{\omega_0} \quad (7.53)$$

The ratio of the energy stored to the energy dissipated is thus

$$\frac{w_s}{w_d} = \frac{\frac{1}{2} L I_M^2}{\frac{1}{2} I_M^2 R \frac{2\pi}{\omega_0}} = \frac{\omega_0 L}{R} \frac{1}{2\pi} = \frac{Q}{2\pi} \quad (7.54)$$

This gives us the physical interpretation of the *Quality Factor* Q as 2π times the ratio of energy stored per cycle to energy dissipated per cycle in an RLC circuit

$$Q = 2\pi \frac{w_s}{w_d} \quad (7.55)$$

We can now see that if $Q \gg 1$, then an initial energy in the tank tends to slosh back and forth for many cycles. In fact, we can see that in roughly Q cycles, the energy of the tank is depleted.

Parallel RLC Circuits

The parallel RLC circuit shown in Fig. 7.8 is the dual of the series circuit. By “dual” we mean that the role of voltage and current are interchanged. Hence the circuit is most naturally probed with a current source i_s . In other words, the circuit has current gain as opposed to voltage gain, and the admittance minimizes at resonance as opposed to the impedance.

Finally, the role of capacitance and inductance are also interchanged. In principle, therefore, we don't have to repeat all the detailed calculations we just performed for the series case, but in practice it's worthwhile exercise.

The admittance of the circuit is given by

$$Y = j\omega C + \frac{1}{j\omega L} + G = G + j\omega C \left(1 - \frac{1}{\omega^2 LC}\right) \quad (7.56)$$

which has the same form as Eq. 7.1. The resonant frequency also occurs when $\Im(Y) = 0$, or when $\omega = \omega_0 = \pm \frac{1}{\sqrt{LC}}$. Likewise, at resonance the admittance takes on a minimal value. Equivalently, the impedance at resonance is maximum. This property makes the parallel *RLC* circuit an important element in tuned amplifier loads (see Sec. 8). It's also easy to show that at resonance the circuit has a current gain of Q

$$i_C = j\omega_0 C v_o = j\omega_0 C \frac{i_s}{Y(j\omega_0)} = j\omega_0 C \frac{i_s}{G} = jQ \times i_s \quad (7.57)$$

where we have defined the circuit Q factor at resonance by

$$Q = \frac{\omega_0 C}{G} \quad (7.58)$$

in complete analogy with Eq. 7.3. Likewise, the current gain through the inductor is also easily derived

$$i_L = -jQ \times i_s \quad (7.59)$$

The equivalent expressions for the circuit Q factor are given by the inverse of the relations of Eq. 7.5

$$Q = \frac{\omega_0 C}{G} = \frac{R}{\omega_0 L} = \frac{R}{\frac{1}{\sqrt{LC}} L} = \frac{R}{\sqrt{\frac{L}{C}}} = \frac{R}{Z_0} \quad (7.60)$$

The phase response of a resonant circuit is also related to the Q factor. For the parallel *RLC* circuit the phase of the admittance is given by

$$\angle Y(j\omega) = \tan^{-1} \left(\frac{\omega C \left(1 - \frac{1}{\omega^2 LC}\right)}{G} \right) \quad (7.61)$$

The rate of change of phase at resonance is given by

$$\left. \frac{d\angle Y(j\omega)}{d\omega} \right|_{\omega_0} = \frac{2Q}{\omega_0} \quad (7.62)$$

A plot of the admittance phase as a function of frequency and Q is shown in Fig. 7.9.

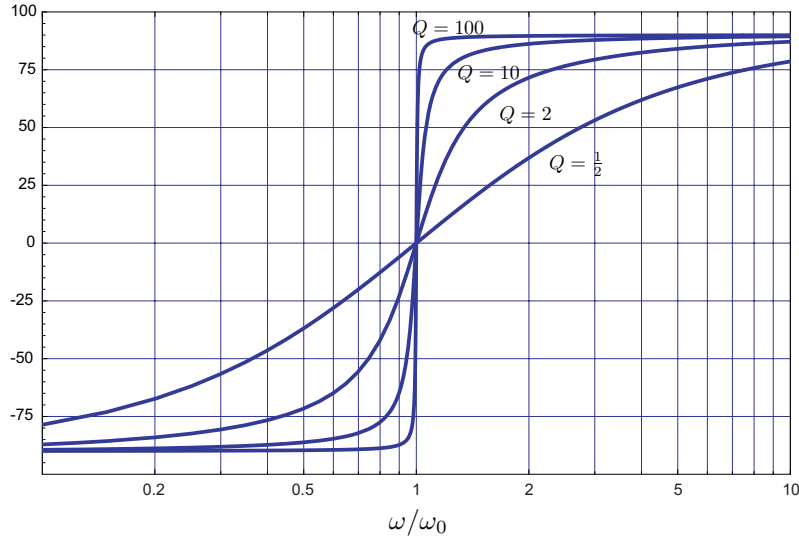


Figure 7.9: The phase of a second order admittance as function of frequency. The rate of change of phase at resonance is proportional to the Q factor.

Circuit Transfer Function

Given the duality of the series and parallel RLC circuits, it's easy to deduce the behavior of the circuit. Whereas the series RLC circuit acted as a filter and was only sensitive to voltages near resonance ω_0 , likewise the parallel RLC circuit is only sensitive to currents near resonance

$$H(j\omega) = \frac{i_o}{i_s} = \frac{v_o G}{v_o Y(j\omega)} = \frac{G}{j\omega C + \frac{1}{j\omega L} + G} \quad (7.63)$$

which can be put into the same canonical form as before

$$H(j\omega) = \frac{j\omega \frac{\omega_0}{Q}}{\omega_0^2 + (j\omega)^2 + j\frac{\omega\omega_0}{Q}} \quad (7.64)$$

where we have appropriately re-defined the circuit Q to correspond the parallel RLC circuit. Notice that the impedance of the circuit takes on the same form

$$Z(j\omega) = \frac{1}{Y(j\omega)} = \frac{1}{j\omega C + \frac{1}{j\omega L} + G} \quad (7.65)$$

which can be simplified to

$$Z(j\omega) = \frac{j\frac{\omega}{\omega_0} \frac{1}{GQ}}{1 + \left(\frac{j\omega}{\omega_0}\right)^2 + j\frac{\omega}{\omega_0 Q}} \quad (7.66)$$

At resonance, the real terms in the denominator cancel

$$Z(j\omega_0) = \frac{j\frac{R}{Q}}{\underbrace{1 + \left(\frac{j\omega_0}{\omega_0}\right)^2}_{=0} + j\frac{1}{Q}} = R \quad (7.67)$$

It's not hard to see that this circuit has the same half power bandwidth as the series RLC circuit, since the denominator has the same functional form

$$\frac{\Delta\omega}{\omega_0} = \frac{1}{Q} \quad (7.68)$$

A plot of this impedance versus frequency has the same form as Fig. 7.4 multiplied by the resistance R .

Energy storage in a parallel RLC circuit is completely analogous to the series RLC case and in fact the general equation relating circuit Q to energy storage and dissipation also holds in the parallel RLC circuit.

7.2 The Many Faces of Q

As we have seen, in RLC circuits the most important parameter is the circuit Q and resonance frequency ω_0 . Not only do these parameters describe the circuit in a general way, but they also give us immediate insight into the circuit behavior.

The Q factor can be computed several ways, depending on the application. For instance, if the circuit is designed as a filter, then the most important Q relation is the half-power bandwidth

$$Q = \frac{\omega_0}{\Delta\omega} \quad (7.69)$$

We shall also find many applications where the phase selectivity of these circuits is of importance. An example is a resonant oscillator where the noise of the system is rejected by the tank based on the phase selectivity. In an oscillator any “excess phase” in the loop tends to move the oscillator away from the natural resonant frequency. It is therefore desirable to maximize the rate of change of phase of the circuit impedance as a function of frequency. For the parallel RLC circuit we derived the phase of the admittance (Eq. 7.62) which gives us another way to interpret and compute Q

$$Q = \frac{\omega_0}{2} \frac{d\angle Y(j\omega)}{d\omega} \quad (7.70)$$

For applications where the circuit is used as a voltage or current multiplier, the ratio of reactive voltage (current) to real voltage (current) is most relevant. As we shall see, in

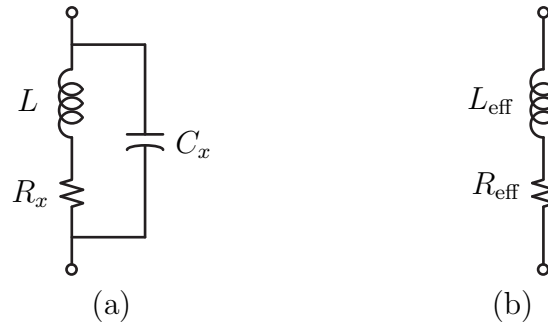


Figure 7.10: (a) A simple model for an inductor with winding capacitance C_x and winding resistance R_x . (b) A simplified equivalent circuit for the non-ideal inductor model.

RFID systems (Sec. 10.10) this is an important application of the circuit. For a series case we found

$$Q = \frac{v_L}{v_R} = \frac{v_C}{v_R} \quad (7.71)$$

and for the parallel case

$$Q = \frac{i_L}{i_R} = \frac{i_C}{i_R} \quad (7.72)$$

Finally, when the step response or time domain transient response is of interest, the circuit Q or equivalently, the damping factor ζ , describes the behavior of the circuit, with $\zeta = 1$ the boundary between damped behavior and under-damped oscillatory response.

The last and one of the most important interpretations of Q is in the definition of energy, relating the energy storage and losses in a RLC “tank” circuit. We can define the of Q a circuit at frequency ω as the energy stored in the tank W divided by the rate of energy loss

$$Q = W / \frac{dW}{d\phi} = \omega W / \frac{dW}{dt}$$

Practical Issues with Resonators

Inductor Equivalent Circuit

The previous discussion was oversimplified since any real RLC circuit will consists of non-ideal and lossy L ’s and C ’s. For example, consider the simple equivalent circuit for the inductor shown in Fig. 7.10a, where C_x accounts for the winding capacitance and R_x is the series winding resistance. This simple model is sufficiently accurate over a narrow range of frequencies for inductors realized on non-lossy substrates or an air coil inductor. In many situations we’d like to model the inductor as an equivalent ideal inductor with series loss, as shown in Fig. 7.10b. This is done by simply equating the impedance at a given frequency

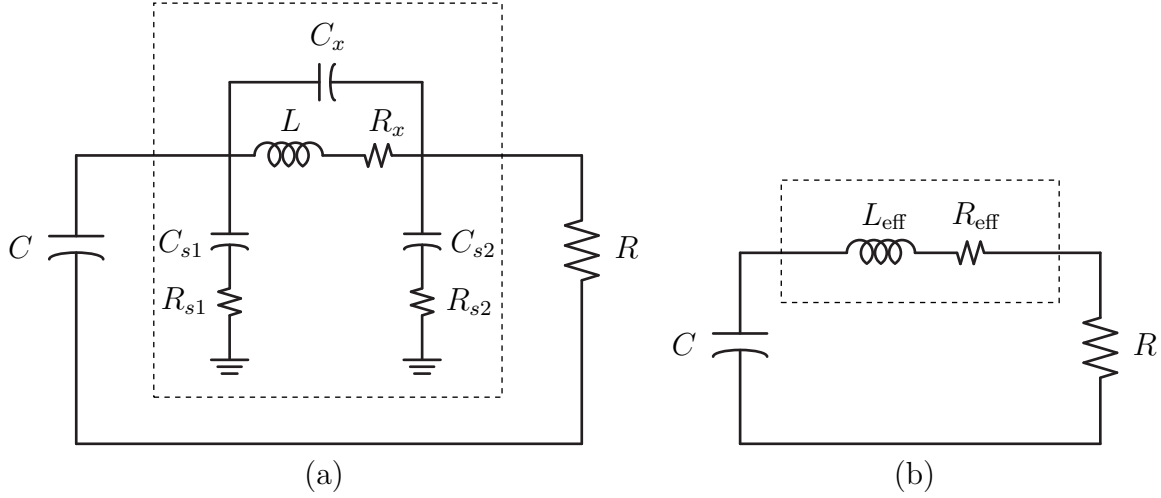


Figure 7.11: (a) A series RLC circuit containing a non-ideal inductor L . (b) A simplified equivalent circuit for the series RLC circuit.

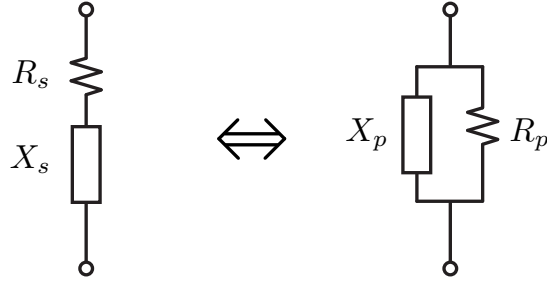
resulting in

$$R_{\text{eff}} \approx R \left(1 + \left(\frac{\omega}{\omega_0} \right)^2 \right) \quad (7.73)$$

$$L_{\text{eff}} \approx L \left(1 + \left(\frac{\omega}{\omega_0} \right)^2 \right) \quad (7.74)$$

The above approximation holds when the circuit is operated far below the inductor self-resonant frequency (SRF) $\omega \ll \omega_0$. Note that the second time constant in the circuit RC is at an even higher frequency than the resonant frequency for $Q > 1$.

For more complex structures, such as inductor modeled on a lossy substrate such as silicon, one approach is to simply model each element with an equivalent circuit, as shown in Fig. 7.11a. Here we assume that the capacitor and resistor are nearly ideal but the inductor has parasitic capacitance and resistance, modeling the self-resonance and the conductor and substrate losses. Analyzing such a circuit is trivial but messy, leading to higher order equations containing many poles/zeros and it's unlikely to give us insight into the circuit behavior. An alternative approach to observe that no matter how complicated the inductor model, at a fixed frequency below the component resonance frequency, the net impedance of the inductor can be represented as $Z_L = R_{\text{eff}} + j\omega L_{\text{eff}}$. While this is obviously true, we will derive some simple formulas for quickly deriving this equivalent impedance from a complicated circuit model.

Figure 7.12: A series to parallel transformation for an arbitrary impedance Z .

Shunt-Series Transformation

The key calculation aid is the series to parallel transformation. Consider the impedance shown in Fig. 7.12, which we wish to represent as a parallel impedance. We can do this at a single frequency as long as the impedance of the series network equals the impedance of the shunt network

$$R_s + jX_s = \frac{1}{\frac{1}{R_p} + \frac{1}{jX_p}} \quad (7.75)$$

Equating the real and imaginary parts

$$R_s = \frac{R_p X_p^2}{R_p^2 + X_p^2} \quad (7.76)$$

$$X_s = \frac{R_p^2 X_p}{R_p^2 + X_p^2} \quad (7.77)$$

which can be simplified by using the definition of Q

$$Q_s = \frac{X_s}{R_s} = \frac{R_p^2 X_p}{R_p X_p^2} = \frac{R_p}{X_p} = Q_p = Q \quad (7.78)$$

which shows that

$$R_p = R_s(1 + Q^2) \quad (7.79)$$

and

$$X_p = X_s(1 + Q^{-2}) \approx X_s \quad (7.80)$$

where the approximation applies under high Q conditions.

Simplifying Practical *RLC* Resonators

The simplified *RLC* circuit appears in Fig. 7.11b, which has the same equivalent form as a second-order *RLC* circuit. Here the effective inductance L_{eff} of the circuit is different from L . If the circuit is operated far below the SRF of the inductor, then $L_{\text{eff}} \approx L$. The loss in the circuit now includes the effective series resistance and equivalent shunt substrate losses of the inductor. Again, at frequencies far below the SRF of the inductor, the resistance is dominated by the conductive loss of the inductor winding. We can thus conclude that for a practical *RLC* circuit employing non-ideal *RLC* elements, we can treat the circuit as a simple series *RLC* if all elements are used below their self-resonant frequency and represented as equivalent series impedances. The self-resonant frequency of the circuit is then determined by the net capacitance and inductance in the loop, and the Q factor is determined by the total series resistance in the loop. For this reason, series *RLC* circuits are sensitive to any series resistance in the circuit and the layout must be done properly in order to minimize any contact or interconnect resistance.

It is thus clear that the circuit Q is necessarily lower than the component Q_x , where Q_x is defined in the “series” sense. If the net impedance of a component is $Z = R + jX$, then

$$Q_x = \frac{X}{R} \quad (7.81)$$

At resonance the circuit Q is given by

$$Q = \frac{X'}{R + R_{x,L} + R_{x,C}} \quad (7.82)$$

where X' is the net capacitive reactance at resonance and $R_{x,L|C}$ represent the series losses in the reactive components. Given that typically $X' \approx X$, we can re-write the above as

$$\frac{1}{Q} \approx \frac{R + R_{x,1} + R_{x,2}}{X} = \frac{1}{Q_{id}} + \frac{1}{Q_L} + \frac{1}{Q_C} \quad (7.83)$$

where Q_{id} is the Q of the circuit using “ideal” components. This means that the circuit Q is approximately the parallel combination of the Q ’s

$$Q = Q_{id} || Q_L || Q_C < Q_{id} \quad (7.84)$$

Example 11:

Design a series *RLC* circuit with $R = 5\Omega$, using an inductor with $L = 5$ nH and component $Q_L = 30$ and a capacitor with component $Q_C = 200$ to resonate at 1 GHz.

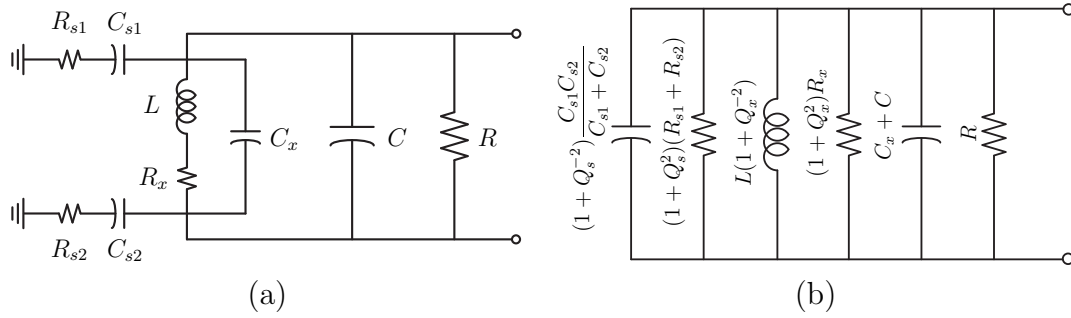


Figure 7.13: (a) A parallel RLC circuit containing a non-ideal inductor L . (b) A simplified equivalent circuit for the parallel RLC circuit.

We begin by calculating the equivalent series resistance of each component.

$$R_{x,L} = \frac{X_L}{Q_L} = \frac{31.416}{30} \approx 1.05\Omega$$

$$R_{x,C} = \frac{X_C}{Q_C} = \frac{31.416}{200} \approx 0.16\Omega$$

The total series resistance of the circuit is thus $R_T = 6.21\Omega$, resulting in a net $Q = 5$. In comparison, the unloaded $Q = 6.3$.

The exact same considerations apply for a parallel RLC circuit with the exception that now *shunt* parasitics de- Q the circuit. To see this, consider a non-ideal RLC circuit shown in Fig. 7.13. Now we convert each non-ideal element into an ideal admittance $Y = G_x + jB'$. The net conductance of the circuit is given by

$$G_T = G_{x,L} + G_{x,C} + G \quad (7.85)$$

The resulting equivalent circuit is shown in Fig. 7.13. For operation below the SRF of the components, therefore, Eq. 7.84 applies.

LC Tanks

In many applications, such as oscillators, we use an LC tank as a frequency reference. In an oscillator, for instance, the frequency of oscillation is determined by the frequency where the phase shift through the loop is a 0° (any multiple of 2π). As the phase selectivity of an RLC tank is determined by the Q , we maximize the “tank” Q by using the highest quality



Figure 7.14: (a) An LC tank layout employing a ring inductor and two series connected MIM capacitors. (b) An inferior LC tank layout due to extra lead inductance and loss.

inductance and capacitance available. Furthermore, we eliminate or minimize the loading resistance so we omit R to obtain an LC tank. Any residual R in the parallel RLC tank is due to losses (component Q_c) or unwanted loading.

The tank impedance at resonance is therefore real and only limited by the realizable quality factor Q

$$Z(\omega_0) = R_p = \omega_0 L \times Q \quad (7.86)$$

The layout of an integrated LC tank circuit appears in Fig. 7.14a. In the layout of the LC tank in an IC environment, it's often easy to forget that every wire interconnect adds resistance and potentially couples to the substrate and thus it can de- Q the circuit. Here a small ring inductor resonates with MIM capacitors. An electric ground shield surrounds the ring without forming a closed loop. Notice that the MIM capacitors are placed directly underneath the leads of the inductor. The measured impedance of this structure is shown in Fig. 7.15. As expected, the circuit behaves as an LC circuit with the ring inductor losses dominating the Q . Despite the high frequency resonance of 56 GHz, the ring tank behaves extraordinarily like a simple lumped LC circuit. This follows because the dimensions of the structure are much smaller than wavelength over the operating range.

It's important to note that the layout of Fig. 7.14b is sub-optimal (but commonly used) as it adds unnecessary lead inductance and resistance to the parallel tank. Every effort should be made in the layout to put the capacitor leads as close to the inductor leads to minimize losses.

Notice that the layout in Fig. 7.14a uses two series MIM capacitors. This is done for two important reasons. Even though the net capacitance is the same as a single capacitor of half the size, larger capacitors have better matching and are more accurate. Furthermore, due to the differential excitation, the capacitor common node is not excited and acts as an AC ground. This is beneficial since the bottom plate is closer to the substrate and thus is

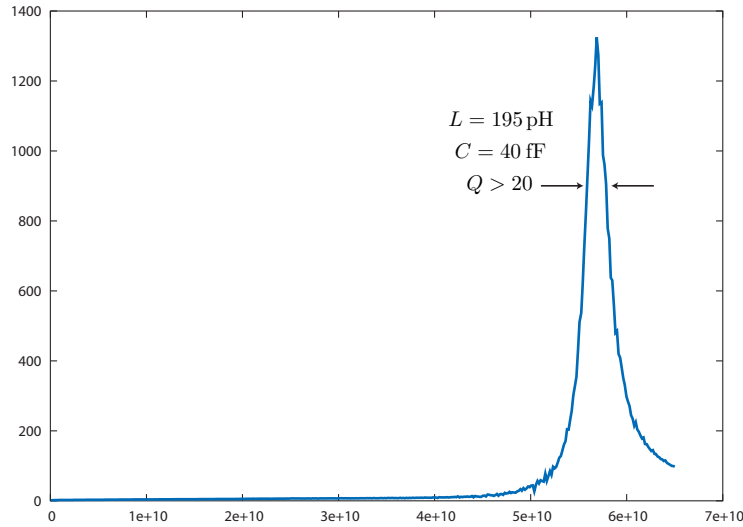
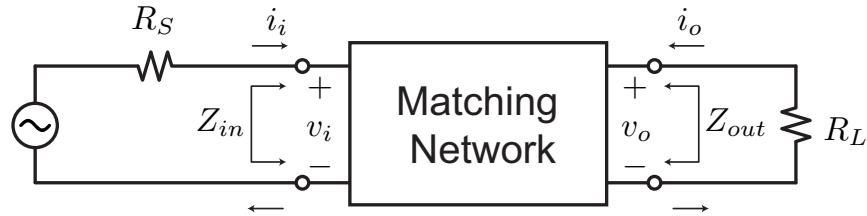
Figure 7.15: The on-chip measured LC tank impedance.

Figure 7.16: A generic matching network as a black box.

a lossier node.

7.3 Impedance Matching

In the words of one experienced designer, “RF design is all about impedance matching.” In this section we’d like to show how inductors and capacitors are handy elements at impedance matching. Viewed as a black-box shown in Fig. 7.16, an impedance matcher changes a given load resistance R_L to a source resistance R_S . Without loss of generality, assume $R_S > R_L$, and a power match factor of $m = R_S/R_L$ is desired. In fact any matching network that boosts the resistance by some factor can be flipped over to do the opposite matching.

Since $R_L = v_o/i_o$ and $R_S = v_i/i_i$, we can see that this transformation can be achieved by a voltage gain, $v_i = kv_o$. Assuming the black box is realized with passive elements without

memory, power conservation implies

$$i_i v_i = i_o v_o \quad (7.87)$$

thus the current must drop by the same factor, $i_i = k^{-1}i_o$, resulting in

$$Z_{in} = \frac{v_i}{i_i} = \frac{k v_o}{k^{-1} i_o} = k^2 \frac{v_o}{i_o} = k^2 R_L \quad (7.88)$$

which means that $k = \sqrt{m}$ to achieve an impedance match. There are many ways to realize such a circuit block and in this section we'll explore techniques employing inductors and capacitors. In Ch. 10 we'll explore transformer based impedance matching.

Why Play the Matchmaker?

Optimal Power Transfer

Perhaps the most important reason for matching is to maximize the power transfer from a source to a load. Recall that the maximum power available from a fixed voltage source with impedance Z_S is obtained when the load is the complex conjugate impedance, or $Z_L = Z_S^*$. To see that such an optimum impedance must exist notice that the power delivered is zero when an open or short is attached to the source and non-zero for any practical value of the load. By continuity we can see that the curve of P_L has a maximum.

Optimal Noise Figure

There are other reasons to match impedances and we'll mention them in passing. Another important case is to minimize the noise figure of an amplifier driven for a given source impedance. It can be shown that the noise figure of a two-port (e.g. a single transistor or a multi-stage amplifier) takes on the following general form

$$F = F_{min} + \frac{R_n}{G_g} |Y_s - Y_{s,opt}|^2 \quad (7.89)$$

The parameters R_n , G_g , and $Y_{s,opt}$ are properties of the amplifier at a particular bias point. The noise figure is thus minimized when the source impedance equal to $Y_{s,opt}$. So another function for a matching network is to perform this transformation. In fact, in a modern integrated circuit one has control over the physical dimension of the transistor and thus one can size a transistor appropriately so that a noise match corresponds to an optimal power gain match.

Minimum Reflections in Transmission Lines

Another important reason for impedance matching will become evident when we study switching transients on a transmission line (Ch. 12). Here impedance matching is more commonly known as “terminating” a transmission line. Without a proper termination, reflections can lead to inter-symbol interference. A practical example is a ghost of a television screen caused by reflections off the antenna and television amplifier. These reflections travel back and forth on the feed-line and produce weak secondary copies of the signals, which appear as ghosts on the screen.

Optimal Efficiency

Power amplifiers present more reasons to match impedances. In particular, while an impedance match results in maximum power transfer, an entirely different impedance is needed to achieve *optimal efficiency*. To see this observe that the drain efficiency of an amplifier can be written as

$$\eta = \frac{P_L}{P_{dc}} = \frac{\frac{1}{2}v_o i_o}{I_Q V_{sup}} \quad (7.90)$$

where I_Q is the average current drawn from the supply voltage V_{sup} over one cycle and v_o and i_o are the output voltage and current swings in the amplifier. Re-writing the above equation into normalized form

$$\eta = \frac{1}{2} \hat{I} \hat{V} \quad (7.91)$$

where $\hat{I} = i_o/I_Q$ is the normalized current swing and $\hat{V} = v_o/V_{sup}$ is the normalized voltage swing. By conservation of energy $\hat{I} \times \hat{V} \leq 2$. For a tuned amplifier, $\hat{V} \leq 1$ and $\hat{I} \leq 2$. Once these values have been specified to achieve a certain efficiency, the value of the load impedance is fixed by the ratio

$$R_{L,opt} = \frac{v_o}{i_o} = \frac{\hat{V}}{\hat{I}} \times \frac{V_{sup}}{I_Q} \quad (7.92)$$

Let's do an example. Say we'd like to deliver 1 W of power in a modern CMOS process with $V_{sup} < 2$ V (due to breakdown). Since the maximum voltage swing cannot exceed the supply ($\hat{V} \leq 1$), the required current swing is found from the required output power

$$\frac{1}{2} i_o v_o = P_L \quad (7.93)$$

or $i_o \geq 2P_L/V_{sup}$, which works out to $i_o \geq 1$ A. The optimal load impedance is thus as low as $2V/1A = 2 \Omega$, a very small resistance. The load in most communication systems is the the system impedance Z_0 , usually $Z_0 = 50\Omega$ (RF) or 75Ω (video), or even a higher impedance. Clearly an impedance matching network is needed to to convert the load impedance Z_0 to 2Ω to achieve the required output power and optimal efficiency.

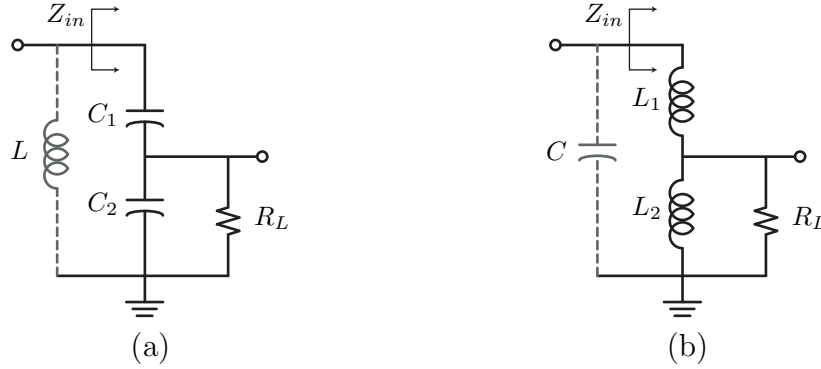


Figure 7.17: (a) A tapped capacitive divider impedance transformer. (b) A tapped inductor impedance transformer. The reactance in the structure can be resonated with an appropriate elements (shown in dashed line).

Capacitive and Inductive Dividers

Perhaps the simplest matching networks are simple voltage dividers. Consider the capacitive voltage divider shown in Fig. 7.17a. At RF frequencies, if $R_L \gg X_2$, then we can see that the circuit will work as advertised. Assuming that negligible current flows into R_L , the current flowing into the capacitors is given by

$$i = \frac{v_i}{j(X_1 + X_2)} \quad (7.94)$$

the voltage across the is therefore

$$v_o = v_{C_2} = jX_2 \times i = v_i \frac{X_2}{X_1 + X_2} = v_i \frac{1}{1 + \frac{C_2}{C_1}} = kv_i \quad (7.95)$$

which means that the load resistance is boosted by a factor of k^2

$$R_{in} \approx \left(1 + \frac{C_2}{C_1}\right)^2 R_L \quad (7.96)$$

We can arrive at the same destination by using the shunt $\leftrightarrow$ series transformation twice. The final value of R_{in} is given by a $1 + Q_2^2$ reduction following by a $1 + Q_s^2$ enhancement

$$R_{in} = \frac{1 + Q_s^2}{1 + Q_2^2} R_L \quad (7.97)$$

where $Q_2 = \frac{R_L}{X_2}$, $X_s = X_1 || X'_2$, and

$$Q_s = \frac{X_s}{R_L} (1 + Q_2^2) \quad (7.98)$$

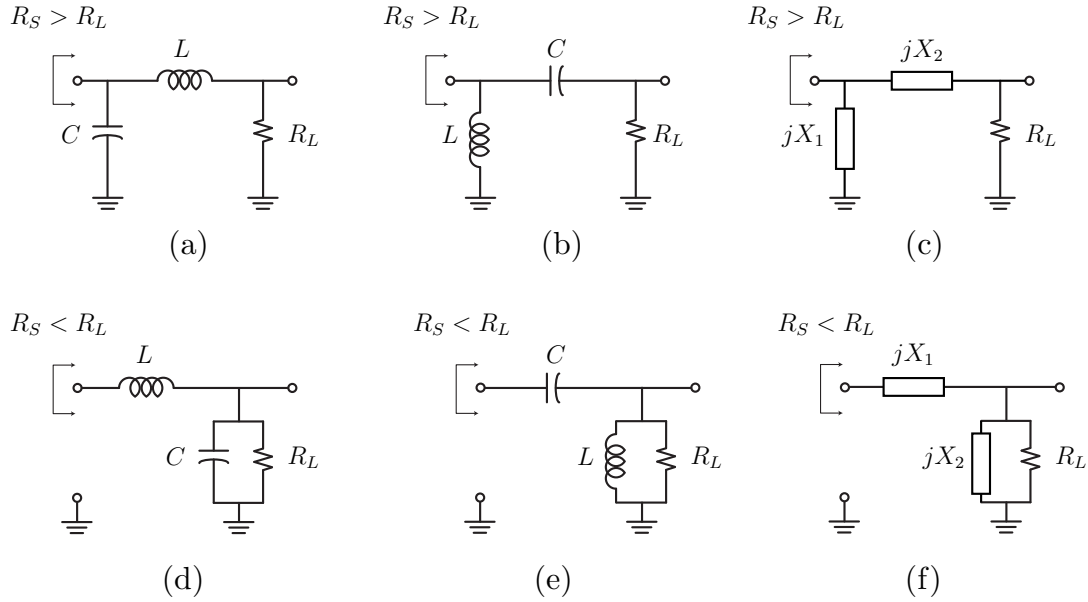


Figure 7.18: Several incarnations of L -matching networks. In (a)-(c) the load is connected in series with the reactance boosting the input resistance. In (d)-(f) the load is in shunt with the reactance, lowering the input resistance.

The final expression is derived after some algebra

$$R_{in} = \frac{R_L}{1 + Q_2^2} + \left(\frac{X_s}{R_L} \right)^2 + \left(\frac{X_s}{X_2} \right)^2 R_L \quad (7.99)$$

Under the assumption that $X_2 \ll R_L$, the final term dominates

$$R_{in} = \left(\frac{X_s}{X_2} \right)^2 R_L \approx \left(1 + \frac{C_2}{C_1} \right)^2 R_L \quad (7.100)$$

as expected. The reactance of the capacitive divider can be absorbed by a resonating inductance as shown in Fig. 7.17. In a similar vein, an inductive divider matching circuit can be designed as shown in Fig. 7.17.

An L -Match

Consider the L -Matching networks, shown in Fig. 7.18, named due to the topology of the network. We shall see that one direction of the L -match boosts the load impedance (in series with load) whereas the other lowers the load impedance (in shunt with the load). Let's focus on the first two networks shown in Fig. 7.18ab. Here, in absence of the source, we have a

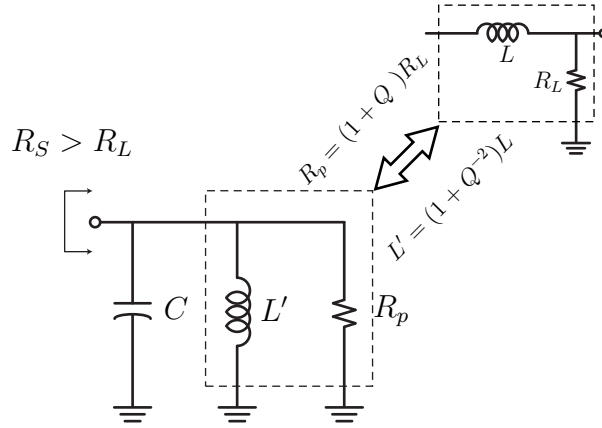


Figure 7.19: The transformed L matching network into a parallel RLC equivalent circuit.

simple series RLC circuit. Recall that in resonance, the voltage across the reactive elements is Q times larger than the voltage on the load! In essence, that is enough to perform the impedance transformation. Without doing any calculations, you can immediately guess that the impedance seen by the source is about Q^2 larger than R_L . Furthermore, since the circuit is operating in resonance, the net impedance seen by the source is purely real. To be sure, let's do the math.

A quick way to accomplish this feat is to begin with the series to parallel transformation, as shown in Fig. 7.19, where the load resistance in series with the inductor is converted to an equivalent parallel load equal to

$$R_p = (1 + Q^2)R_L \quad (7.101)$$

where $Q = X_L/R_L$, and $X'_L = X_L(1 + Q^{-2})$. The circuit is now nothing but a parallel RLC circuit and it's clear that at resonance the source will see only R_p , or a boosted value of R_L . The boosting factor is indeed equal to $Q^2 + 1$, very close to the value we guessed from the outset.

To gain insight into the operation of Fig. 7.18d-f, consider an Norton equivalent of the same circuit shown in Fig. 7.20. Now the circuit is easy to understand since it's simply a parallel resonant circuit. We know that at resonance the current through the reactances is Q times larger than the current in the load. Since the current in the series element (L in Fig. 7.18d) is controlled by the source voltage, we can immediately see that $i_s = Qi_L$, thus providing the required current gain to lower the load resistance by a factor of Q^2 .

As you may guess, the mathematics will yield a similar result. Simply do a parallel to series transformation of the load to obtain

$$R_s = \frac{R_p}{1 + Q^2} \quad (7.102)$$

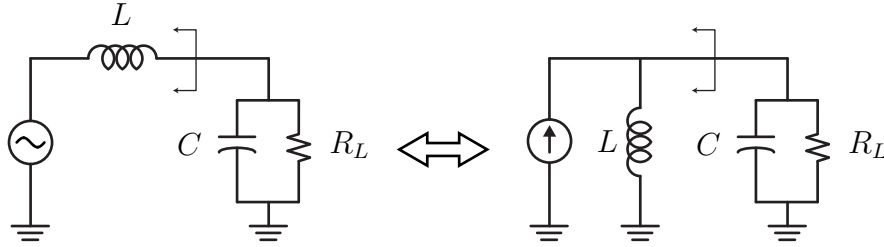


Figure 7.20: The source voltage driving the L matching network can be transformed into an equivalent Norton current source.

$$X'_p = \frac{X_p}{1 + Q^{-2}} \quad (7.103)$$

The resulting circuit is a simple series RLC circuit. At resonance, the source will only see the reduced series resistance R_s .

L -Match Design Equations

The following design procedure applies to an L -match using the generic forms of Fig. 7.18c,f. The actual choice between Fig. 7.18a,d and Fig. 7.18b,e depends on the application. For instance Fig. 7.18b,e provide AC coupling (DC isolation) which may be required in many applications. In other applications a common DC voltage may be needed, making the networks of Fig. 7.18a,d the obvious choice.

Let $R_{hi} = \max(R_S, R_L)$ and $R_{lo} = \min(R_S, R_L)$. The L -matching networks shown in Fig. 7.18 are designed as follows:

1. Calculate the boosting factor $m = \frac{R_{hi}}{R_{lo}}$.
2. Compute the required circuit Q by $(1 + Q^2) = m$, or $Q = \sqrt{m - 1}$.
3. Pick the required reactance from the Q . If you're boosting the resistance, e.g. $R_S > R_L$, then $X_s = Q \cdot R_L$. If you're dropping the resistance, $X_p = \frac{R_L}{Q}$.
4. Compute the effective resonating reactance. If $R_S > R_L$, calculate $X'_s = X_s(1 + Q^{-2})$ and set the shunt reactance in order to resonate, $X_p = -X'_s$. If $R_S < R_L$, then calculate $X'_p = \frac{X_p}{1 + Q^{-2}}$ and set the series reactance in order to resonate, $X_s = -X'_p$.
5. For a given frequency of operation, pick the value of L and C to satisfy these equations.

Insertion Loss of an L -Matching Network

We'd like to include the losses in our passive elements into the design of the matching network. The most detrimental effect of the component Q is the insertion loss which reduces the power transfer from source to load.

Let's begin by using our intuition to derive an approximate expression for the loss. Note that the power delivered to the input of the matching network P_{in} can be divided into two components

$$P_{in} = P_L + P_{diss} \quad (7.104)$$

where P_L is the power delivered to the load and P_{diss} is the power dissipated by the non-ideal inductors and capacitors. The insertion loss is therefore given by

$$IL = \frac{P_L}{P_{in}} = \frac{P_L}{P_L + P_{diss}} = \frac{1}{1 + \frac{P_{diss}}{P_L}} \quad (7.105)$$

Recall that for the equivalent series RLC circuit in resonance, the voltages across the reactances are Q times larger than the voltage across R_L . We can show that the reactive power is also a factor of Q larger. For instance the energy in the inductor is given by

$$W_m = \frac{1}{4} L i_s^2 = \frac{1}{4} \frac{v_s^2}{4R_S^2} L \quad (7.106)$$

or

$$\omega_0 \times W_m = \frac{1}{4} \frac{v_s^2}{4R_S} \frac{\omega_0 L}{R_S} = \frac{1}{2} \frac{v_s^2}{8R_S} Q = \frac{1}{2} P_L \times Q \quad (7.107)$$

where P_L is the power to the load at resonance

$$P_L = \frac{v_L^2}{2R_S} = \frac{v_s^2}{4 \cdot 2 \cdot R_S} = \frac{v_s^2}{8R_S} \quad (7.108)$$

The total reactive power is thus exactly Q times larger than the power in the load

$$\omega_0(W_m + W_e) = Q \times P_L \quad (7.109)$$

By the definition of the component Q_c factor, the power dissipated in the non-ideal elements of net quality factor Q_c is simply

$$P_{diss} = \frac{P_L \cdot Q}{Q_c} \quad (7.110)$$

which by using Eq. 7.105 immediately leads to the following expression for the insertion loss

$$IL = \frac{1}{1 + \frac{Q}{Q_c}} \quad (7.111)$$

The above equation is very simple and insightful. Note that using a higher network Q , e.g. a higher matching ratio, incurs more insertion loss with the simple single stage matching network. Furthermore, the absolute component Q is not important but only the component Q_c normalized to the network Q . Thus if a low matching ratio is needed, the actual components can be moderately lossy without incurring too much insertion loss.

Also note that the the actual inductors and capacitors in the circuit can be modeled with very complicated sub-circuits, with several parasitics to model distributed and skin effect, but in the end, at a given frequency, one can calculate the equivalent component Q_c factor and use it in the above equation.

Note that Q_c is the net quality factor of the passive elements. If one element dominates, such as a low- Q inductor, then Q_L can be used in its place. The exact analysis for a lossy inductor and capacitor is simple enough and yields an expression that is identical to Eq. 7.111 when only inductor losses are taken into account but differs when both inductor and capacitors losses are included

$$IL = \frac{1}{1 + \frac{Q}{Q_L}} \frac{1}{1 + \frac{Q}{Q_C}} \quad (7.112)$$

which can be written as

$$IL = \frac{1}{1 + Q(Q_L^{-1} + Q_C^{-1}) + \frac{Q^2}{Q_L Q_C}} \quad (7.113)$$

which equals the general expression we derived under “high- Q ” conditions, e.g. $Q_c \gg Q$.

When completing the design with real elements, it’s also necessary to shift the component values slightly due to the extra loss. While formulas for these perturbations can be calculated, a modern computer and optimizer really make this exercise unnecessary.

Reactance Absorption

In most situations the load and source impedances are often complex and our discussion so far only applies to real load and source impedances. An easy way to handle complex loads is to simply absorb them with reactive elements. For example, consider the complex load shown in Fig. 7.21. To apply an L -matching circuit, we can begin by simply resonating out the load reactance at the desired operating frequency. For instance, we add an inductance L_{res} in shunt with the capacitor to produce a real load. From here the design procedure is identical. Note that we can absorb the inductor L_{res} into the shunt L -matching element.

From now onwards we can simply discuss the real matching problem since a complex load or source can be handled in a similar fashion. Often there are multiple ways to perform the absorption with each choice yielding slightly different network properties such as Q (bandwidth), and different frequency selectivity (e.g. low-pass, high-pass, bandpass).

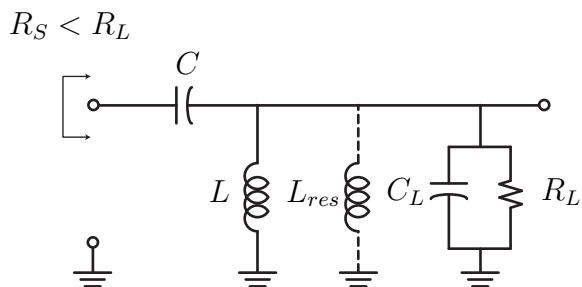


Figure 7.21: The complex load C_L in parallel with R_L is matched to a real source impedance by first applying an parallel inductor L_{res} to resonate out C_L . The load can now be matched using a standard matching network. In the final design, the resonating L_{res} can be simply absorbed into L .

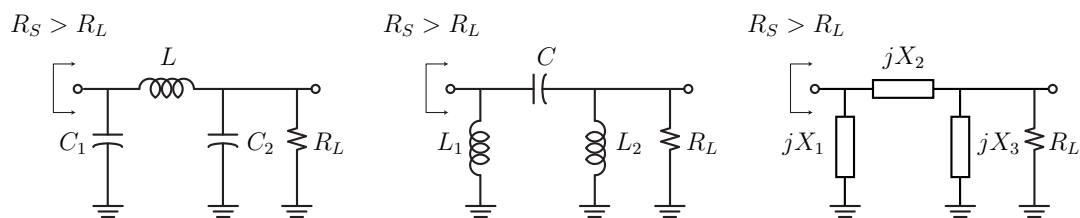


Figure 7.22: Several incarnations of a Π matching network. The first is a low-pass structure, the second a high-pass structure. The third is a general Π network.

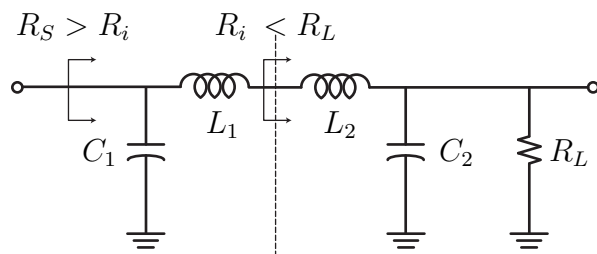


Figure 7.23: The Π network can be decomposed into a back-to-front cascade of two L matching networks. The impedance is first reduced down to $R_i < R_L$, then increased back up to $R_S > R_L > R_i$.

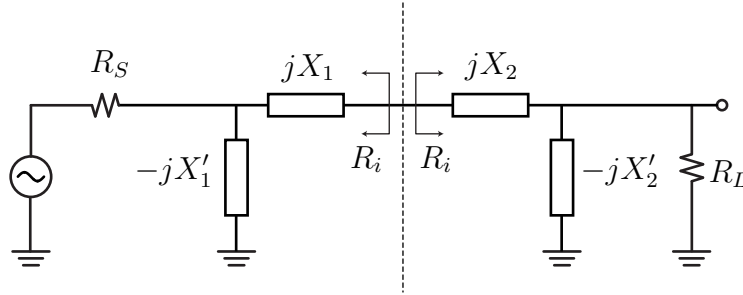


Figure 7.24: The reflected input and output impedance are both equal to R_i at the center of the Π network.

A Π -Match

The L -Match circuit is simple and elegant but is somewhat constrained. In particular, we cannot freely choose the Q of the circuit since it is fixed by the required matching factor m . This restriction is easily solved with the Π -Matching circuit, also named from its topology, shown in Fig. 7.22. The idea behind the Π match can be easily understood by studying the cascade of two back-to-front L matches as shown in Fig. 7.23. In this circuit the first L match will lower the load impedance to an intermediate value R_i

$$R_i = \frac{R_L}{1 + Q_1^2} \quad (7.114)$$

or

$$Q_1 = \sqrt{\frac{R_L}{R_i} - 1} \quad (7.115)$$

Since $R_i < R_L$, the second L match needs to boost the value of R_i up to R_s . The Q of the second L network is thus

$$Q_2 = \sqrt{\frac{R_s}{R_i} - 1} > \sqrt{\frac{R_s}{R_L} - 1} \quad (7.116)$$

When we combine the two L networks, we obtain a Π network with a higher Q than possible with a single stage transformation. In general the Q , or equivalently the bandwidth $B = \frac{\omega_0}{Q}$, is a free parameter that can be chosen at will for a given application. Note that when the source is connected to the input, the circuit is symmetric about the center, as shown in Fig. 7.24. Now it's rather easy to compute the network Q by drawing a series equivalent circuit about the center of the structure, as shown in Fig. 7.25. If the capacitors and inductors in series are combined, the result is a simple RLC circuit with Q given by

$$Q = \frac{X_1 + X_2}{2R_i} = \frac{Q_1 + Q_2}{2} \quad (7.117)$$

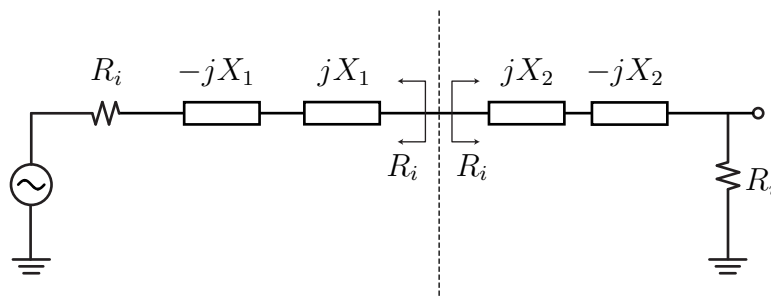


Figure 7.25: The L sections can be converted into series sections to produce one big LCR circuit.

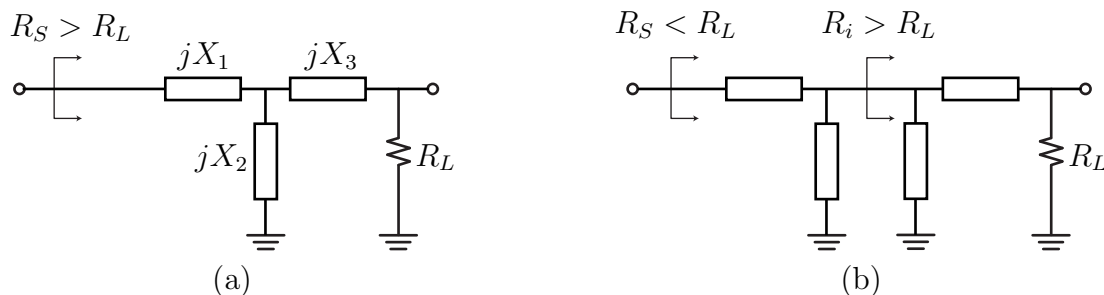


Figure 7.26: (a) The T -matching network can be decomposed into two front-to-back L sections. (b) The first L section boosts the resistance to a value of $R_i > R_L$ and the second L structure drops the impedance to $R_S < R_i$.

It's important to note the inclusion of the source resistance when calculating the network Q as we are implicitly assuming a power match. In a power amplifier, the source impedance may be different and the above calculation should take that into consideration. For instance, if the PA is modeled as a high impedance current source (Class A/B operation), then the factor of 2 disappears. The design procedure begins with the specification of the network Q . Eq. 7.117 is then used to find R_i , and from there the L -match procedure outlined above takes over.

A T -Match

The T -matching network, shown in Fig. 7.26a, is the dual of the Π network. By now you can see that the names all correspond the physical topology of the circuit. The T network can also be decomposed into a cascade of two back-to-front L networks, as shown in Fig. 7.26b. The first L transforms the resistance up to some intermediate value $R_i > R_S$, and the second L transforms the resistance back down to R_S . Thus the net Q is higher than a single stage

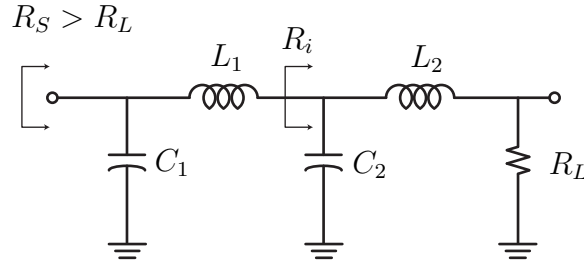


Figure 7.27: A two-stage low-pass L matching network. The first stage steps up the intermediate resistance $R_S < R_i < R_L$, thus lowering the Q over a single stage design.

match. The network Q can be derived in an analogous fashion and yields the same solution

$$Q = \frac{1}{2} \left(\sqrt{\frac{R_i}{R_L}} - 1 + \sqrt{\frac{R_i}{R_S}} - 1 \right) \quad (7.118)$$

Multi-Section Low Q Matching

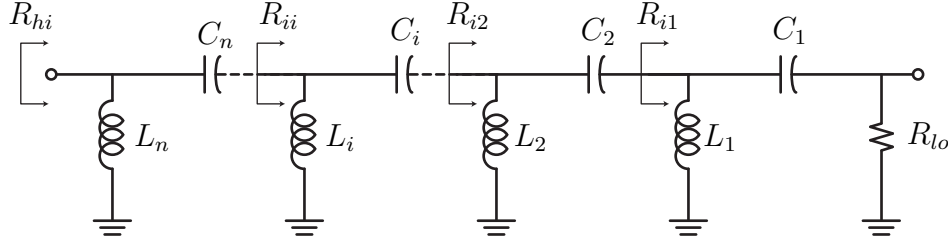
We have seen that the Π and T matching networks are essentially two stage networks which can boost the network Q . In many applications we actually would like to achieve the opposite effect, e.g. low network Q is desirable in broadband applications. Furthermore, a low Q design is less susceptible to process variations. Also, a lower Q network lowers the loss of the network, as evident by examining Eq. 7.111.

To lower the Q of an L matching network, we can employ more than one stage to change the impedance in smaller steps. Recall that $Q = \sqrt{m - 1}$, and a large m factor requires a high Q match. If we simply change the impedance by a factor $k < m$, the Q of the first L section is reduced. Likewise, a second L section will further change the resistance to the desired R_S with a step size $l < m$, where $l \cdot k = m$. An example two-stage network is shown in Fig. 7.27a. Reflecting all impedances to the center of the network, the real part of the impedance looking left or right is R_i at resonance. Thus the power dissipation is equal for both networks. The overall Q is thus given by

$$Q = \frac{\omega(W_{s1} + W_{s2})}{P_{d1} + P_{d2}} = \frac{\omega W_{s1}}{2P_d} + \frac{\omega W_{s2}}{2P_d} = \frac{Q_1 + Q_2}{2} \quad (7.119)$$

$$Q = \frac{1}{2} \left(\sqrt{\frac{R_i}{R_L}} - 1 + \sqrt{\frac{R_S}{R_i}} - 1 \right) \quad (7.120)$$

Note the difference between the above and Eq. 7.118. The R_i term appears once in the denominator and once in the numerator since it's an intermediate value. What's the lowest

Figure 7.28: A high-pass multi-section L matching network.

Q achievable? To find out, take the derivative of 7.120 with respect to R_i and solve for the minimum

$$R_{i,\text{opt}} = \sqrt{R_L R_S} \quad (7.121)$$

which results in a Q approximately lower by a square root factor

$$Q_{\text{opt}} = \sqrt{\sqrt{\frac{R_S}{R_L}} - 1} \approx m^{1/4} \quad (7.122)$$

It's clear that the above equations apply to the opposite case when $R_L > R_S$ by simply interchanging the role of the source and the load.

To even achieve a lower Q , we can keep adding sections as shown in Fig. 7.28. The optimally low Q value is obtained when the intermediate impedances are stepped in geometric progression

$$\frac{R_{i1}}{R_{lo}} = \frac{R_{i2}}{R_{i1}} = \frac{R_{i3}}{R_{i2}} = \dots = \frac{R_{hi}}{R_{in}} = 1 + Q^2 \quad (7.123)$$

where $R_{hi} = \max(R_S, R_L)$ and $R_{lo} = \min(R_S, R_L)$. In the limit that $n \rightarrow \infty$, we take very small “baby” steps from R_{lo} to R_{hi} and the circuit starts to look like a tapered transmission line. Multiplying each term in the above equation

$$\frac{R_{i1}}{R_{lo}} \cdot \frac{R_{i2}}{R_{i1}} \cdot \frac{R_{i3}}{R_{i2}} \cdot \dots \cdot \frac{R_{hi}}{R_{in}} = \frac{R_{hi}}{R_{lo}} = (1 + Q^2)^N \quad (7.124)$$

which results in the optimally Q factor for the overall network

$$Q = \sqrt{\left(\frac{R_{hi}}{R_{lo}}\right)^{1/N} - 1} \quad (7.125)$$

The loss in the optimal multi-section line can be calculated as follows. Using the same approach as Sec. 7.3, note that the total power dissipated in the matching network is given by

$$P_{\text{diss}} = \frac{NQP_L}{Q_u} \quad (7.126)$$

where N sections are used, each with equal Q due to the condition set forth by Eq. 7.123. This leads to the following expression

$$IL = \frac{1}{1 + N \frac{Q}{Q_u}} \quad (7.127)$$

or

$$IL = \frac{1}{1 + \frac{N}{Q_u} \sqrt{\left(\frac{R_{hi}}{R_{lo}}\right)^{1/N} - 1}} \quad (7.128)$$

It's interesting to observe that this expression has an optimum for a particular value of N . It's easy enough to plot IL for a few values of N to determine the optimal number of sections. Intuitively adding sections can decrease the insertion loss since it also lowers the network Q factor. Adding too many sections, though, can counterbalance this benefit.

Example 12:

Suppose a power amplifier delivering 100 W of power has an optimal load resistance of $.5\Omega$, but needs to drive a 50Ω antenna. Design a matching network assuming that the component Q 's of 30 are available.

First note that a matching factor of $m = 50/.5 = 100$ is needed. The table below shows the network Q and insertion loss as a function of the number of sections N . Clearly three sections yields the optimal solution. But since a three section filter is more expensive, and has only marginally better performance, a two section matching network may be preferable.

N	Q (Eq. 7.125)	IL (dB) (Eq. 7.128)
1	9.95	-1.24
2	3	-0.79
3	1.91	-0.76
4	1.47	-0.78
5	1.23	-0.81
6	1.07	-0.85

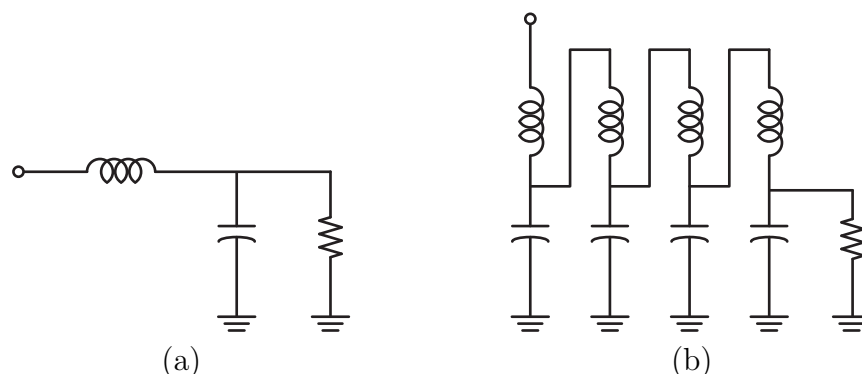


Figure 7.29: (a) A single stage LC voltage divider has a low-pass transfer characteristic. Its topology identical to a L matching network. (b) Cascades of voltage dividers are equivalent to cascades of L sections leading to higher out of band attenuation.

7.4 Distributed Matching Networks

Matching circuits employing transmission lines are covered in Ch. 9. Quarter wave transmission lines, transmission line stubs, and other distributed structures will be covered. Transformer based matching, including transmission line transformers, are covered in Ch. 10 and Ch. 11.

7.5 Filters

A filter is a circuit with a specified frequency response characteristic. Filters are key elements in high speed communication circuits since often our information is buried in a lot of noise and interference. A filter can attenuate out-of-band signals and thus reduce the required dynamic range of analog and digital circuits, which leads directly to power savings (e.g. lower resolution ADC and fewer bits in the DSP).

Matching networks and filters have much in common. We may view a matching network as a filter with different load and source impedances. In effect all the circuits we have met in this chapter are filters, with the important distinction that while some filtering action was occurring, it was not a well controlled part of the design.

LC filters grow naturally from a simple low-pass LC dividers shown in Fig. 7.29a. At low frequencies, the inductor is a short and the capacitor is an open and so the input passes to the output unattenuated. At higher frequencies, though, the inductor tends to increase in reactance and the capacitance shunts the output to ground. How do we increase the out-of-band attenuation? Why not simply cascade another LC filter section as shown in Fig. 7.29b. In fact, we can continue to add sections to increase the out-of-band attenuation.

A high-pass version of this circuit is the dual where the capacitors and inductors switch

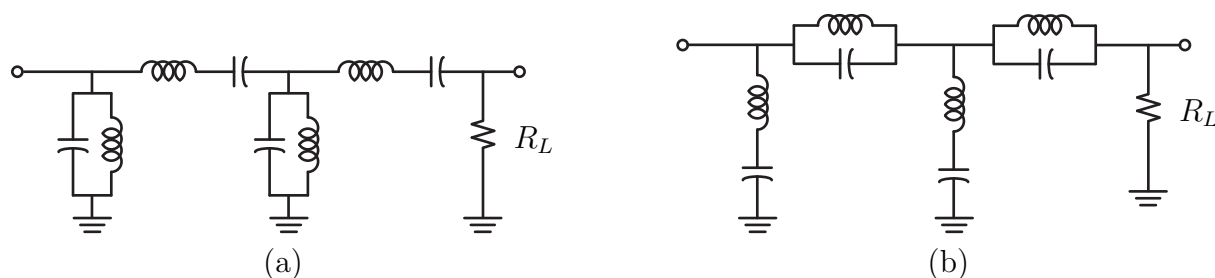


Figure 7.30: (a) A bandpass multi-section filter. (b) A multi-section notch filter.

places, as shown in Fig. 7.28. A bandpass version of the circuit is also easy if we observe that a series LC circuit is a short at resonance and a shunt LC circuit is an open at resonance. Then the circuit of Fig. 7.30a acts like a bandpass filter. If we switch the locations of the series and parallel resonant tanks, we obtain the network shown in Fig. 7.30b, a notch filter. Now the circuit response is a null at resonance.

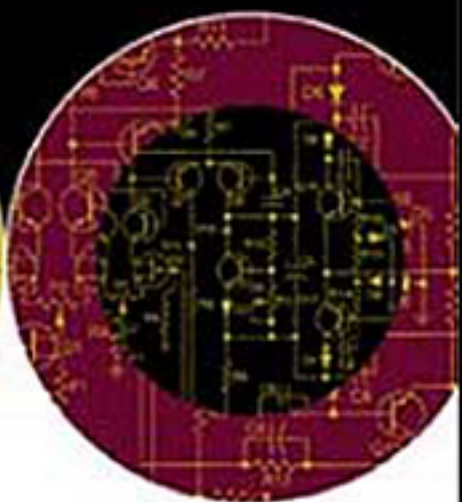
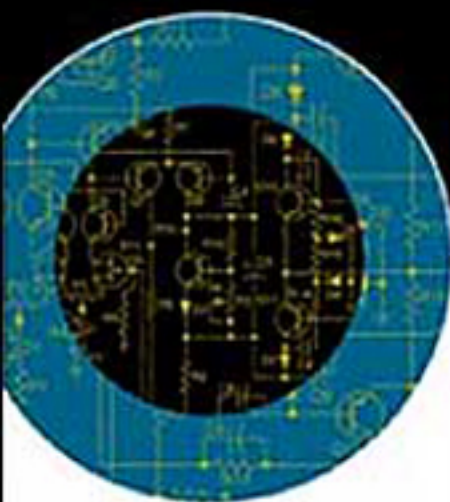
The design of prototype filters is a very well developed discipline and many good sources exists [69] that tabulate filters into families with distinct characteristics (say minimum ripple or linear phase response).

7.6 References

This chapter has origins in lecture notes I used in several communication circuits courses taught at Berkeley. I learned this material from classic references, such as *Communication Circuits: Analysis and Design* [8] and *Solid State Radio* [31]. A more recent addition to the bookshelf, Tom Lee's, *The Design of CMOS RFIC* [34] book also has an excellent chapter covering some of this material.

THIRD EDITION

SECRETS OF
**RF CIRCUIT
DESIGN**



JOSEPH J. CARR

1

CHAPTER

Introduction to RF electronics

Radio-frequency (RF) electronics differ from other electronics because the higher frequencies make some circuit operation a little hard to understand. Stray capacitance and stray inductance afflict these circuits. Stray capacitance is the capacitance that exists between conductors of the circuit, between conductors or components and ground, or between components. Stray inductance is the normal inductance of the conductors that connect components, as well as internal component inductances. These stray parameters are not usually important at dc and low ac frequencies, but as the frequency increases, they become a much larger proportion of the total. In some older very high frequency (VHF) TV tuners and VHF communications receiver front ends, the stray capacitances were sufficiently large to tune the circuits, so no actual discrete tuning capacitors were needed.

Also, skin effect exists at RF. The term *skin effect* refers to the fact that ac flows only on the outside portion of the conductor, while dc flows through the entire conductor. As frequency increases, skin effect produces a smaller zone of conduction and a correspondingly higher value of ac resistance compared with dc resistance.

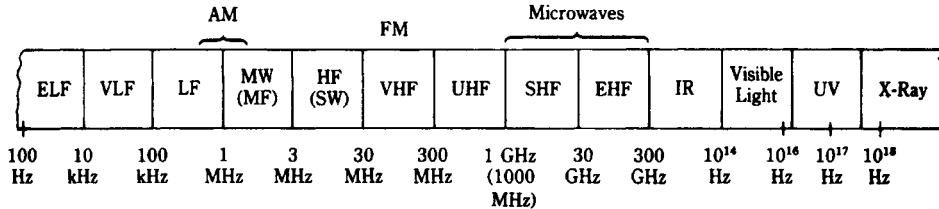
Another problem with RF circuits is that the signals find it easier to radiate both from the circuit and within the circuit. Thus, coupling effects between elements of the circuit, between the circuit and its environment, and from the environment to the circuit become a lot more critical at RF. Interference and other strange effects are found at RF that are missing in dc circuits and are negligible in most low-frequency ac circuits.

The electromagnetic spectrum

When an RF electrical signal radiates, it becomes an electromagnetic wave that includes not only radio signals, but also infrared, visible light, ultraviolet light, X-rays, gamma rays, and others. Before proceeding with RF electronic circuits, therefore, take a look at the electromagnetic spectrum.

2 Introduction to RF electronics

The electromagnetic spectrum (Fig. 1-1) is broken into bands for the sake of convenience and identification. The spectrum extends from the very lowest ac frequencies and continues well past visible light frequencies into the X-ray and gamma-ray region. The extremely low frequency (ELF) range includes ac power-line frequencies as well as other low frequencies in the 25- to 100-hertz (Hz) region. The U.S. Navy uses these frequencies for submarine communications.



1-1 The electromagnetic spectrum from VLF to X-ray. The RF region covers from less than 100 kHz to 300 GHz.

The very low frequency (VLF) region extends from just above the ELF region, although most authorities peg it to frequencies of 10 to 100 kilohertz (kHz). The low-frequency (LF) region runs from 100 to 1000 kHz—or 1 megahertz (MHz). The medium-wave (MW) or medium-frequency (MF) region runs from 1 to 3 MHz. The amplitude-modulated (AM) broadcast band (540 to 1630 kHz) spans portions of the LF and MF bands.

The high-frequency (HF) region, also called the *shortwave bands* (SW), runs from 3 to 30 MHz. The VHF band starts at 30 MHz and runs to 300 MHz. This region includes the frequency-modulated (FM) broadcast band, public utilities, some television stations, aviation, and amateur radio bands. The ultrahigh frequencies (UHF) run from 300 to 900 MHz and include many of the same services as VHF. The microwave region begins above the UHF region, at 900 or 1000 MHz, depending on source authority.

You might well ask how microwaves differ from other electromagnetic waves. Microwaves almost become a separate topic in the study of RF circuits because at these frequencies the wavelength approximates the physical size of ordinary electronic components. Thus, components behave differently at microwave frequencies than they do at lower frequencies. At microwave frequencies, a 0.5-W metal film resistor, for example, looks like a complex RLC network with distributed L and C values—and a surprisingly different R value. These tiniest of distributed components have immense significance at microwave frequencies, even though they can be ignored as negligible at lower RFs.

Before examining RF theory, first review some background and fundamentals.

Units and physical constants

In accordance with standard engineering and scientific practice, all units in this book will be in either the CGS (centimeter-gram-second) or MKS (meter-kilogram-second) system unless otherwise specified. Because the metric system de-

depends on using multiplying prefixes on the basic units, a table of common metric prefixes (Table 1-1) is provided. Table 1-2 gives the standard physical units. Table 1-3 gives physical constants of interest in this and other chapters. Table 1-4 gives some common conversion factors.

Table 1-1. Metric prefixes

Metric prefix	Multiplying factor	Symbol
tera	10^{12}	T
giga	10^9	G
mega	10^6	M
kilo	10^3	K
hecto	10^2	h
deka	10	da
deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	u
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f
atto	10^{-18}	a

Table 1-2. Units of measure

Quantity	Unit	Symbol
Capacitance	farad	F
Electric charge	coulomb	Q
Conductance	mhos	
Conductivity	mhos/meter	Ω/m
Current	ampere	A
Energy	joule (watt-second)	j
Field	volts/meter	E
Flux linkage	weber (volt/second)	
Frequency	hertz	Hz
Inductance	henry	H
Length	meter	m
Mass	gram	g
Power	watt	W
Resistance	ohm	Ω
Time	second	s
Velocity	meter/second	m/s
Electric potential	volt	V

4 Introduction to RF electronics

Table 1-3. Physical constants

Constant	Value	Symbol
Boltzmann's constant	1.38×10^{-23} J/K	K
Electric charge (e^-)	1.6×10^{-19} C	q
Electron (volt)	1.6×10^{-19} J	eV
Electron (mass)	9.12×10^{-31} kg	m
Permeability of free space	$4\pi \times 10^{-7}$ H/m	U_0
Permittivity of free space	8.85×10^{-12} F/m	ϵ_0
Planck's constant	6.626×10^{-34} J-s	h
Velocity of electromagnetic waves	3×10^8 m/s	c
Pi (π)	3.1416	π

Table 1-4. Conversion factors

1 inch	= 2.54 cm
1 inch	= 25.4 mm
1 foot	= 0.305 m
1 statute mile	= 1.61 km
1 nautical mile	= 6,080 feet (6,000 feet) ^a
1 statute mile	= 5,280 feet
1 mile	= 0.001 in = 2.54×10^{-5} m
1 kg	= 2.2 lb
1 neper	= 8.686 dB
1 gauss	= 10,000 teslas

^a Some navigators use 6,000 feet for ease of calculation. The nautical mile is 1/360 of the Earth's circumference at the equator, more or less.

Wavelength and frequency

For all wave forms, the velocity, wavelength, and frequency are related so that the product of frequency and wavelength is equal to the velocity. For radiowaves, this relationship can be expressed in the following form:

$$\lambda F \sqrt{\epsilon} = c, \quad (1-1)$$

where

λ = wavelength in meters (m)

F = frequency in hertz (Hz)

ϵ = dielectric constant of the propagation medium

c = velocity of light (300,000,000 m/s).

The dielectric constant (ϵ) is a property of the medium in which the wave propagates. The value of ϵ is defined as 1.000 for a perfect vacuum and very nearly 1.0 for dry air (typically 1.006). In most practical applications, the value of ϵ in dry air is taken to be 1.000. For media other than air or vacuum, however, the velocity of prop-

agation is slower and the value of ϵ relative to a vacuum is higher. Teflon, for example, can be made with ϵ values from about 2 to 11.

Equation (1-1) is more commonly expressed in the forms of Eqs. (1-2) and (1-3):

$$\lambda = \frac{c}{F \sqrt{\epsilon}} \quad (1-2)$$

and

$$F = \frac{c}{\lambda \sqrt{\epsilon}}. \quad (1-3)$$

[All terms are as defined for Eq. (1-1).]

Microwave letter bands

During World War II, the U.S. military began using microwaves in radar and other applications. For security reasons, alphabetic letter designations were adopted for each band in the microwave region. Because the letter designations became ingrained, they are still used throughout industry and the defense establishment. Unfortunately, some confusion exists because there are at least three systems currently in use: pre-1970 military (Table 1-5), post-1970 military (Table 1-6), and the IEEE and industry standard (Table 1-7). Additional confusion is created because the military and defense industry use both pre- and post-1970 designations simultaneously and industry often uses military rather than IEEE designations. The old military designations (Table 1-5) persist as a matter of habit.

Skin effect

There are three reasons why ordinary lumped constant electronic components do not work well at microwave frequencies. The first, mentioned earlier in this chapter, is that component size and lead lengths approximate microwave wavelengths.

**Table 1-5. Old U.S. military
microwave frequency bands
(WWII–1970)**

Band designation	Frequency range
P	225–390 MHz
L	390–1550 MHz
S	1550–3900 MHz
C	3900–6200 MHz
X	6.2–10.9 GHz
K	10.9–36 GHz
Q	36–46 GHz
V	46–56 GHz
Q	56–100 GHz

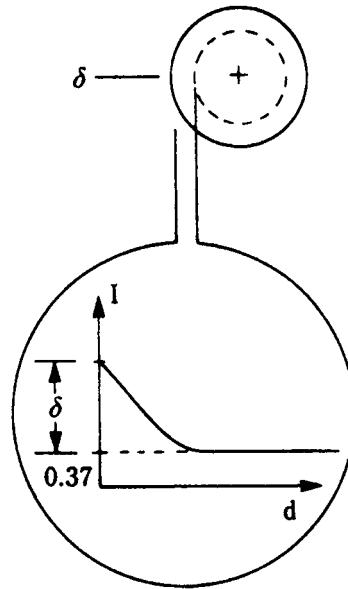
Table 1-6. New U.S. military microwave frequency bands (Post-1970)

Band designation	Frequency range
A	100–250 MHz
B	250–500 MHz
C	500–1000 MHz
D	1000–2000 MHz
E	2000–3000 MHz
F	3000–4000 MHz
G	4000–6000 MHz
H	6000–8000 MHz
I	8000–10000 MHz
J	10–20 GHz
K	20–40 GHz
L	40–60 GHz
M	60–100 GHz

Table 1-7. IEEE/Industry standard frequency bands

Band designation	Frequency range
HF	3–30 MHz
VHF	0–300 MHz
UHF	300–1000 MHz
L	1000–2000 MHz
S	2000–4000 MHz
C	4000–8000 MHz
X	8000–12000 MHz
Ku	12–18 GHz
K	18–27 GHz
Ka	27–40 GHz
Millimeter	40–300 GHz
Submillimeter	>300 GHz

The second is that distributed values of inductance and capacitance become significant at these frequencies. The third is the phenomenon of skin effect. While dc current flows in the entire cross section of the conductor, ac flows in a narrow band near the surface. Current density falls off exponentially from the surface of the conductor toward the center (Fig. 1-2). At the critical depth (δ , also called the depth of penetration), the current density is $1/e = 1/2.718 = 0.368$ of the surface current density.

**1-2**

In ac circuits, the current flows only in the outer region of the conductor. This effect is frequency-sensitive and it becomes a serious consideration at higher RF frequencies.

The value of δ is a function of operating frequency, the permeability (μ) of the conductor, and the conductivity (σ). Equation (1-4) gives the relationship.

$$\delta = \sqrt{\frac{1}{2\pi F\sigma\mu}} \quad (1-4)$$

where

δ = critical depth

F = frequency in hertz

μ = permeability in henrys per meter

σ = conductivity in mhos per meter.

RF components, layout, and construction

Radio-frequency components and circuits differ from those of other frequencies principally because the unaccounted for “stray” inductance and capacitance forms a significant portion of the entire inductance and capacitance in the circuit. Consider a tuning circuit consisting of a 100-pF capacitor and a 1- μ H inductor. According to an equation that you will learn in a subsequent chapter, this combination should resonate at an RF frequency of about 15.92 MHz. But suppose the circuit is poorly laid out and there is 25 pF of stray capacitance in the circuit. This capacitance could come from the interaction of the capacitor and inductor leads with the chassis or with other components in the circuit. Alternatively, the input capacitance of a transistor or integrated circuit (IC) amplifier can contribute to the total value of the “strays” in the circuit (one popular RF IC lists 7 pF of input capacitance). So, what does this extra 25 pF do to our circuit? It is in parallel with the 100-pF discrete

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capacitor so it produces a total of 125 pF. Reworking the resonance equation with 125 pF instead of 100 pF reduces the resonant frequency to 14.24 MHz.

A similar situation is seen with stray inductance. All current-carrying conductors exhibit a small inductance. In low-frequency circuits, this inductance is not sufficiently large to cause anyone concern (even in some lower HF band circuits), but as frequencies pass from upper HF to the VHF region, strays become terribly important. At those frequencies, the stray inductance becomes a significant portion of total circuit inductance.

Layout is important in RF circuits because it can reduce the effects of stray capacitance and inductance. A good strategy is to use broad printed circuit tracks at RF, rather than wires, for interconnection. I've seen circuits that worked poorly when wired with #28 Kovar-covered "wire-wrap" wire become quite acceptable when redone on a printed circuit board using broad (which means low-inductance) tracks.

Figure 1-3 shows a sample printed circuit board layout for a simple RF amplifier circuit. The key feature in this circuit is the wide printed circuit tracks and short distances. These tactics reduce stray inductance and will make the circuit more predictable.

Although not shown in Fig. 1-3, the top (components) side of the printed circuit board will be all copper, except for space to allow the components to interface with the bottom-side printed tracks. This layer is called the "ground plane" side of the board.



1-3
Typical RF printed circuit layout.

Impedance matching in RF circuits

In low-frequency circuits, most of the amplifiers are voltage amplifiers. The requirement for these circuits is that the source impedance must be very low compared with the load impedance. A sensor or signal source might have an output impedance of, for example, 25 Ω . As long as the input impedance of the amplifier receiving that signal is very large relative to 25 Ω , the circuit will function. "Very large" typically means greater than 10 times, although in some cases greater than 100 times is preferred. For the 25- Ω signal source, therefore, even the most stringent case is met by an input impedance of 2500 Ω , which is very far below the typical input impedance of real amplifiers.

RF circuits are a little different. The amplifiers are usually specified in terms of power parameters, even when the power level is very tiny. In most cases, the RF circuit will have some fixed system impedance (50, 75, 300, and 600 Ω being common, with 50 Ω being nearly universal), and all elements of the circuit are expected to

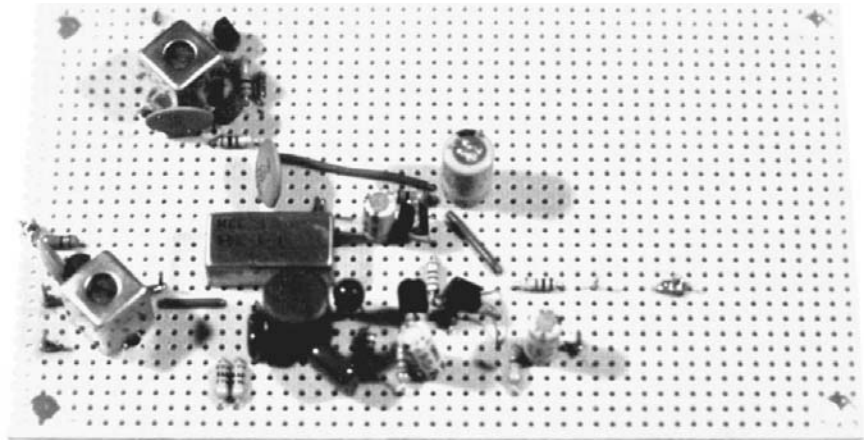
match the system impedance. Although a low-frequency amplifier typically has a very high input impedance and very low output impedance, most RF amplifiers will have the same impedance (usually $50\ \Omega$) for both input and output.

Mismatching the system impedance causes problems, including loss of signal—especially where power transfer is the issue (remember, for maximum power transfer, the source and load impedances must be equal). Radio-frequency circuits very often use transformers or impedance-matching networks to affect the match between source and load impedances.

Wiring boards

Radio-frequency projects are best constructed on printed circuit boards that are specially designed for RF circuits. But that ideal is not always possible. Indeed, for many hobbyists or students, it might be impossible, except for the occasional project built from a magazine article or from this book. This section presents a couple of alternatives to the use of printed circuit boards.

Figure 1-4 shows the use of perforated circuit wiring board (commonly called *perfboard*). Electronic parts distributors, RadioShack, and other outlets sell various versions of this material. Most commonly available perfboard offers $0.042''$ holes spaced on $0.100''$ centers, although other hole sizes and spacings are available. Some perfboard is completely blank, and other stock material is printed with any of several different patterns. The offerings of RadioShack are interesting because several different patterns are available. Some are designed for digital IC applications and others are printed with a pattern of circles, one each around the $0.042''$ holes.



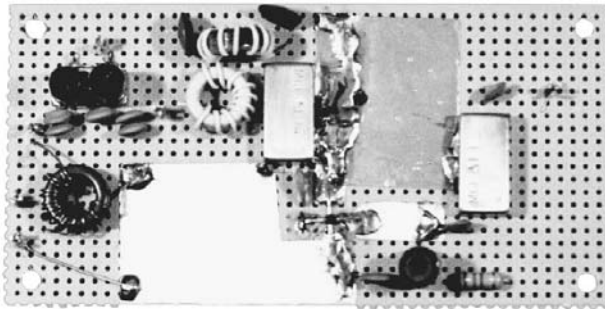
1-4 Perfboard layout.

In Fig. 1-4, the components are mounted on the top side of an unprinted board. The wiring underneath is “point-to-point” style. Although not ideal for RF circuits, it will work throughout the HF region of the spectrum and possibly into the low VHF (especially if lead lengths are kept short).

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Notice the shielded inductors on the board in Fig. 1-4. These inductors are slug-tuned through a small hole in the top of the inductor. The standard pin pattern for these components does not match the 0.100-hole pattern that is common to perfboard. However, if the coils are canted about half a turn from the hole matrix, the pins will fit on the diagonal. The grounding tabs for the shields can be handled in either of two ways. First, bend them 90° from the shield body and let them lay on the top side of the perfboard. Small wires can then be soldered to the tabs and passed through a nearby hole to the underside circuitry. Second, drill a pair of $\frac{1}{16}$ " holes (between two of the premade holes) to accommodate the tabs. Place the coil on the board at the desired location to find the exact location of these holes.

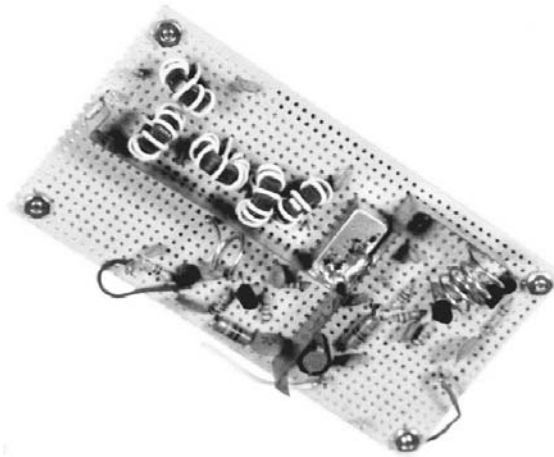
Figure 1-5 shows another variant on the perfboard theme. In this circuit, pressure-sensitive (adhesive-backed) copper foil is pressed onto the surface of the perfboard to form a ground plane. This is not optimum, but it works for “one-off” homebrew projects up to HF and low-VHF frequencies.



1-5 Perfboard layout with RF ground plane.

The perfboard RF project in Fig. 1-6 is a frequency translator. It takes two frequencies (F_1 and F_2), each generated in a voltage-tuned variable-frequency oscillator (VFO) circuit, and mixes them together in a double-balanced mixer (DBM) device. A low-pass filter (the toroidal inductors seen in Fig. 1-6) selects the difference frequency ($F_2 - F_1$). It is important to keep the three sections (osc1, osc2, and the low-pass filter) isolated from each other. To accomplish this goal, a shield partition is provided. In the center of Fig. 1-6, the metal package of the mixer is soldered to the shield partition. This shield can be made from either 0.75" or 1.00" brass strip stock of the sort that is available from hobby and model shops.

Figure 1-7 shows a small variable-frequency oscillator (VFO) that is tuned by an air variable capacitor. The capacitor is a 365-pF “broadcast band” variable. I built this circuit as the local oscillator for a high-performance AM broadcast band receiver project. The shielded, slug-tuned inductor, along with the capacitor, tunes the 985- to 2055-kHz range of the LO. The perfboard used for this project was a preprinted RadioShack. The printed foil pattern on the underside of the perfboard is a matrix of small circles of copper, one copper pad per 0.042" hole. The perfboard is held off the chassis by nylon spacers and 4-40 $\times$ 0.75" machine screws and hex nuts.

**1-6**

The use of shielding on perfboard.

**1-7**

VFO circuit build on perfboard.

Chassis and cabinets

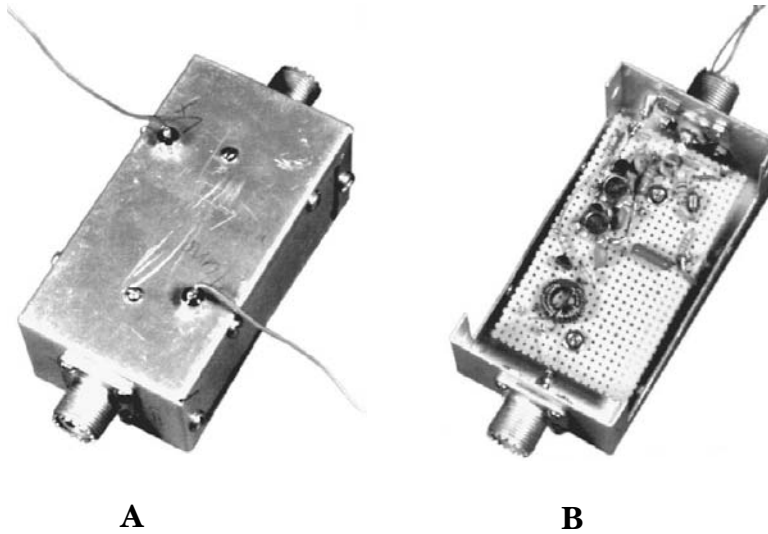
It is probably wise to build RF projects inside shielded metal packages wherever possible. This approach to construction will prevent external interference from harming the operation of the circuit and prevent radiation from the circuit from interfering with external devices. Figure 1-8 shows two views of an RF project built inside an aluminum chassis box; Fig. 1-8A shows the assembled box and Fig. 1-8B shows an internal view. These boxes have flanged edges on the top portion that overlap the metal side/bottom panel. This overlap is important for interference reduction. Shun those cheaper chassis boxes that use a butt fit, with only a couple of nipples and dimples to join the boxes together. Those boxes do not shield well.

The input and output terminals of the circuit in Fig. 1-8 are SO-239 “UHF” coaxial connectors. Such connectors are commonly used as the antenna terminal on shortwave radio receivers. Alternatives include “RCA phono jacks” and “BNC” coaxial connectors. Select the connector that is most appropriate to your application.

RF shielded boxes

At one time, more than 2 decades ago, I loathed small RF electronic projects above about 40-m as “too hard.” As I grew in confidence, I learned a few things about

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1-8 Shielded RF construction: (A) closed box showing dc connections made via coaxial capacitors; (B) box opened.

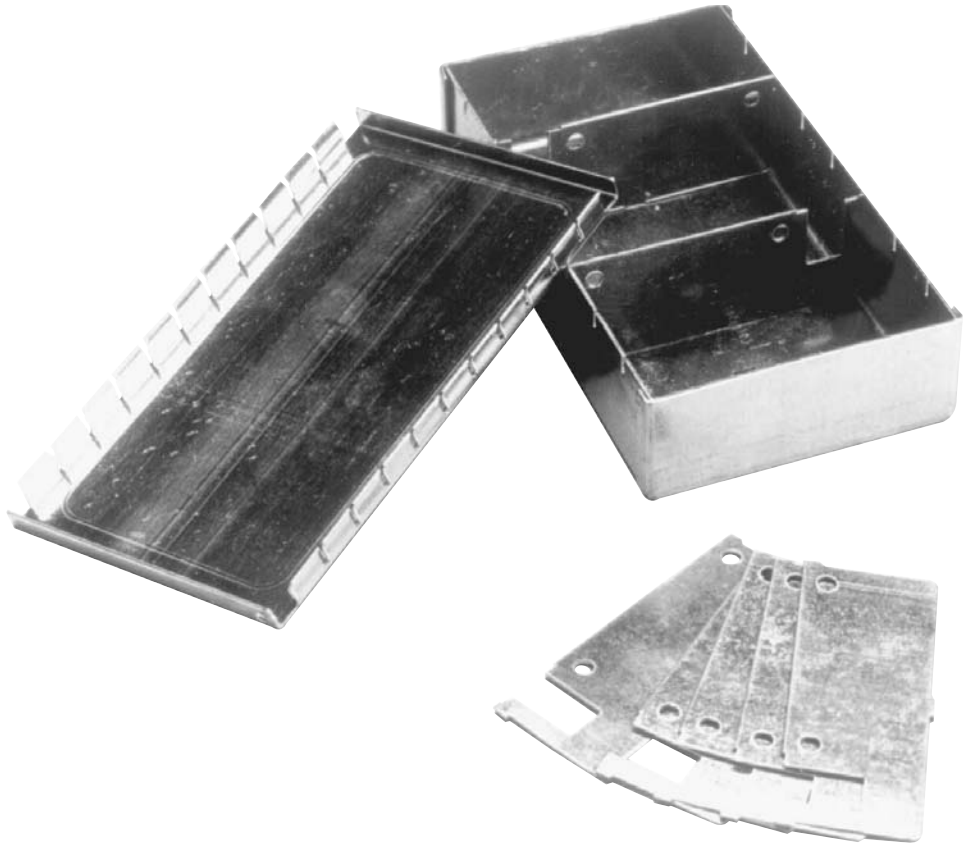
RF construction (e.g., layout, grounding, and shielding) and found that by following the rules, one can be as successful building RF stuff as at lower frequencies.

One problem that has always been something of a hassle, however, is the shielding that is required. You could learn layout and grounding, but shielding usually required a better box than I had. Most of the low-cost aluminum electronic hobbyist boxes on the market are alright for dc to the AM broadcast band, but as frequency climbs into the HF and VHF region, problems begin to surface. What you thought was shielded “t’ain’t.” If you’ve read my columns or feature articles over the years, you will recall that I caution RF constructors to use the kind of aluminum box with an overlapping flange of at least 0.25”, and a good tight fit. Many hobbyist-grade boxes on the market just simply are not good enough.

Enter SESCOM, Inc. [Dept. JJC, 2100 Ward Drive, Henderson, NV, 89015-4249; (702) 565-3400 and (for voice orders only) 1-800-634-3457 and (for FAX orders only) 1-800-551-2749]. SESCOM makes a line of cabinets, 19” racks, rack mount boxes, and RF shielded boxes. Their catalog has a lot of interesting items for radio and electronic hobbyist constructors. I was particularly taken by their line of RF shielded boxes. Why? Because it seems that RF projects are the main things I’ve built for the past 10 years.

Figure 1-9 shows one of the SESCOM RF shielded steel boxes in their SB-x line. Notice that it uses the “finger” construction in order to get a good RF-tight fit between the lid and the body of the box. Also notice that the box comes with some snap-in partitions for internal shielding between sections. The box body is punched to accept the tabs on these internal partitions, which can then be soldered in place for even better stability and shielding.

At first, I was a little concerned about the material; the boxes are made of hot tin-plated steel rather than aluminum. The tin plating makes soldering easy, but steel

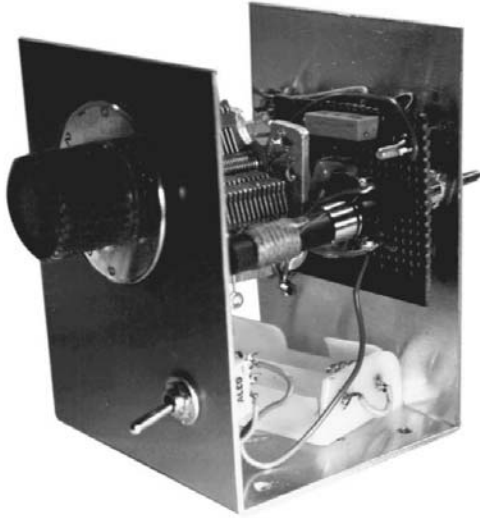


1-9 RF project box with superior shielding because of the finger-grip design of the top cover (one of a series made by SESCO).

is hard on drill bits. I found, however, in experimenting with the SB-5 box supplied to me by SESCO that a good-quality set of drill bits had no difficulty making a hole. Sure, if you use old, dull drill bits and lean on the drill like Attila the Hun, then you'll surely burn it out. But by using a good-quality, sharp bit and good workmanship practices to make the hole, there is no real problem.

The boxes come in 11 sizes from $2.1" \times 1.9"$ footprint to a $6.4" \times 2.7"$ footprint, with heights of 0.63," 1.0, or 1.1". Prices compare quite favorably with the prices of the better-quality aluminum boxes that don't shield so well at RF frequencies.

The small project in Fig. 1-10 is a small RF preselector for the AM broadcast band. It boosts weak signals and reduces interference from nearby stations. The tuning capacitor is mounted to the front panel and is fitted with a knob to facilitate tuning. An on/off switch is also mounted on the front panel (a battery pack inside the aluminum chassis box provides dc power). The inductor that works with the capacitor is passed through the perfboard (where the rest of the circuit is located) to the rear panel (where its adjustment slug can be reached).

**1-10**

Battery-powered RF project.

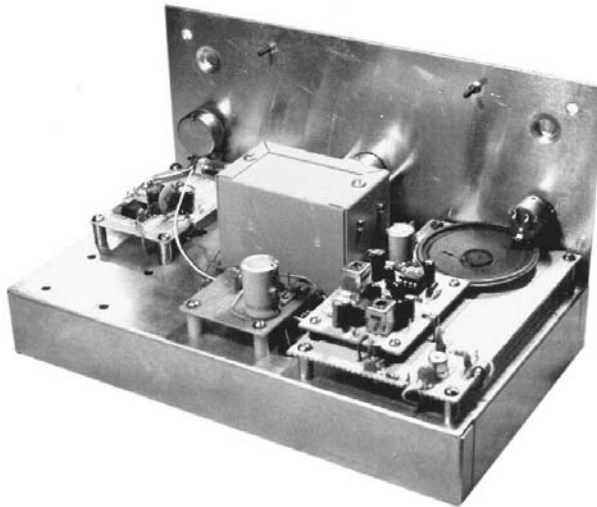
The project in Fig. 1-11 is a test that I built for checking out direct-conversion receiver designs. The circuit boards are designed to be modularized so that different sections of the circuit can easily be replaced with new designs. This approach allows comparison (on an “apples versus apples” basis) of different circuit designs.

Coaxial cable transmission line (“coax”)

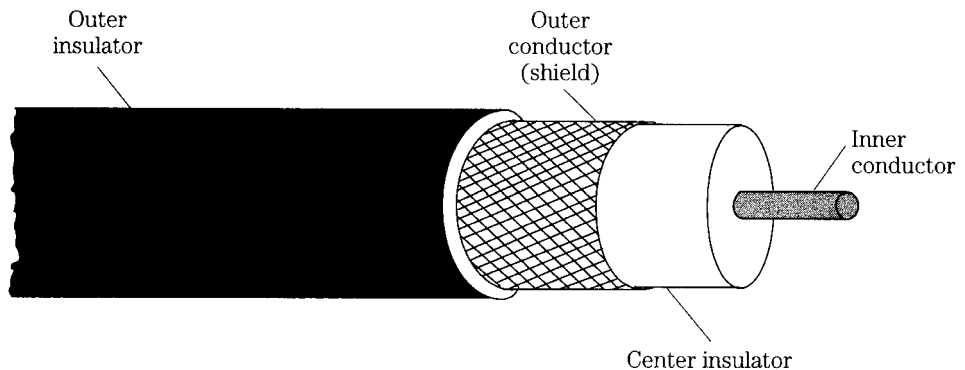
Perhaps the most common form of transmission line for shortwave and VHF/UHF receivers is coaxial cable. “Coax” consists of two conductors arranged concentric to each other and is called *coaxial* because the two conductors share the same center axis (Fig. 1-12). The inner conductor will be a solid or stranded wire, and the other conductor forms a shield. For the coax types used on receivers, the shield will be a braided conductor, although some multistranded types are also sometimes seen. Coaxial cable intended for television antenna systems has a $75\text{-}\Omega$ characteristic impedance and uses metal foil for the outer conductor. That type of outer conductor results in a low-loss cable over a wide frequency range but does not work too well for most applications outside of the TV world. The problem is that the foil is aluminum, which doesn’t take solder. The coaxial connectors used for those antennas are generally Type-F crimp-on connectors and have too high of a casualty rate for other uses.

The inner insulator separating the two conductors is the dielectric, of which there are several types; polyethylene, polyfoam, and Teflon are common (although the latter is used primarily at high-UHF and microwave frequencies). The velocity factor (V) of the coax is a function of which dielectric is used and is outlined as follows:

Dielectric type	Velocity factor
Polyethylene	0.66
Polyfoam	0.80
Teflon	0.70

**1-11**

Receiver chassis used as a "test bench" to try various modifications to a basic design.

**1-12** Coaxial cable (cut-away view).

Coaxial cable is available in a number of characteristic impedances from about 35 to 125 Ω , but the vast majority of types are either 52- or 75- Ω impedances. Several types that are popular with receiver antenna constructors include the following:

RG-8/U or RG-8/AU	52 Ω	Large diameter
RG-58/U or RG-58/AU	52 Ω	Small diameter
RG-174/U or RG-174/AU	52 Ω	Tiny diameter
RG-11/U or RG-11/AU	75 Ω	Large diameter
RG-59/U or RG-59/AU	75 Ω	Small diameter

Although the large-diameter types are somewhat lower-loss cables than the small diameters, the principal advantage of the larger cable is in power-handling capability. Although this is an important factor for ham radio operators, it is totally unimportant to receiver operators. Unless there is a long run (well over 100 feet), where cumulative losses become important, then it is usually more practical on receiver antennas to opt for the small-diameter (RG-58/U and RG-59/U) cables; they

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are a lot easier to handle. The tiny-diameter RG-174 is sometimes used on receiver antennas, but its principal use seems to be connection between devices (e.g., receiver and either preselector or ATU), in balun and coaxial phase shifters, and in instrumentation applications.

Installing coaxial connectors

One of the mysteries faced by newcomers to the radio hobbies is the small matter of installing coaxial connectors. These connectors are used to electrically and mechanically fasten the coaxial cable transmission line from the antenna to the receiver. There are two basic forms of coaxial connector, both of which are shown in Fig. 1-13 (along with an alligator clip and a banana-tip plug for size comparison). The larger connector is the PL-259 UHF connector, which is probably the most-common form used on radio receivers and transmitters (do not take the “UHF” too seriously, it is used at all frequencies). The PL-259 is a male connector, and it mates with the SO-239 female coaxial connector.

The smaller connector in Fig. 1-12 is a BNC connector. It is used mostly on electronic instrumentation, although it is used in some receivers (especially in handheld radios).

The BNC connector is a bit difficult, and very tedious, to correctly install so I recommend that most readers do as I do: Buy them already mounted on the wire. But the PL-259 connector is another matter. Besides not being readily available already mounted very often, it is relatively easy to install.

Figure 1-14A shows the PL-259 coaxial connector disassembled. Also shown in Fig. 1-14A is the diameter-reducing adapter that makes the connector suitable for use with smaller cables. Without the adapter, the PL-259 connector is used for RG-8/U and RG-11/U coaxial cable, but with the correct adapter, it will be used with smaller RG-58/U or RG-59/U cables (different adapters are needed for each type).



1-13

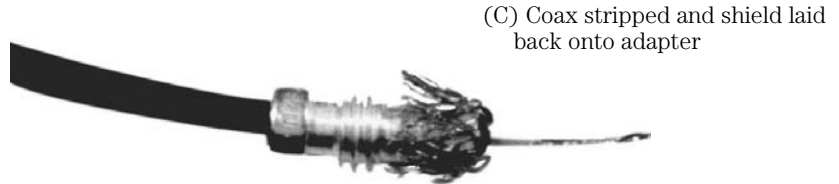
Various types of coaxial connectors, cable ends, and adapters.



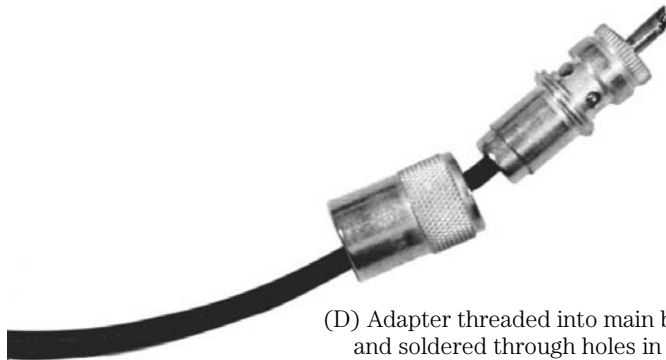
(A) Disassembled PL-29 connector



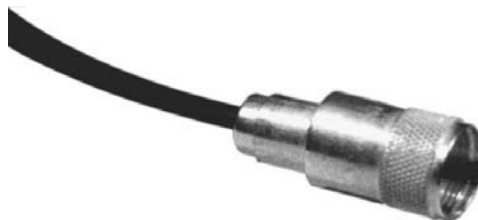
(B) Adapter and shield placed over the coax



(C) Coax stripped and shield laid back onto adapter



(D) Adapter threaded into main barrel and soldered through holes in barrel



(E) Finished connector.

1-14 Installing the PL-259 UHF connector.

The first step is to slip the adapter and thread the outer shell of the PL-259 over the end of the cable (Fig. 1-14B). You will be surprised at how many times, after the connector is installed, you find that one of these components is still sitting on the workbench . . . requiring the whole job to be redone (sigh). If the cable is short enough that these components are likely to fall off the other end, or if the cable is dangling a particularly long distance, then it might be wise to trap the adapter and outer shell in a knotted loop of wire (note: the knot should not be so tight as to kink the cable).

The second step is to prepare the coaxial cable. There are a number of tools for stripping coaxial cable, but they are expensive and not terribly cost-effective for anyone who does not do this stuff for a living. You can do just as effective a job with a scalpel or X-acto knife, either of which can be bought at hobby stores and some electronics parts stores. Follow these steps in preparing the cable:

1. Make a circumscribed cut around the body of the cable $\frac{3}{8}$ " from the end, and then make a longitudinal cut from the first cut to the end.
2. Now strip the outer insulation from the coax, exposing the shielded outer conductor.
3. Using a small, pointed tool, carefully unbraid the shield, being sure to separate the strands making up the shield. Lay it back over the outer insulation, out of the way.
4. Finally, using a wire stripper, side cutters or the scalpel, strip $\frac{5}{8}$ " of the inner insulation away, exposing the inner conductor. You should now have $\frac{5}{8}$ " of inner conductor and $\frac{3}{8}$ " of inner insulation exposed, and the outer shield destrand and laid back over the outer insulation.

Next, slide the adapter up to the edge of the outer insulator and lay the unbraided outer conductor over the adapter (Fig. 1-14C). Be sure that the shield strands are neatly arranged and then, using side cutters, neatly trim it to avoid interfering with the threads. Once the shield is laid onto the adapter, slip the connector over the adapter and tighten the threads (Fig. 1-14D). Some of the threads should be visible in the solder holes that are found in the groove ahead of the threads. It might be a good idea to use an ohmmeter or continuity connector to be sure that there is no electrical connection between the shield and inner conductor (indicating a short circuit).

Warning

Soldering involves using a hot soldering iron. The connector will become dangerously hot to the touch. Handle the connector with a tool or cloth covering.

- Solder the inner conductor to the center pin of the PL-259. Use a 100-W or greater soldering gun, not a low-heat soldering pencil.
- Solder the shield to the connector through the holes in the groove.
- Thread the outer shell of the connector over the body of the connector.

After you make a final test to make sure there is no short circuit, the connector is ready for use (Fig. 1-14E).

2 CHAPTER

RF components and tuned circuits

This chapter covers inductance (L) and capacitance (C), how they are affected by ac signals, and how they are combined into LC-tuned circuits. The tuned circuit allows the radio-frequency (RF) circuit to be selective about the frequency being passed. Alternatively, in the case of oscillators, LC components set the operating frequency of the circuit.

Tuned resonant circuits

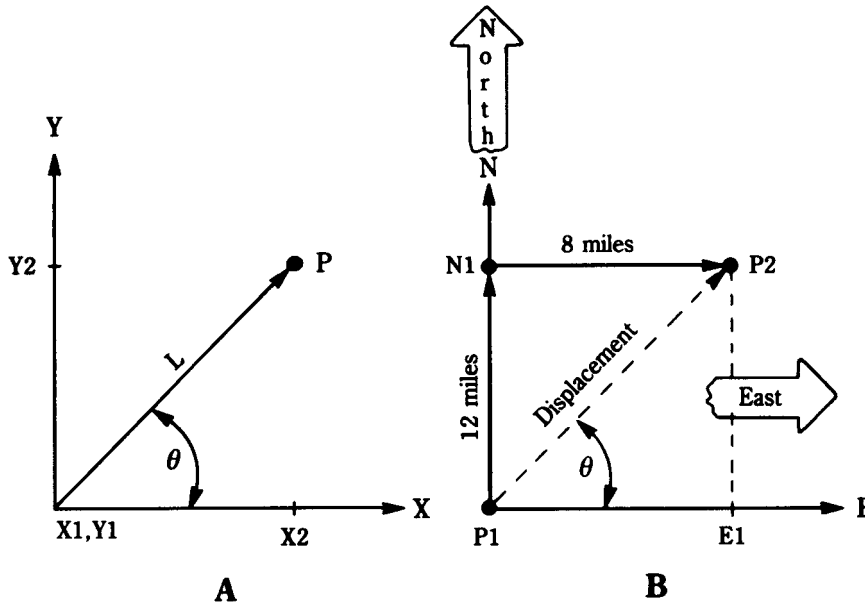
Tuned resonant circuits, also called *tank circuits* or *LC circuits*, are used in the radio front end to select from the myriad of stations available at the antenna. The tuned resonant circuit is made up of two principal components: inductors and capacitors, also known in old radio books as condensers. This section examines inductors and capacitors separately, and then in combination, to determine how they function to tune a radio's RF, intermediate-frequency (IF), and local oscillator (LO) circuits. First, a brief digression is needed to discuss vectors because they are used in describing the behavior of these components and circuits.

Vectors

A vector (Fig. 2-1A) is a graphical device that is used to define the magnitude and direction (both are needed) of a quantity or physical phenomenon. The length of the arrow defines the magnitude of the quantity, and the direction in which it points defines the direction of action of the quantity being represented.

Vectors can be used in combination with each other. For example, Fig. 2-1B shows a pair of displacement vectors that define a starting position (P_1) and a final position (P_2) for a person traveling 12 miles north from point P_1 and then 8 miles east to arrive at point P_2 . The displacement in this system is the hypotenuse of the

20 RF components and tuned circuits



2-1 (A) Vector notation is used in RF circuit analysis. The resultant of vector X and vector Y is vector L between (X_1, Y_1) and (X_2, Y_2) , or point P ; (B) A way of viewing vectors is to measure the displacement of a journey that is 12 miles north and 8 miles east.

right triangle formed by the north vector and the east vector. This concept was once vividly illustrated by a university bumper sticker's directions to get to a rival school: "North 'till you smell it, east 'til you step in it."

Another vector calculation trick is used a lot in engineering, science, and especially in electronics. You can translate a vector parallel to its original direction and still treat it as valid. The east vector (E) has been translated parallel to its original position so that its tail is at the same point as the tail of the north vector (N). This allows you to use the Pythagorean theorem to define the vector. The magnitude of the displacement vector to P_2 is given by

$$P_2 = \sqrt{N^2 + E^2}. \quad (2-1)$$

But recall that the magnitude only describes part of the vector's attributes. The other part is the direction of the vector. In the case of Fig. 2-1B, the direction can be defined as the angle between the east vector and the displacement vector. This angle (θ) is given by

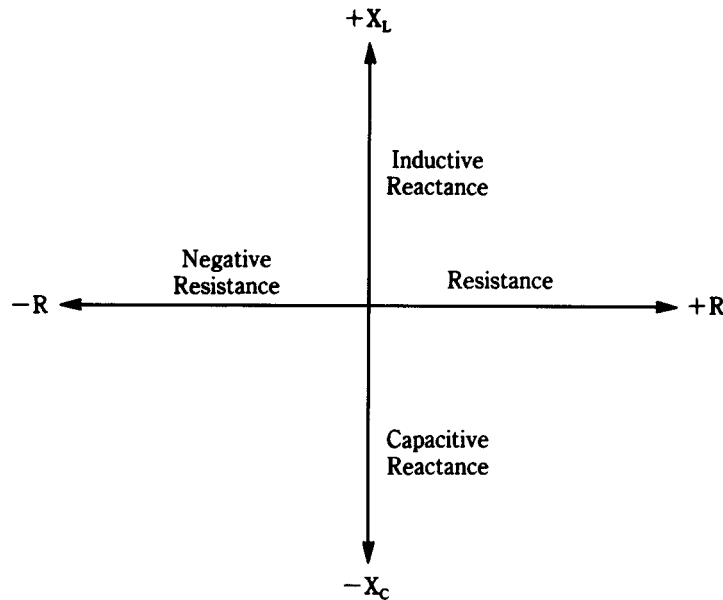
$$\theta = \arccos \left(\frac{E_1}{P} \right). \quad (2-2)$$

In generic vector notation, there is no natural or standard frame of reference so that the vector can be drawn in any direction so long as the user understands what it means. This system has adopted a method that is basically the same as the old-

fashioned Cartesian coordinate system X-Y graph. In the example of Fig. 2-1B, the X axis is the east–west vector and the Y axis is the north–south vector.

In electronics, vectors are used to describe voltages and currents in ac circuits. They are standardized (Fig. 2-2) on a similar Cartesian system where the inductive reactance (X_L) (i.e., the opposition to ac exhibited by inductors) is graphed in the north direction, the capacitive reactance (X_C) is graphed in the south direction, and the resistance (R) is graphed in the east direction.

Negative resistance (the west direction) is sometimes seen in electronics. It is a phenomenon in which the current decreases when the voltage increases. Some RF examples of negative resistance include tunnel diodes and Gunn diodes.



2-2 Vector system used in ac or RF circuit analysis.

Inductance and inductors

Inductance is the property of electrical circuits that opposes changes in the flow of current. Notice the word “changes”—it is important. As such, it is somewhat analogous to the concept of inertia in mechanics. An inductor stores energy in a magnetic field (a fact that you will see is quite important). In order to understand the concept of inductance, you must understand three physical facts:

1. When an electrical conductor moves relative to a magnetic field, a current is generated (or induced) in the conductor. An electromotive force (EMF or voltage) appears across the ends of the conductor.
2. When a conductor is in a magnetic field that is changing, a current is induced in the conductor. As in the first case, an EMF is generated across the conductor.

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3. When an electrical current moves in a conductor, a magnetic field is set up around the conductor.

According to Lenz's law, the EMF induced in a circuit is “. . . in a direction that opposes the effect that produced it.” From this fact, you can see the following effects:

1. A current induced by either the relative motion of a conductor and a magnetic field or changes in the magnetic field always flows in a direction that sets up a magnetic field that opposes the original magnetic field.
2. When a current flowing in a conductor changes, the magnetic field that it generates changes in a direction that induces a further current into the conductor that opposes the current change that caused the magnetic field to change.
3. The EMF generated by a change in current will have a polarity that is opposite to the polarity of the potential that created the original current.

Inductance is measured in henrys (H). The accepted definition of the henry is the inductance that creates an EMF of 1 V when the current in the inductor is changing at a rate of 1 A/S or

$$V = L \left(\frac{\Delta I}{\Delta t} \right) \quad (2-3)$$

where

V = induced EMF in volts (V)

L = inductance in henrys (H)

I = current in amperes (A)

t = time in seconds (s)

Δ = “small change in . . .”

The henry (H) is the appropriate unit for inductors used as the smoothing filter chokes used in dc power supplies, but is far too large for RF and IF circuits. In those circuits, subunits of millihenrys (mH) and microhenrys (μ H) are used. These are related to the henry as follows: 1 H = 1,000 mH = 1,000,000 μ H. Thus, 1 mH = 10^{-3} H and 1 μ H = 10^{-6} H.

The phenomena to be concerned with here is called *self-inductance*: when the current in a circuit changes, the magnetic field generated by that current change also changes. This changing magnetic field induces a countercurrent in the direction that opposes the original current change. This induced current also produces an EMF, which is called the *counter electromotive force* (CEMF). As with other forms of inductance, self-inductance is measured in henrys and its subunits.

Although inductance refers to several phenomena, when used alone it typically means self-inductance and will be so used in this chapter unless otherwise specified (e.g., mutual inductance). However, remember that the generic term can have more meanings than is commonly attributed to it.

Inductance of a single straight wire

Although it is commonly assumed that “inductors” are “coils,” and therefore consist of at least one, usually more, turns of wire around a cylindrical form, it is also true that a single, straight piece of wire possesses inductance. This inductance of a

wire in which the length is at least 1000 times its diameter (d) is given by the following:

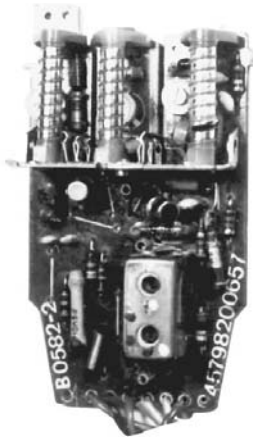
$$L_{\mu\text{H}} = 0.00508b \left(Ln \left(\frac{4a}{d} \right) - 0.75 \right). \quad (2-4)$$

The inductance values of representative small wires is very small in absolute numbers but at higher frequencies becomes a very appreciable portion of the whole inductance needed. Consider a 12" length of #30 wire ($d = 0.010$ in). Plugging these values into Eq. (2-4) yields the following:

$$L_{\mu\text{H}} = 0.00508 (12 \text{ in}) \left(Ln \left(\frac{4 \times 1 \text{ in}}{0.010 \text{ in}} \right) - 0.75 \right) \quad (2-5)$$

$$L_{\mu\text{H}} = 0.365 \mu\text{H}. \quad (2-6)$$

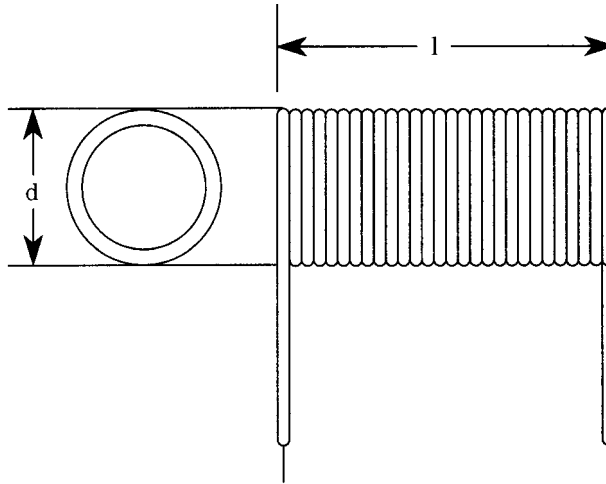
An inductance of $0.365 \mu\text{H}$ seems terribly small; at 1 MHz, it is small compared with inductances typically used as that frequency. But at 100 MHz, $0.365 \mu\text{H}$ could easily be more than the entire required circuit inductance. RF circuits have been created in which the inductance of a straight piece of wire is the total inductance. But when the inductance is an unintended consequence of the circuit wiring, it can become a disaster at higher frequencies. Such unintended inductance is called *stray inductance* and can be reduced by using broad, flat conductors to wind the coils. An example is the printed circuit coils wound on cylindrical forms in the FM radio receiver tuner in Fig. 2-3.



2-3
Printed circuit inductors.

Self-inductance can be increased by forming the conductor into a multiturn coil (Fig. 2-4) in such a manner that the magnetic field in adjacent turns reinforces itself. This requirement means that the turns of the coil must be insulated from each other. A coil wound in this manner is called an “inductor,” or simply a “coil,” in RF/IF circuits. To be technically correct, the inductor pictured in Fig. 2-4 is called a *solenoid wound coil* if the length (l) is greater than the diameter (d). The inductance of the coil is actually self-inductance, but the “self-” part is usually dropped and it is simply called *inductance*.

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2-4 Inductance is a function of the length (l) and diameter (d) of the coil.

Several factors affect the inductance of a coil. Perhaps the most obvious factors are the length, the diameter, and the number of turns in the coil. Also affecting the inductance is the nature of the core material and its cross-sectional area. In the examples of Fig. 2-3, the core is simply air and the cross-sectional area is directly related to the diameter. In many radio circuits, the core is made of powdered iron or ferrite materials.

For an air-core solenoid coil, in which the length is greater than $0.4d$, the inductance can be approximated by the following:

$$L_p = \frac{d^2 N^2}{18 d + 40 l} \quad (2-7)$$

The core material has a certain magnetic permeability (μ), which is the ratio of the number of lines of flux produced by the coil with the core inserted to the number of lines of flux with an air core (i.e., core removed). The inductance of the coil is multiplied by the permeability of the core.

Combining inductors in series and in parallel

When inductors are connected together in a circuit, their inductances combine similar to the resistances of several resistors in parallel or in series. For inductors in which their respective magnetic fields do not interact, the following equations are used:

Series connected inductors:

$$L_{\text{total}} = L_1 + L_2 + L_3 + \cdots + L_n \quad (2-8)$$

Parallel connected inductors:

$$L_{\text{total}} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_n}} \quad (2-9)$$

In the special case of the two inductors in parallel:

$$L_{\text{total}} = \frac{L_1 \times L_2}{L_1 + L_2}. \quad (2-10)$$

If the magnetic fields of the inductors in the circuit interact, the total inductance becomes somewhat more complicated to express. For the simple case of two inductors in series, the expression would be as follows.

Series inductors:

$$L_{\text{total}} = L_1 + L_2 \pm 2M, \quad (2-11)$$

where

M = mutual inductance caused by the interaction of the two magnetic fields.

(Note: $+M$ is used when the fields aid each other, and $-M$ is used when the fields are opposing.)

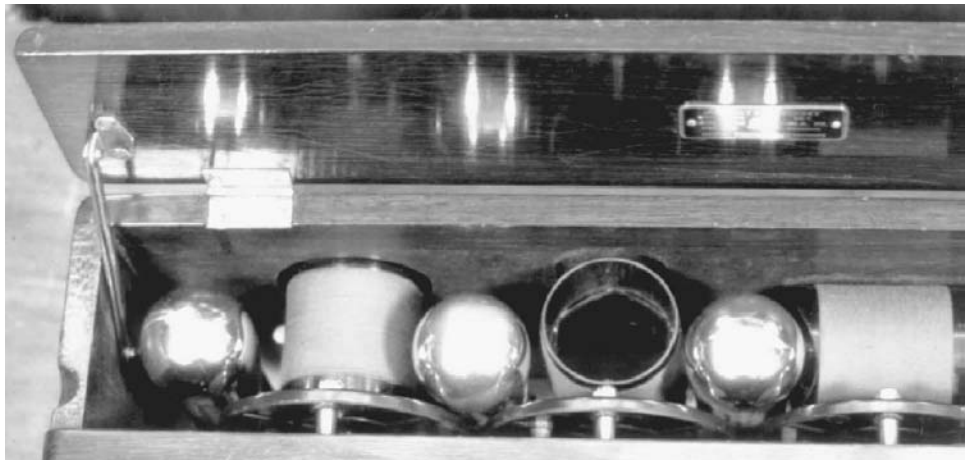
Parallel inductors:

$$L_{\text{total}} = \frac{1}{\left(\frac{1}{L_1 \pm M}\right) + \left(\frac{1}{L_2 \pm M}\right)}. \quad (2-12)$$

Some LC tank circuits use air-core coils in their tuning circuits (Fig. 2-5). Notice that two of the coils in Fig. 2-5 are aligned at right angles to the other one. The reason for this arrangement is not mere convenience but rather is a method used by the radio designer to prevent interaction of the magnetic fields of the respective coils. In general, for coils in close proximity to each other the following two principles apply:

1. Maximum interaction between the coils occurs when the coils' axes are parallel to each other.
2. Minimum interaction between the coils occurs when the coils' axes are at right angles to each other.

For the case where the coils' axes are along the same line, the interaction depends on the distance between the coils.



2-5 Inductors in an antique radio set.

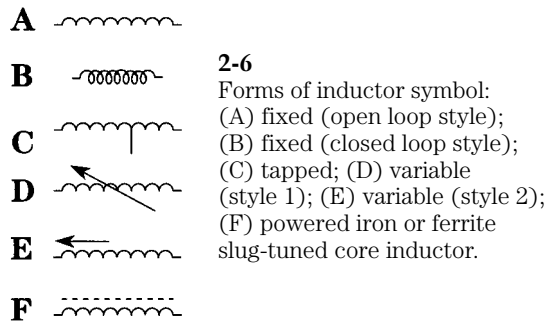
Inductor circuit symbols

Figure 2-6 shows various circuit symbols used in schematic diagrams to represent inductors. Figures 2-6A and 2-6B represent alternate, but equivalent, forms of the same thing; i.e., a fixed value, air-core inductor (“coil” in the vernacular). The other forms of inductor symbol shown in Fig. 2-6 are based on Fig. 2-6A but are just as valid if the “open-loop” form of Fig. 2-6B is used instead.

The form shown in Fig. 2-6C is a tapped fixed-value air-core inductor. By providing a tap on the coil, different values of fixed inductance are achieved. The inductance from one end of the coil to the tap is a fraction of the inductance available across the entire coil. By providing one or more taps, several different fixed values of inductance can be selected. Radio receivers and transmitters sometimes use the tap method, along with a bandswitch, to select different tuning ranges or “bands.”

Variable inductors are shown in Figs. 2-6D and 2-6E. Both forms are used in schematic diagrams, although in some countries Fig. 2-6D implies a form of construction whereby a wiper or sliding electrical contact rides on the uninsulated turns of the coil. Figure 2-6E implies a construction where variable inductance is achieved by moving a magnetic core inside of the coil.

Figure 2-6F indicates a fixed value (or tapped, if desired) inductor with a powdered iron, ferrite or nonferrous (e.g., brass) core. The core will increase (ferrite or powdered iron) or decrease (brass) the inductance value relative to the same number of turns on an air core coil.



Inductors in ac circuits

Impedance (Z) is the total opposition to the flow of ac in a circuit and as such it is analogous to resistance in dc circuits. Impedance is made up of a resistance component (R) and a component called reactance (X). Like resistance, reactance is measured in ohms. If the reactance is produced by an inductor, then it is called *inductive reactance* (X_L) and if by a capacitor it is called *capacitive reactance* (X_C). Inductive reactance is a function of the inductance and the frequency of the ac source:

$$X_L = 2\pi FL \quad (2-13)$$

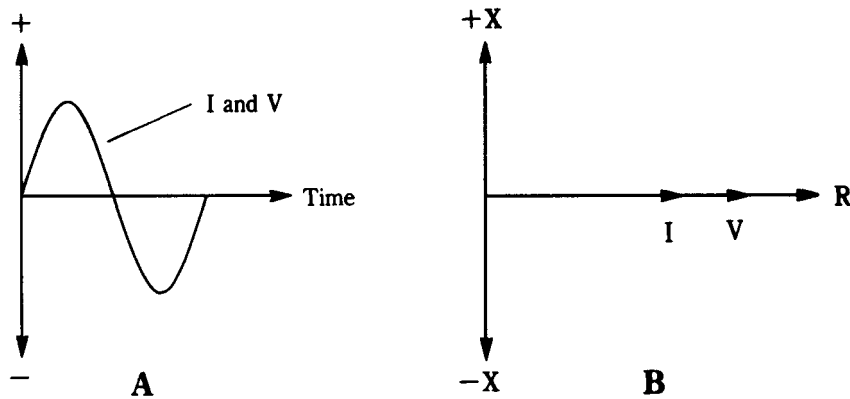
where

X_L = inductive reactance in ohms (Ω)

F = ac frequency in hertz (Hz)

L = inductance in henrys (H).

In a purely resistive ac circuit (Fig. 2-7A), the current (I) and voltage (V) are said to be in phase with each other (i.e., they rise and fall at exactly the same times in the ac cycle). In vector notation (Fig. 2-7B), the current and voltage vectors are along the same axis, which is an indication of the zero-degree phase difference between the two.



2-7 (A) Current and voltage in phase with each other (sine wave with vector notation); (B) vector relationship.

In an ac circuit that contains only an inductor (Fig. 2-8A), and is excited by a sine-wave ac source, the change in current is opposed by the inductance. As a result, the current in an inductive circuit lags behind the voltage by 90° . This is shown vectorially in Fig. 2-8B, and as a pair of sine waves in Fig. 2-8C.

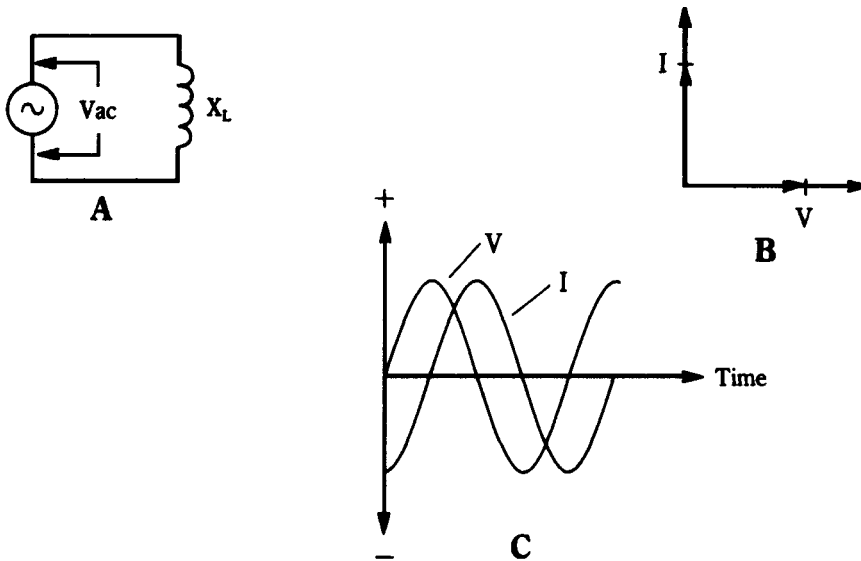
The ac circuit that contains a resistance and an inductance (Fig. 2-9B) shows a phase shift (θ), shown vectorially in Fig. 2-9A, other than the 90° difference seen in purely inductive circuits. The phase shift is proportional to the voltage across the inductor and the current flowing through it. The impedance of this circuit is found by the Pythagorean rule described earlier, also called the root of the sum of squares method (see Fig. 2-9):

$$Z = \sqrt{R^2 + X_L^2}. \quad (2-14)$$

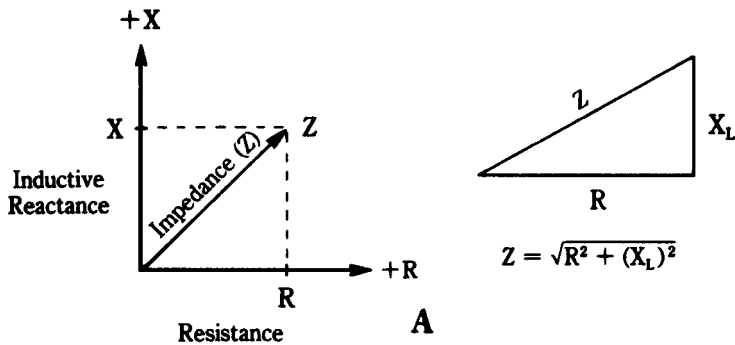
The coils used in radio receivers come in a variety of different forms and types, but all radios (except the very crudest untuned crystal sets) will have at least one coil.

Now let us turn our attention to the other member of the LC tuned circuit, the capacitor.

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2-8 (A) Inductor ac circuit; (B) vector relationships; (C) sine-wave representation.



2-9 (A) Resistor-inductor (RL) circuit; (B) vector relationships.

Air-core inductors

An air-core inductor actually has no core so it might also be called a *coreless coil*. Although it can be argued that the performance of an inductor differs between air and vacuum cores, the degree of difference is so negligible as to fall into the “decimal dust” category.

Three different forms of air-core inductor can be recognized. If the length (b) of a cylindrical coil is greater than, or equal to, the diameter (d) then the coil is said to be solenoid-wound. But if the length is much shorter than the diameter then the coil is said to be *loop-wound*. There is a gray area around the breakpoint between these inductors where the loop-wound coil seems to work somewhat like a solenoid-wound coil, but in the main most loop-wound coils are such that $b < d$. The principal uses of loop-wound coils is in making loop antennas for interference nulling and radio direction finding (RDF) applications.

Solenoid-wound air-core inductors

An example of the solenoid-wound air-core inductor was shown in Fig. 2-4. This form of coil is longer than its own diameter. The inductance of the solenoid-wound coil is given by the following:

$$L_{\mu\text{H}} = \frac{a^2 N^2}{9a + 10b}, \quad (2-15)$$

where

$L_{\mu\text{H}}$ is the inductance in microhenrys (μH)

a is the coil radius in inches (in)

b is the coil length in inches (in)

N is the number of turns in the coil.

This equation will allow calculation of the inductance of a known coil, but we usually need to know the number of turns (N) required to achieve some specific inductance value determined by the application. For this purpose, we rearrange the equation in the form:

$$N = \frac{\sqrt{L(9a + 10b)}}{a}. \quad (2-16)$$

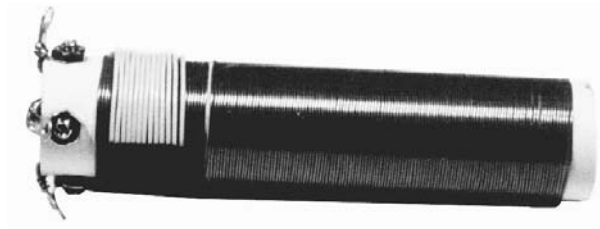
Several different forms of solenoid-wound air-core inductor are shown in Fig. 2-10. The version shown in Fig. 2-10A is homemade on a form of 25-mm PVC plumbing pipe, sawn to a length of about 80 mm and fitted at one end with solder lugs secured with small machine screws and hex nuts. The main inductor is shown in the dark-colored #24 AWG enamel-coated wire, while a small winding is made from #26 AWG insulated hook-up wire. The use of two coaxial inductors makes this assembly a transformer. The small primary winding can be connected between ground and an aerial, and the larger secondary winding can be resonated with a variable capacitor.

The air-core coil shown in Fig. 2-10B is part of an older radio transmitter, where it forms the anode tuning inductance.¹ Because several different frequency bands must be accommodated, there are actually several coils on the same form. The re-

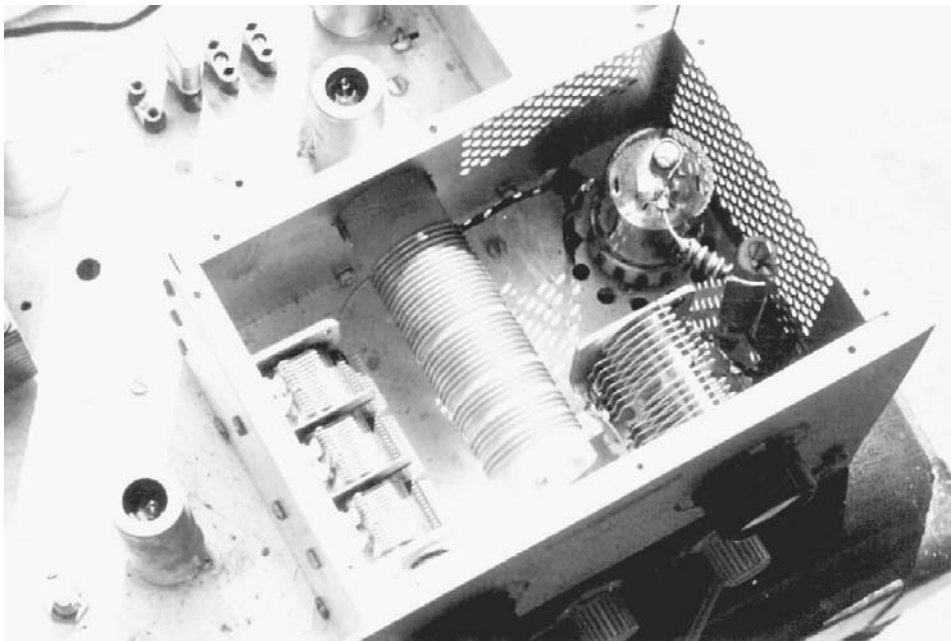
¹ Amateur radio operators might recognize this unit as the Heathkit DX-60B transmitter.

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quired sections are switch-selected according to the band of operation. Another method for achieving tapped inductance is shown in Fig. 2-10C. This coil is a commercial air-core coil made by Barker & Williamson. Some models of this coil stock come with alternate windings indented to facilitate the connection of a tap. In any case, it is easy to press in the windings adjacent to the connection point. The variant shown in Fig. 6-10D was found, oddly enough, on a 1000-W HF motorcycle mobile. The whip antenna is resonated by using an alligator clip to select the number of turns from the coil.

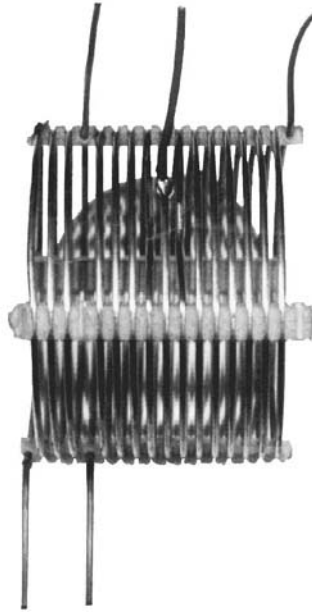


A



B

2-10 (A) Solenoid wound inductor with transformer coupling link; (B) inductor used as a tank circuit in radio transmitter; (C) tapped inductor; (D) tapped inductor on mobile antenna; (E) roller inductor.

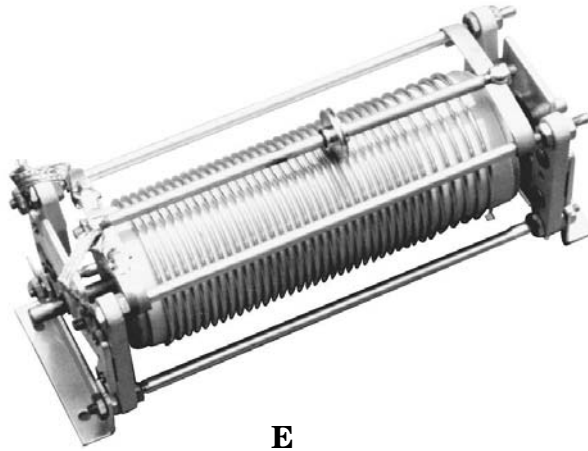


C



D

2-10 *Continued*

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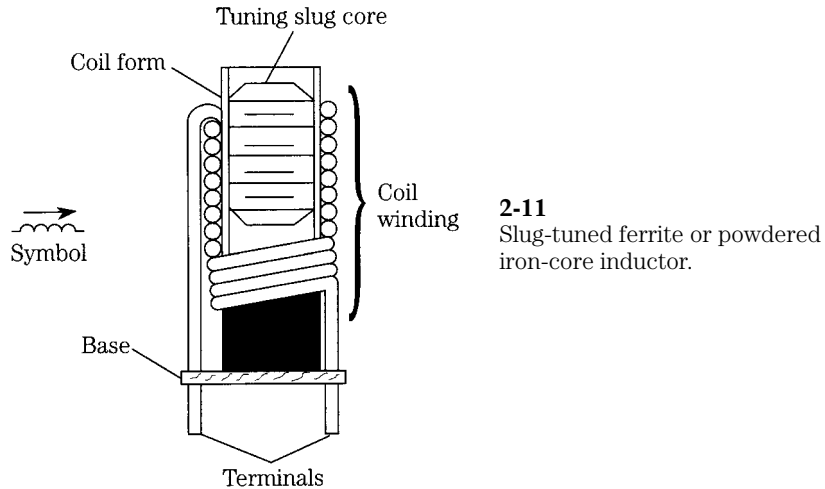
The air-core coil shown in Fig. 2-10E is a rotary inductor of the type found in some HF transmitters, antenna-tuning units, and other applications where continuous control of frequency is required. The inductor coil is mounted on a ceramic form that can be rotated using a shaft protruding from one end. As the form rotates, a movable shorting element rides along the turns of the coil to select the required inductance. Notice in Fig. 2-10E that the pitch (number of turns per unit length) is not constant along the length of the coil. This “pitch-winding” method is used to provide a nearly constant change of inductance for each revolution of the adjustment shaft.

Adjustable coils

There are several practical problems with the preceding standard fixed coil. For one thing, the inductance cannot easily be adjusted—either to tune the radio or to trim the tuning circuits to account for the tolerances in the circuit.

Air-core coils are difficult to adjust. They can be lengthened or shortened, the number of turns can be changed, or a tap or series of taps can be established on the coil in order to allow an external switch to select the number of turns that are allowed to be effective. None of these methods is terribly elegant—even though all have been used in one application or another.

The solution to the adjustable inductor problem that was developed relatively early in the history of mass-produced radios, and is still used today, is to insert a powdered iron or ferrite core (or “slug”) inside the coil form (Fig. 2-11). The permeability of the core will increase or decrease the inductance according to how much of the core is inside the coil. If the core is made with either a hexagonal hole or screwdriver slot, then the inductance of the coil can be adjusted by moving the core in or out of the coil. These coils are called *slug-tuned inductors*.



Capacitors and capacitance

Capacitors are the other component used in radio tuning circuits. Like the inductor, the capacitor is an energy-storage device. Although the inductor stores electrical energy in a magnetic field, the capacitor stores energy in an electrical (or “electrostatic”) field. Electrical charge, Q , is stored in the capacitor. But more about that shortly.

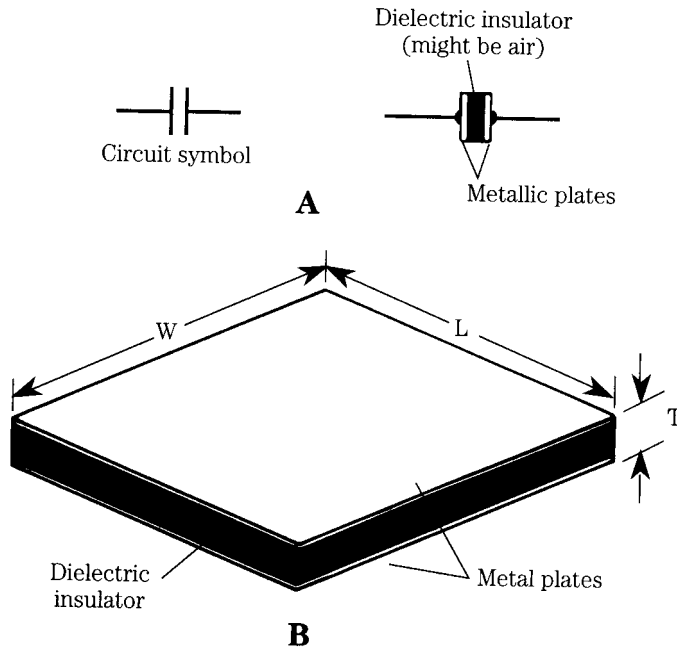
The basic capacitor consists of a pair of metallic plates that face each other and are separated by an insulating material, called a *dielectric*. This arrangement is shown schematically in Fig. 2-12A and in a more physical sense in Fig. 2-12B. The fixed capacitor shown in Fig. 2-12B consists of a pair of square metal plates separated by a dielectric. Although this type of capacitor is not terribly practical, it was once used quite a bit in transmitters. Spark transmitters of the 1920s often used a glass and tinfoil capacitor that looked very much like Fig. 2-12B. Layers of glass and foil are sandwiched together to form a high-voltage capacitor. A 1-ft square capacitor made of $\frac{1}{8}$ -in-thick glass and foil has a capacitance of about 2000 picofarads (pF).

Units of capacitance

Capacitance (C) is a measure of a capacitor’s ability to store current or, more properly, electrical charge. The principal unit of capacitance is the farad (F) (named after physicist Michael Faraday). One farad is the capacitance that will store one coulomb of electrical charge (6.28×10^{18} electrons) at an electrical potential of 1 V, or, in math form:

$$1F = \frac{1Q}{1V}, \quad (2-17)$$

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2-12 (A) Capacitors consist of a pair of conductors separated by a dielectric (insulator); (B) parallel plate capacitor.

where

C = capacitance in farads (F)

Q = electrical charge in coulombs (q)

V = electrical potential in volts (V)

The farad is far too large for practical electronics work, so subunits are used. The microfarad (μF) is 0.000001 farads ($1\text{F} = 10^6 \mu\text{F}$). The picofarad (pF) is $0.000001 \mu\text{F} = 10^{-12}$ farads. In older radio texts and schematics, the picofarad was called the *micromicrofarad* ($\mu\mu\text{F}$).

The capacitance of the capacitor is directly proportional to the area of the plates (in terms of Fig. 2-12B, $L \times W$), inversely proportional to the thickness (T) of the dielectric (or the spacing between the plates, if you prefer), and directly proportional to the dielectric constant (K) of the dielectric.

The dielectric constant is a property of the insulating material used for the dielectric. The dielectric constant is a measure of the material's ability to support electric flux and is thus analogous to the permeability of a magnetic material. The standard of reference for the dielectric constant is a perfect vacuum, which is said to have a value of $K = 1.00000$. Other materials are compared with the vacuum. The values of K for some common materials are as follows:

- vacuum: 1.0000
- dry air: 1.0006
- paraffin (wax) paper: 3.5

- glass: 5 to 10
- mica: 3 to 6
- rubber: 2.5 to 35
- dry wood: 2.5 to 8
- pure (distilled) water: 81

The value of capacitance in any given capacitor is found using the following:

$$C = \frac{0.0885 KA(N - 1)}{T}, \quad (2-18)$$

where

C = capacitance in picofarads

K = dielectric constant

A = area of one of the plates ($L \times W$), assuming that the two plates are identical

N = number of identical plates

T = thickness of the dielectric.

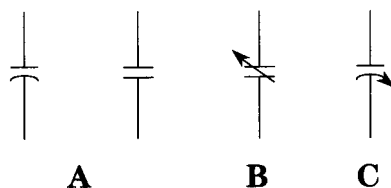
Breakdown voltage

The capacitor works by supporting an electrical field between two metal plates. This potential, however, can get too large. When the electrical potential (i.e., the voltage) gets too large, free electrons in the dielectric material (there are a few, but not too many, in any insulator) might flow. If a stream of electrons gets started, then the dielectric might break down and allow a current to pass between the plates. The capacitor is then shorted. The maximum breakdown voltage of the capacitor must not be exceeded. However, for practical purposes, there is a smaller voltage called the *dc working voltage (WVdc) rating*, which is the maximum safe voltage that can be applied to the capacitor. Typical values found in common electronic circuits are from 8 to 1000 WVdc, with values to many kilovolts less commonly available.

Circuit symbols for capacitors

The circuit symbols used to designate fixed-value capacitors are shown in Fig. 2-13A. Both types of symbols are common. In certain types of capacitors, the curved plate shown on the left in Fig. 2-13A is usually the outer plate (i.e., the one closest to the outside package of the capacitor). This end of the capacitor is often indicated by a colored band next to the lead attached to that plate.

The symbol for the variable capacitor is shown in Fig. 2-13B. The symbol for a variable capacitor is the fixed-value symbol with an arrow through the plates. Small trimmer and padder capacitors are often denoted by the symbol in Fig. 2-13C. The variable set of plates is designated by the arrow.



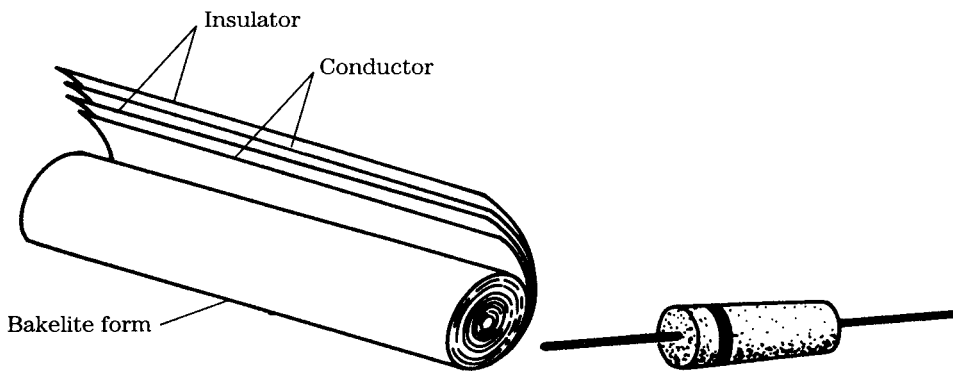
2-13

Capacitor symbols: (A) fixed-value; (B) variable; (C) trimmer and padder.

Fixed capacitors

Several types of fixed capacitors are used in typical electronic circuits. They are classified by dielectric type: paper, mylar, ceramic, mica, polyester, and others.

The construction of an old-fashioned paper capacitor is shown in Fig. 2-14. It consists of two strips of metal foil sandwiched on both sides of a strip of paraffin wax paper. The strip sandwich is then rolled up into a tight cylinder. This rolled-up cylinder is then packaged in either a hard plastic, bakelite, or paper-and-wax case. When the case is cracked, or the wax plugs are loose, replace the capacitor even though it tests as good—it won't be for long. Paper capacitors come in values from about 300 pF to about 4 μ F. The breakdown voltages will be from 100 to 600 WVdc.

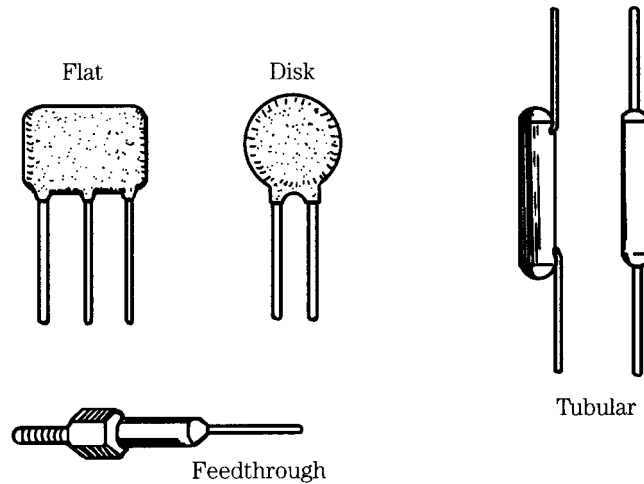


2-14 Paper capacitor construction.

The paper capacitor was used for a number of different applications in older circuits, such as bypassing, coupling, and dc blocking. Unfortunately, no component is perfect. The long rolls of foil used in the paper capacitor exhibit a significant amount of stray inductance. As a result, the paper capacitor is not used for high frequencies. Although they are found in some shortwave receiver circuits, they are rarely (if ever) used at VHF.

In modern applications, or when servicing older equipment containing paper capacitors, use a mylar dielectric capacitor in place of the paper capacitor. Select a unit with exactly the same capacitance rating and a WVdc rating that is equal to or greater than the original WVdc rating.

Several different forms of ceramic capacitors are shown in Fig. 2-15. These capacitors come in values from a few picofarads to 0.5 μ F. The working voltages range from 400 WVdc to more than 30,000 WVdc. The common garden-variety disk ceramic capacitors are usually rated at either 600 to 1000 WVdc. Tubular ceramic capacitors are typically much smaller in value than disk or flat capacitors and are used extensively in VHF and UHF circuits for blocking, decoupling, bypassing, coupling, and tuning.



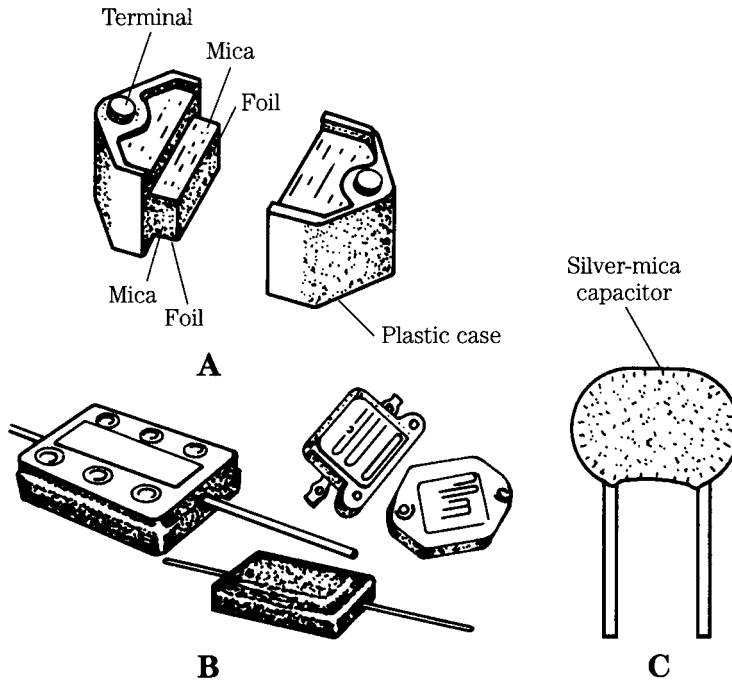
2-15 Ceramic capacitors.

The feedthrough type of ceramic capacitor is used to pass dc and low-frequency ac lines through a shielded panel. These capacitors are often used to filter or decouple lines that run between circuits separated by the shield for purposes of electromagnetic interference (EMI) reduction.

Ceramic capacitors are often rated as to the temperature coefficient. This specification is the change of capacitance per change in temperature in degrees Celsius. A “P” prefix indicates a positive temperature coefficient, an “N” indicates a negative temperature coefficient, and the letters “NPO” indicate a zero temperature coefficient (NPO stands for “negative positive zero”). Do not ad lib on these ratings when servicing a piece of electronic equipment. Use exactly the same temperature coefficient as the original manufacturer used. Nonzero temperature coefficients are often used in oscillator circuits to temperature compensate the oscillator’s frequency drift.

Several different types of mica capacitors are shown in Fig. 2-16. The fixed mica capacitor consists of metal plates on either side of a sheet of mica or a sheet of mica silvered with a deposit of metal on either side. The range of values for mica capacitors tends to be 50 pF to 0.02 μ F at voltages in the range of 400 to 1000 WVdc. The mica capacitor shown in Fig. 2-16C is called a *silver mica capacitor*. These capacitors have a low temperature coefficient, although for most applications, an NPO disk ceramic capacitor will provide better service than all but the best silver mica units (silver mica temperature coefficients have greater variation than NPO temperature coefficients). Mica capacitors are typically used for tuning and other uses in higher-frequency applications.

Today’s equipment designer has a number of different dielectric capacitors available that were not commonly available (or available at all) a few years ago. Polycarbonate, polyester, and polyethylene capacitors are used in a wide variety of applications where the capacitors described in the previous paragraphs once ruled supreme. In digital circuits, tiny 100-WVdc capacitors carry ratings of 0.01 to 0.5 μ F.



2-16 Mica capacitors.

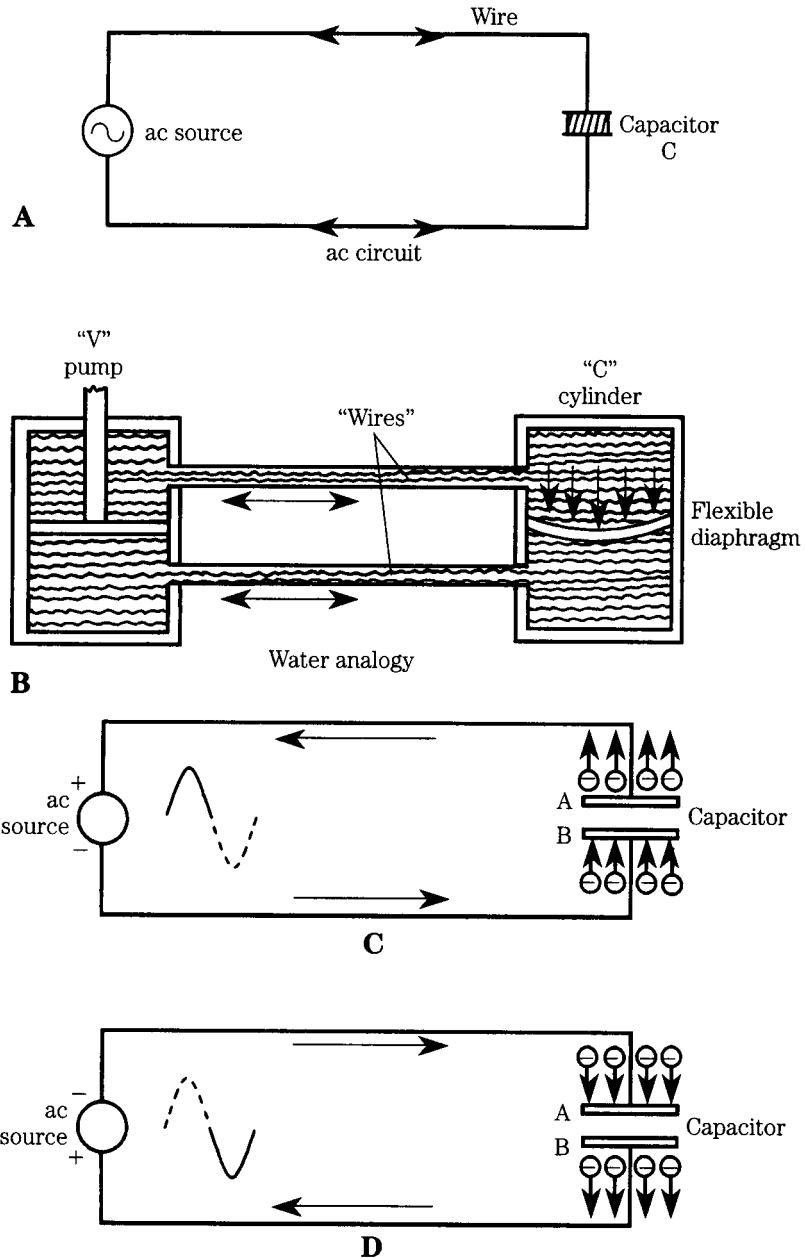
These are used for decoupling the noise on the +5-Vdc power-supply line. In circuits, such as timers and op-amp Miller integrators, where the leakage resistance across the capacitor becomes terribly important, it might be better to use a polyethylene capacitor.

Check current catalogs for various old and new capacitor styles. The applications paragraph in the catalog will tell you what applications each can be used for as well as provide a guide to the type of antique capacitor it will replace.

Capacitors in ac circuits

When an electrical potential is applied across a capacitor, current will flow as charge is stored in the capacitor. As the charge in the capacitor increases, the voltage across the capacitor plates rises until it equals the applied potential. At this point, the capacitor is fully charged, and no further current will flow.

Figure 2-17 shows an analogy for the capacitor in an ac circuit. The actual circuit is shown in Fig. 2-17A. It consists of an ac source connected in parallel across the capacitor. The mechanical analogy is shown in Fig. 2-17B. The capacitor consists of a two-chambered cylinder in which the upper and lower chambers are separated by a flexible membrane or diaphragm. The wires are pipes to the ac source (which is a pump). As the pump moves up and down, pressure is applied to the first side of the diaphragm and then the other, alternately forcing fluid to flow into and out of the two chambers of the capacitor.



2-17 Capacitor circuit analogy and capacitor circuit action.

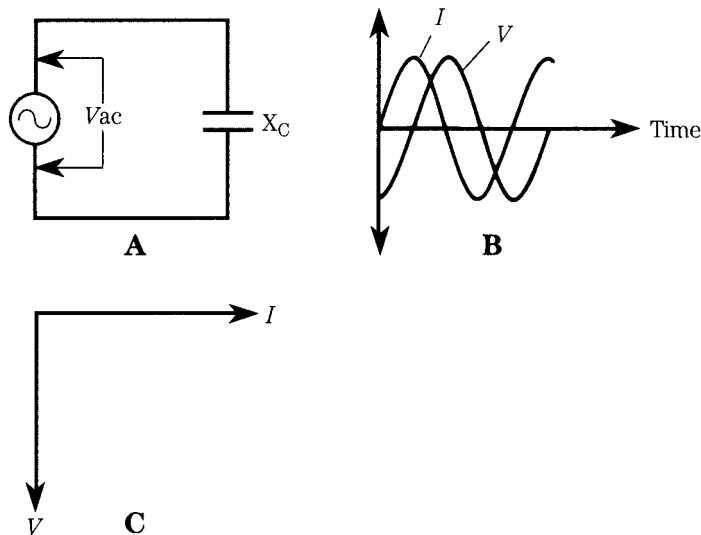
The ac circuit mechanical analogy is not perfect, but it works for these purposes. Apply these ideas to the electrical case. Figure 2-17 shows a capacitor connected across an ac (sine-wave) source. In Fig. 2-17A, the ac source is positive, so negatively charged electrons are attracted from plate A to the ac source and electrons

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from the negative terminal of the source are repelled toward plate B of the capacitor. On the alternate half-cycle (Fig. 2-17B), the polarity is reversed. Electrons from the new negative pole of the source are repelled toward plate A of the capacitor and electrons from plate B are attracted toward the source. Thus, current will flow in and out of the capacitor on alternating half-cycles of the ac source.

Voltage and current in capacitor circuits

Consider the circuit in Fig. 2-18: an ac source connected in parallel with the capacitor. It is the nature of a capacitor to oppose these changes in the applied voltage (the inverse of the action of an inductor). As a result, the voltage lags behind the current by 90 degrees. These relationships are shown in terms of sine waves in Fig. 2-18B and in vector form in Fig. 2-18C.

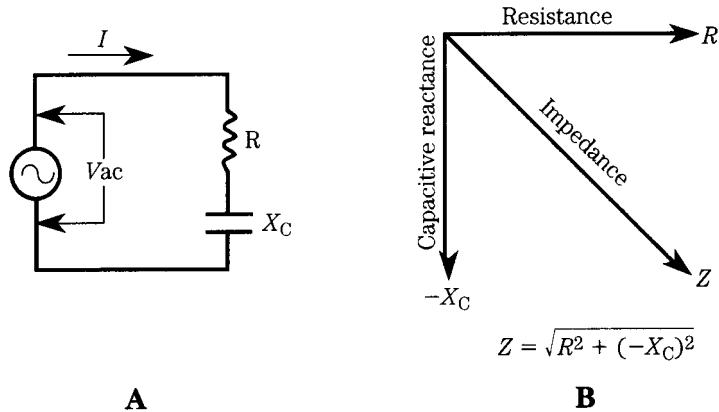


2-18 (A) Ac circuit using a capacitor; (B) sine-wave relationship between V and I ; (C) vector representation.

Do you remember the differences in the actions of inductors and capacitors on voltage and current? In earlier texts, the letter E was used to denote voltage, so you could make a little mnemonic: “ELI the ICE man.”

“ELI the ICE man” suggests that in the inductive (L) circuit, the voltage (E) comes before the current (I): ELI; in a capacitive (C) circuit, the current comes before the voltage: ICE.

The action of a circuit containing a resistance and capacitance is shown in Fig. 2-19A. As in the case of the inductive circuit, there is no phase shift across the resistor, so the R vector points in the east direction (Fig. 2-19B). The voltage across the capacitor, however, is phase-shifted 90° so its vector points south. The total resultant phase shift (ϕ) is found using the Pythagorean rule to calculate the angle between V_R and V_T .



2-19 (A) Resistor-capacitor (RC) circuit; (B) vector representation of circuit action.

The impedance of an RC circuit is found in exactly the same manner as the impedance of an RL circuit; that is, as the root of the sum of the squares:

$$Z = \sqrt{R^2 + X_C^2}. \quad (2-19)$$

LC Resonant tank circuits

When you use an inductor and a capacitor together in the same circuit, the combination forms an LC resonant circuit, which is sometimes called a *tank circuit* or *resonant tank circuit*. These circuits can be used to tune a radio receiver as well as in other applications. There are two basic forms of LC resonant tank circuit: series (Fig. 2-20A) and parallel (Fig. 2-20B). These circuits have much in common and much that makes them fundamentally different from each other.

The condition of resonance occurs when the capacitive reactance and inductive reactance are equal. As a result, the resonant tank circuit shows up as purely resistive at the resonant frequency (see Fig. 2-20C) and as a complex impedance at other frequencies. The LC resonant tank circuit operates by an oscillatory exchange of energy between the magnetic field of the inductor and the electrostatic field of the capacitor, with a current between them carrying the charge.

Because the two reactances are both frequency-dependent, and because they are inverse to each other, the resonance occurs at only one frequency (F_R). You can calculate the standard resonance frequency by setting the two reactances equal to each other and solving for F . The result is as follows:

$$F = \frac{1}{2\pi\sqrt{LC}}, \quad (2-20)$$

where

F is in hertz (Hz)

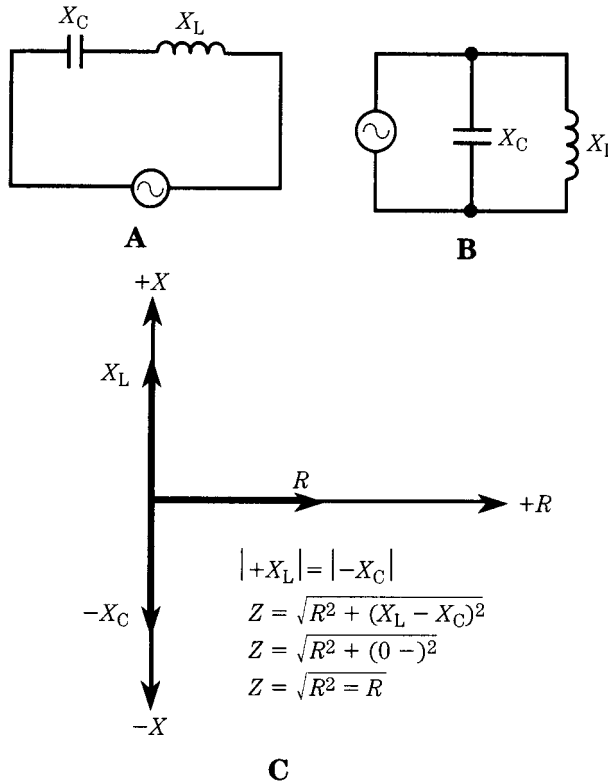
L is in henrys (H)

C is in farads (F).

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Series-resonant circuits

The series-resonant circuit (Fig. 2-20A), like other series circuits, is arranged so that the terminal current (I) from the source (V) flows in both components equally.

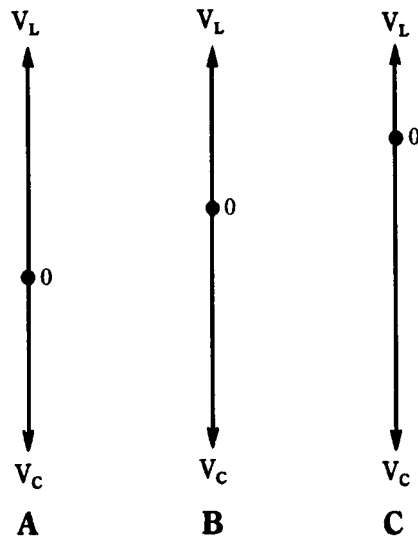


2-20 (A) Series inductor-capacitor (LC) circuit; (B) parallel LC circuit; (C) vector relationships.

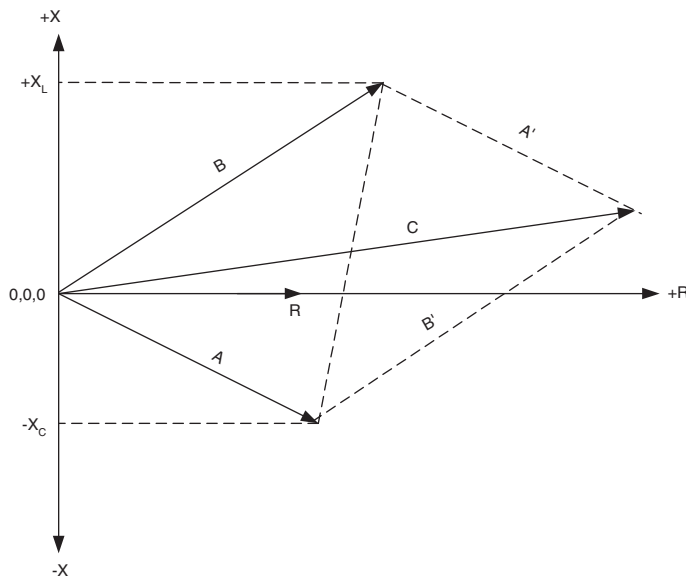
The vector diagrams of Fig. 2-21A through 2-21C show the situation under three different conditions:

- Figure 2-21A: The inductive reactance is larger than the capacitive reactance, so the excitation frequency is greater than F_R . Notice that the voltage drop across the inductor is greater than that across the capacitor, so the total circuit looks like it contains a small inductive reactance.
- Figure 2-21B: The situation is reversed. The excitation frequency is less than the resonant frequency, so the circuit looks slightly capacitive to the outside world.
- Figure 2-21C: The excitation frequency is at the resonant frequency, so $X_C = X_L$ and the voltage drops across the two components are of equal but opposite phase.

In a circuit that contains a resistance, an inductive reactance, and a capacitive reactance, there are three vectors (X_L , X_C , and R) to consider (Fig. 2-22) plus a resultant vector. As in the other circuit, the north direction is X_L , the south direction is X_C , and the east direction is R . Using the parallelogram method, construct a resultant for R and X_C , which is shown as vector A . Next, construct the same kind of vector (B) for R and X_L . The resultant vector (C) is made using the parallelogram method on vectors A and B . Vector C represents the impedance of the circuit: The magnitude is represented by the length and the phase angle by the angle between vector C and R .

**2-21**

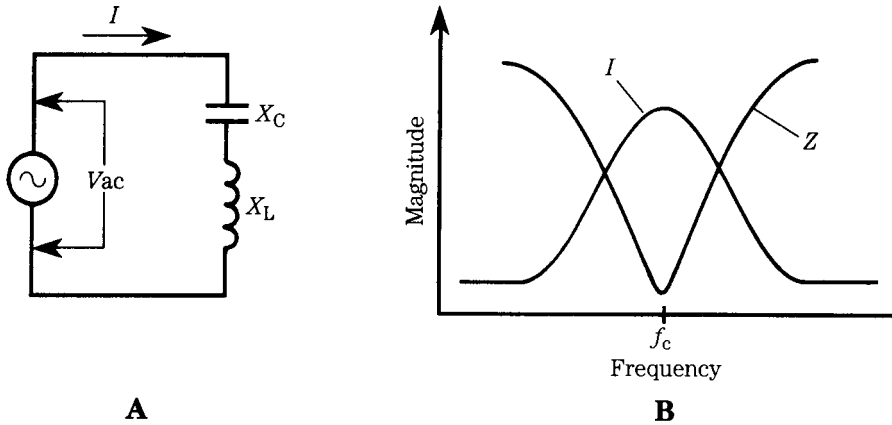
Vector relationships for circuits in which (A) $X_L > X_C$; (B) $X_L < X_C$; and (C) $X_L = X_C$.

**2-22**

Vector relationships for an RLC circuit.

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Figure 2-23A shows a series-resonant LC tank circuit, and Fig. 2-23B shows the current and impedance as a function of frequency. Series-resonant circuits have a low impedance at the resonant frequency and a high impedance at all other frequencies. As a result, the line current from the source is maximum at the resonant frequency and the voltage across the source is minimum.

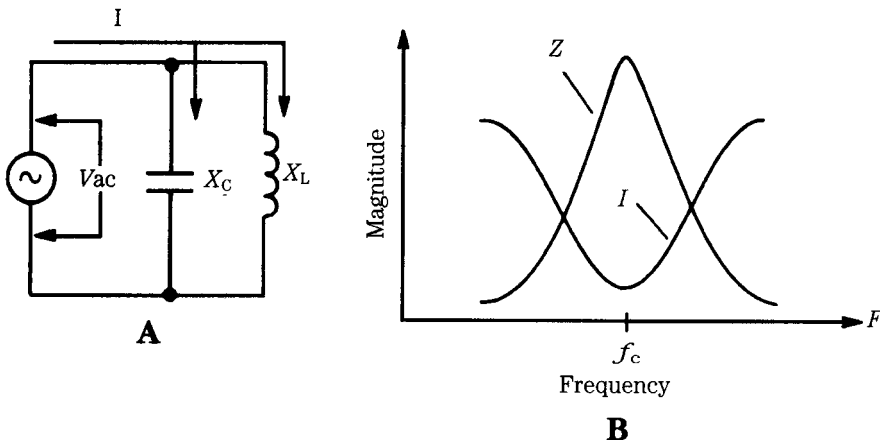


2-23 (A) Series-resonant LC circuit; (B) I and Z vs frequency response.

Parallel-resonant circuits

The parallel-resonant tank circuit (Fig. 2-24A) is the inverse of the series-resonant circuit. The line current from the source splits and flows separately in the inductor and capacitor.

The parallel-resonant circuit has its highest impedance at the resonant frequency and a low impedance at all other frequencies. Thus, the line current from the source is minimum at the resonant frequency (Fig. 2-24B) and the voltage across the LC tank circuit is maximum. This fact is important in radio tuning circuits, as you will see later.



2-24 (A) Parallel-resonant LC circuit; (B) I and Z vs frequency response.

Choosing component values for LC-resonant tank circuits

In some cases, one of the two basic type of resonant tank circuit (either series or parallel) is clearly preferred over the other, but in other cases either could be used if it is used correctly. For example, in a wave trap (i.e., a circuit that prevents a particular frequency from passing) a parallel-resonant circuit in series with the signal line will block its resonant frequency while passing all frequencies removed from resonance; a series-resonant circuit shunted across the signal path will bypass its resonant frequency to common (or “ground”) while allowing frequencies removed from resonance to pass.

LC-resonant tank circuits are used to tune radio receivers; it is these circuits that select the station to be received while rejecting others. A superheterodyne radio receiver (the most common type) is shown in simplified form in Fig. 2-25. According to the superhet principal, the *radio frequency being received* (F_{RF}) is converted to another frequency, called the *intermediate frequency* (F_{IF}) by being mixed with a *local oscillator signal* (F_{LO}) in a nonlinear mixer stage. The output of the untamed mixer would be a collection of frequencies defined by the following:

$$F_{\text{IF}} = mF_{\text{RF}} \pm nF_{\text{LO}}, \quad (2-21)$$

where m and n are either integers or zero. For the simplified case that is the subject of this chapter only the first pair of products ($m = n = 1$) are considered, so the output spectrum will consist of F_{RF} , F_{LO} , $F_{\text{RF}} - F_{\text{LO}}$ (difference frequency), and $F_{\text{RF}} + F_{\text{LO}}$ (sum frequency). In older radios, for practical reasons, the difference frequency was selected for F_{IF} ; today either sum or difference frequencies can be selected, depending on the design of the radio.

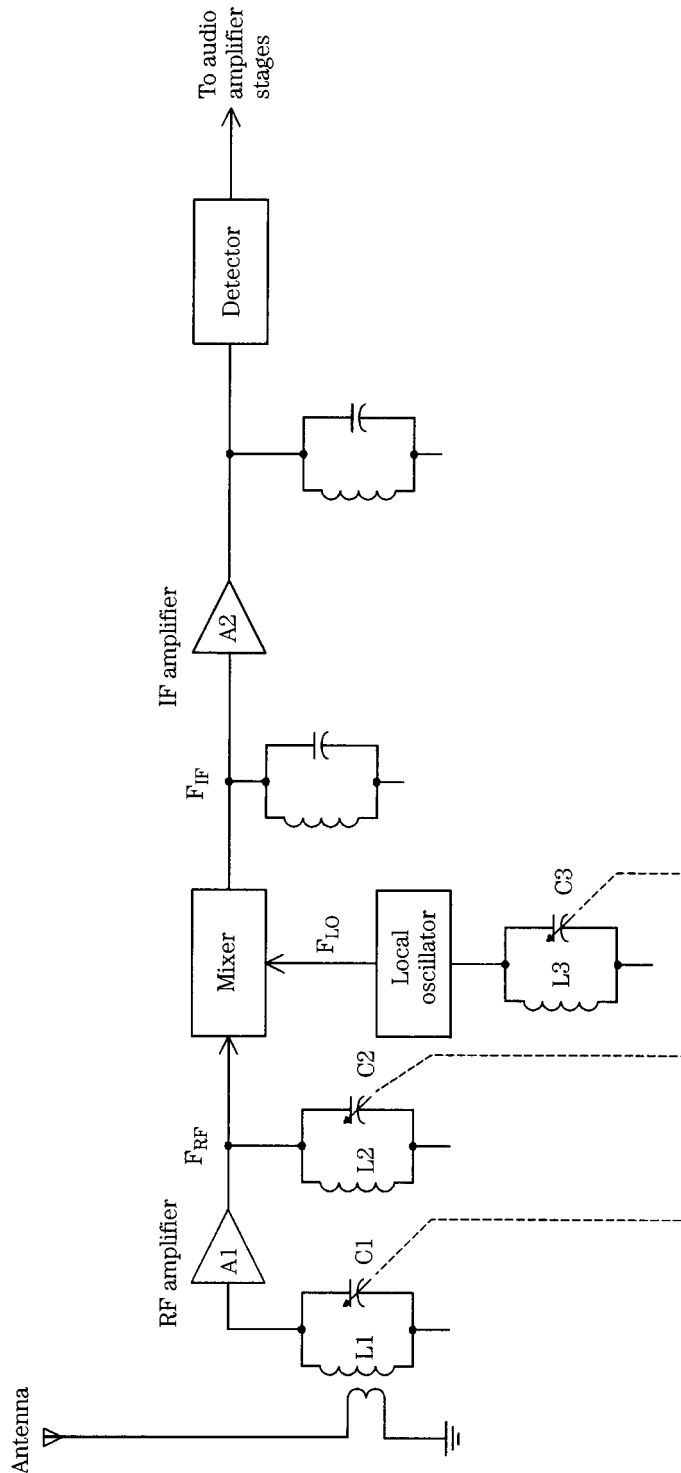
Several LC tank circuits are present in this notional superhet radio. The antenna tank circuit (C_1/L_1) is found at the input of the RF amplifier stage, or if no RF amplifier is used it is at the input to the mixer stage. A second tank circuit (L_2/C_2), tuning the same range as L_1/C_1 , is found at the output of the RF amplifier or at the input of the mixer. Another LC tank circuit (L_3/C_3) is used to tune the local oscillator; it is this tank circuit that sets the frequency that the radio will receive.

Additional tank circuits (only two shown) can be found in the IF amplifier section of the radio. These tank circuits will be fixed-tuned to the IF frequency, which in common AM broadcast-band (BCB) radio receivers is typically 450, 455, 460, or 470 kHz depending on the designer's choices (and sometimes country of origin). Other IF frequencies are also used, but these are most common. FM broadcast receivers typically use a 10.7-MHz IF, and shortwave receivers might use a 1.65-, 8.83-, or 9-MHz frequency or an IF frequency above 30 MHz.

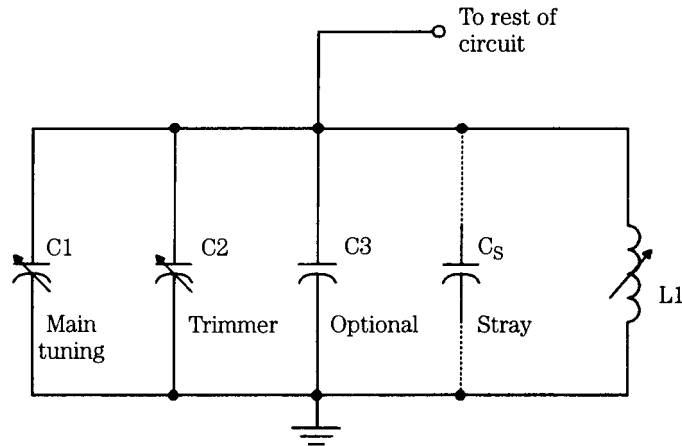
The tracking problem

On a radio that tunes the front end with a single knob, which is the case in almost all receivers today, the three capacitors (C_1 through C_3 in Fig. 2-26) are typically ganged (i.e., mounted on a single rotor shaft). These three tank circuits must track each other; that is, when the RF amplifier is tuned to a certain radio signal frequency, the LO must produce a signal that is different from the RF frequency by the amount of the IF frequency. Perfect tracking is rare, but the fact that your single-knob-tuned radio works is testimony to the fact that the tracking is not too terrible.

The issue of tracking LC tank circuits for the AM BCB receiver has not been a major problem for many years: the band limits are fixed over most of the world and

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2-25 Parallel-resonant circuits used in a radio receiver.



2-26 Capacitors used in a typical radio tuning circuit.

component manufacturers offer standard adjustable inductors and variable capacitors to tune the RF and LO frequencies. Indeed, some even offer three sets of coils: antenna, mixer input/RF amp output, and LO. The reason why the antenna and mixer/RF coils are not the same, despite tuning to the same frequency range, is that these locations see different distributed or “stray” capacitances. In the United States, it is standard to use a 10- to 365-pF capacitor and a 220- μ H inductor for the 540- to 1700-kHz AM BCB. In other countries, slightly different combinations are used; for example, 320, 380, 440, and 500 pF and others are seen in catalogs.

Recently, however, two events coincided that caused me to examine the method of selecting capacitance and inductance values. First, I embarked on a design project to produce an AM DX-er’s receiver that had outstanding performance characteristics. Second, the AM broadcast band was recently extended so that the upper limit is now 1700 rather than 1600 kHz. The new 540- to 1700-kHz band is not accommodated by the now-obsolete “standard” values of inductance and capacitance. So I calculated new candidate values.

The RF amplifier/antenna tuner problem

In a typical RF tank circuit, the inductance is kept fixed (except for a small adjustment range that is used for overcoming tolerance deviations) and the capacitance is varied across the range. The frequency changes as the square root of the capacitance changes. If F_1 is the minimum frequency in the range and F_2 is the maximum frequency then the relationship is as follows:

$$\frac{F_2}{F_1} = \sqrt{\frac{C_{\max}}{C_{\min}}} \quad (2-22)$$

or, in a rearranged form that some find more applicable:

$$\left(\frac{F_2}{F_1}\right)^2 = \frac{C_{\max}}{C_{\min}}. \quad (2-23)$$

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In the case of the new AM receiver, I wanted an overlap of about 15 kHz at the bottom end of the band and 10 kHz at the upper end and so needed a resonant tank circuit that would tune from 525 to 1710 kHz. In addition, because variable capacitors are widely available in certain values based on the old standards, I wanted to use a “standard” AM BCB variable capacitor. A 10- to 380-pF unit from a U.S. vendor was selected.

The minimum required capacitance, $C_{\min}$, can be calculated from the following:

$$\left(\frac{F_2}{F_1}\right)^2 C_{\min} = C_{\min} + \Delta C, \quad (2-24)$$

where

F_1 is the minimum frequency tuned

F_2 is the maximum frequency tuned

$C_{\min}$ is the minimum required capacitance at F_2

ΔC is the difference between $C_{\max}$ and $C_{\min}$.

Example

Find the minimum capacitance needed to tune 1710 kHz when a 10- to 380-pF capacitor ($\Delta C = 380 - 10 \text{ pF} = 370 \text{ pF}$) is used and the minimum frequency is 525 kHz.

Solution

$$\begin{aligned} \left(\frac{F_2}{F_1}\right)^2 C_{\min} &= C_{\min} + \Delta C \\ \left(\frac{1710 \text{ kHz}}{525 \text{ kHz}}\right)^2 C_{\min} &= C_{\min} + 370 \text{ pF} \\ 10.609 C_{\min} &= C_{\min} + 370 \text{ pF} \\ C_{\min} &= 38.51 \text{ pF}. \end{aligned}$$

The maximum capacitance must be $C_{\min} + \Delta C$ or $38.51 + 370 \text{ pF} = 408.51 \text{ pF}$. Because the tuning capacitor (C_1 in Fig. 2-26) does not have exactly this range, external capacitors must be used and because the required value is higher than the normal value additional capacitors are added to the circuit in parallel to C_1 . Indeed, because somewhat unpredictable “stray” capacitances also exist in the circuit, the tuning capacitor values should be a little less than the required values in order to accommodate strays plus tolerances in the actual (versus published) values of the capacitors. In Fig. 2-26, the main tuning capacitor is C_1 (10 to 380 pF), C_2 is a small-value trimmer capacitor used to compensate for discrepancies, C_3 is an optional capacitor that might be needed to increase the total capacitance, and C_s is the stray capacitance in the circuit.

The value of the stray capacitance can be quite high—especially if other capacitors in the circuit are not directly used to select the frequency (e.g., in Colpitts and Clapp oscillators, the feedback capacitors affect the LC tank circuit). In the circuit that I was using, however, the LC tank circuit is not affected by other capacitors. Only the wiring strays and the input capacitance of the RF amplifier or

mixer stage need be accounted. From experience, I apportioned 7 pF to C_s as a trial value.

The minimum capacitance calculated was 38.51; there is a nominal 7 pF of stray capacitance and the minimum available capacitance from C_1 is 10 pF. Therefore, the combined values of C_2 and C_3 must be $38.51 \text{ pF} - 10 \text{ pF} - 7 \text{ pF}$, or 21.5 pF. Because there is considerable reasonable doubt about the actual value of C_s , and because of tolerances in the manufacture of the main tuning variable capacitor (C_1), a wide range of capacitance for $C_2 + C_3$ is preferred. It is noted from several catalogs that 21.5 pF is near the center of the range of 45- and 50-pF trimmer capacitors. For example, one model lists its range as 6.8 to 50 pF; its center point is only slightly removed from the actual desired capacitance. Thus, a 6.8- to 50-pF trimmer was selected, and C_3 was not used.

Selecting the inductance is a matter of choosing the frequency and associated required capacitance at one end of the range and calculating from the standard resonance equation solved for L :

$$L_{\mu\text{H}} = \frac{10^6}{4\pi^2 F_{\text{low}}^2 C_{\text{max}}}$$

$$L_{\mu\text{H}} = \frac{10^6}{(4)(\pi^2)(525,000)^2(4.085 \times 10^{-10})} = 224.97 \approx 225 \text{ pF}.$$

The RF amplifier input LC tank circuit and the RF amplifier output LC tank circuit are slightly different cases because the stray capacitances are somewhat different. In the example, I am assuming a JFET transistor RF amplifier, and it has an input capacitance of only a few picofarads. The output capacitance is not a critical issue in this specific case because I intend to use a 1-mH RF choke in order to prevent JFET oscillation. In the final receiver, the RF amplifier can be deleted altogether, and the LC tank circuit described will drive a mixer input through a link-coupling circuit.

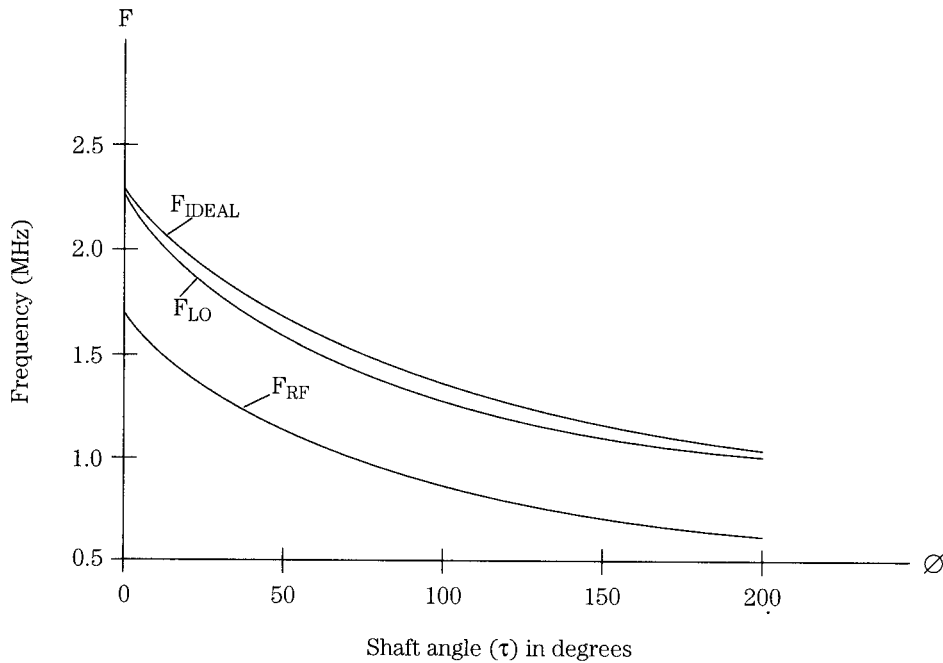
The local oscillator (LO) problem

The local oscillator circuit must track the RF amplifier and must also tune a frequency range that is different from the RF range by the amount of the IF frequency (455 kHz). In keeping with common practice, I selected to place the LO frequency 455 kHz above the RF frequency. Thus, the LO must tune the range from 980 to 2165 kHz.

Three methods can be used to make the local oscillator track with the RF amplifier frequency when single-shaft tuning is desired: the trimmer capacitor method, the padder capacitor method, and the different-value cut-plate capacitor method.

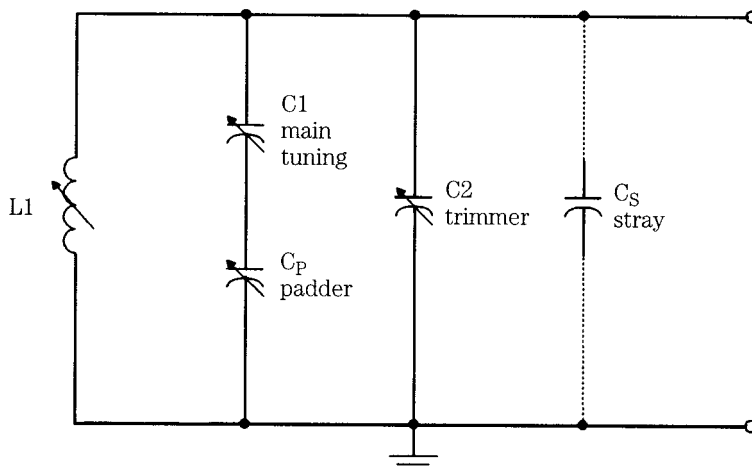
Trimmer capacitor method The trimmer capacitor method is shown in Fig. 2-27 and is the same as the RF LC tank circuit. Using exactly the same method as before, a frequency ratio of $2165/980$ yields a capacitance ratio of $(2165/980)^2 = 4.88:1$. The results are a minimum capacitance of 95.36 pF and a maximum capacitance of 465.36 pF. An inductance of 56.7 μH is needed to resonate these capacitances to the LO range.

There is always a problem associated with using the same identical capacitor for both RF and LO. It seems that there is just enough difference that tracking between

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2-27 The tracking problem.

them is always a bit off. Figure 2-27 shows the ideal LO frequency and the calculated LO frequency. The difference between these two curves is the degree of nontracking. The curves overlap at the ends but are awful in the middle. There are two cures for this problem. First, use a padder capacitor in series with the main tuning capacitor (Fig. 2-28). Second, use a different-value cut-plate capacitor.



2-28 Oscillator-tuned circuit using padder capacitor.

Figure 2-28 shows the use of a padder capacitor (C_p) to change the range of the LO section of the variable capacitor. This method is used when both sections of the variable capacitor are identical. Once the reduced capacitance values of the C_1/C_p combination are determined, the procedure is identical to that above. But first, you must calculate the value of the padder capacitor and the resultant range of the C_1/C_p combination. The padder value is calculated from the following:

$$\frac{C_{1_{\max}} C_p}{C_{1_{\max}} + C_p} = \left(\frac{F_2}{F_1}\right)^2 \left(\frac{C_{1_{\min}} C_p}{C_{1_{\min}} + C_p}\right), \quad (2-25)$$

which solves for C_p . For the values of the selected main tuning capacitor and LO:

$$\frac{(380 \text{ pF})(C_p)}{(380 + C_p)\text{pF}} = (4.88) \left(\frac{(10 \text{ pF})(C_p)}{(10 + C_p) \text{ pF}}\right). \quad (2-26)$$

Solving for C_p by the least common denominator method (crude, but it works) yields a padder capacitance of 44.52 pF. The series combination of 44.52 pF and a 10- to 380-pF variable yields a range of 8.2 to 39.85 pF. An inductance of 661.85 pF is needed for this capacitance to resonate over 980 to 2165 kHz.

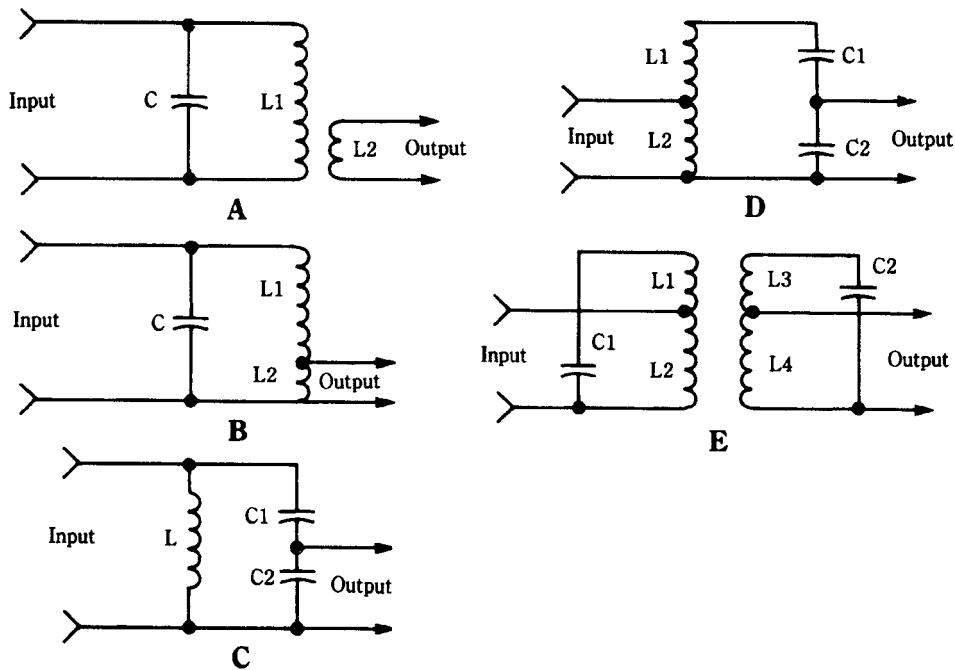
Tuned RF/IF transformers

Most of the resonant circuits used in radio receivers are actually tuned RF transformers that couple signal from one stage to another. Figure 2-29 shows several popular forms of tuned, or coupled, RF/IF tank circuits. In Fig. 2-29A, one winding is tuned and the other is untuned. In the configurations shown, the untuned winding is the secondary of the transformer. This type of circuit is often used in transistor and other solid-state circuits or when the transformer has to drive either a crystal or mechanical bandpass filter circuit. In the reverse configuration (L_1 = output, L_2 = input), the same circuit is used for the antenna coupling network or as the interstage transformer between RF amplifiers in TRF radios.

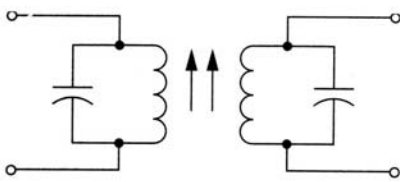
The circuit in Fig. 2-29B is a parallel-resonant LC tank circuit that is equipped with a low-impedance tap. This type of circuit is used to drive a crystal detector or other low-impedance load. Another circuit for driving a low-impedance load is shown in Fig. 2-29C. This circuit splits the capacitance that resonates the coil into two series capacitors. As a result, it is a capacitive voltage divider. The circuit in Fig. 2-29D uses a tapped inductor for matching low-impedance sources (e.g., antenna circuits) and a tapped capacitive voltage divider for low-impedance loads. Finally, the circuit in Fig. 2-29E uses a tapped primary and tapped secondary winding in order to match two low-impedance loads while retaining the sharp bandpass characteristics of the tank circuit.

Construction of RF/IF transformers

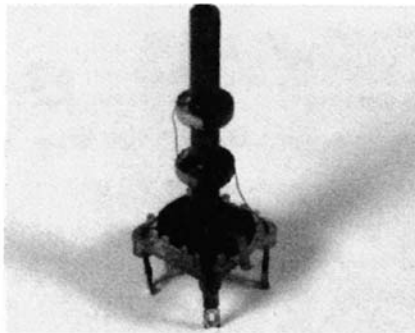
The tuned RF/IF transformers built for radio receivers are typically wound on a common cylindrical form and surrounded by a metal shield that can prevent interaction of the fields of coils that are in close proximity to each other. Figure 2-30A shows the schematic for a typical RF/IF transformer, and the sectioned view (Fig. 2-30B) shows one form of construction. This method of building transformers



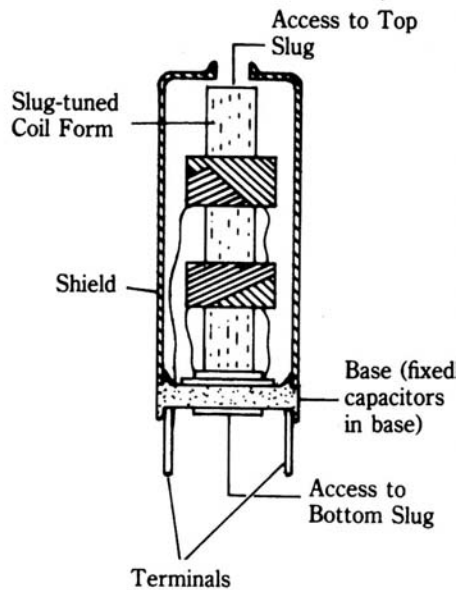
2-29 Coupling circuits used in radio receivers and transmitters.



A



C



B

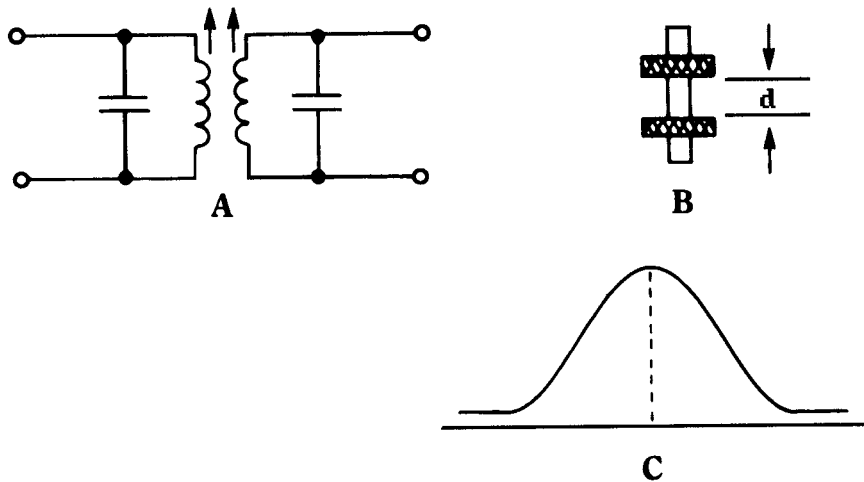
2-30 (A) Tuned RF or IF transformer; (B) IF/RF transformer construction; (C) actual transformer.

was common at the beginning of World War II and continued into the early transistor era. The capacitors were built into the base of the transformer, and the tuning slugs were accessed from holes in the top and bottom of the assembly. In general, expect to find the secondary at the bottom hole and the primary at the top holes.

The term *universal wound* refers to a cross-winding system that minimizes the interwinding capacitance of the inductor and raises the self-resonant frequency of the inductor (a good thing). An actual example of an RF/IF transformer is shown in Fig. 2-30C. The smaller type tends to be post-WWII, and the larger type is pre-WWII.

Bandwidth of RF/IF transformers

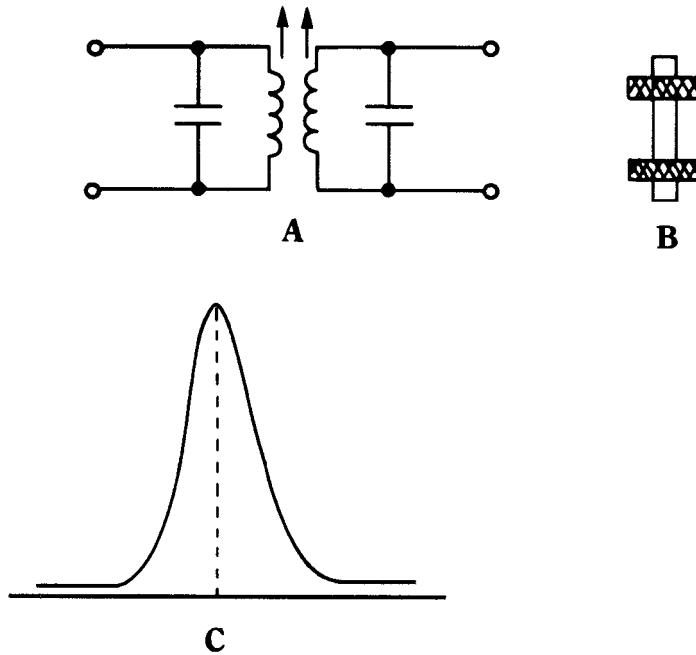
Figure 2-31A shows a parallel-resonant RF/IF transformer, and Fig. 2-31B shows the usual construction in which the two coils (L_1 and L_2) are wound at distance d apart on a common cylindrical form. The bandwidth of the RF/IF transformer is the difference between the frequencies where the signal voltage across the output winding falls off 6 dB from the value at the resonant frequency (F_R), as shown in Fig. 2-31C. If F_1 and F_2 are 6-dB (also called the *3-dB point* when signal power is measured instead of voltage) frequencies, then the bandwidth is $F_2 - F_1$. The shape of the frequency response curve in Fig. 2-31C is said to represent critical coupling.



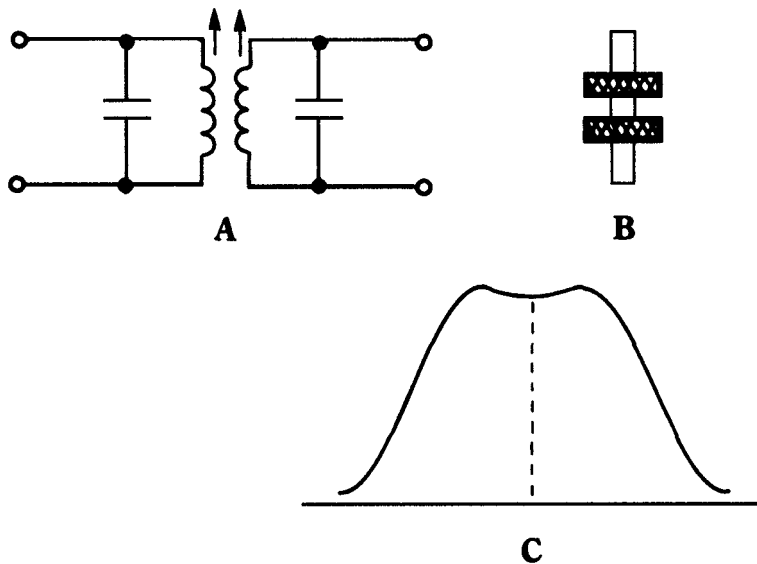
2-31 Moderate coupling IF transformer. (A) The circuit; (B) coil spacing; (C) bandpass response.

An example of a subcritical or undercoupled RF/IF transformer is shown in Figs. 2-32A and 2-32B. As shown in Figs. 2-32A and 2-32B, the windings are farther apart than in the critically coupled case, so the bandwidth (Fig. 2-32C) is much narrower than in the critically coupled case. The subcritically coupled RF/IF transformer is often used in shortwave or communications receivers in order to allow the narrow bandwidth to discriminate between adjacent channels.

The overcritically coupled RF/IF transformer is shown in Fig. 2-33. Notice in Figs. 2-33A and 2-33B that the windings are closer together, so the bandwidth (Fig. 2-33C) is much broader. In some radio schematics and service manuals (not to

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2-32 Loose coupling IF transformer. (A) The circuit; (B) coil spacing; (C) bandpass response.

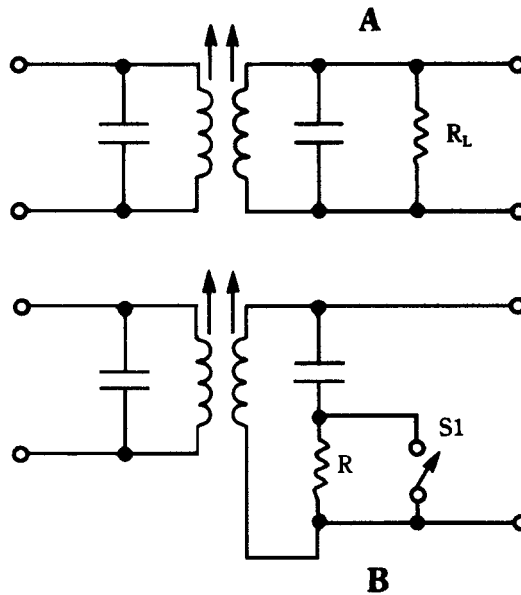


2-33 Over-critical coupling IF transformer. (A) The circuit; (B) coil spacing; (C) bandpass response.

mention early textbooks), this form of coupling was sometimes called *high-fidelity coupling* because it allowed more of the sidebands of the signal (which carry the audio modulation) to pass with less distortion of frequency response.

The bandwidth of the resonant tank circuit, or the RF/IF transformer, can be summarized in a figure of merit called Q . The Q of the circuit is the ratio of the bandwidth to the resonant frequency as follows: $Q = BW/FR$. An overcritically coupled circuit has a low Q , while a narrow bandwidth subcritically coupled circuit has a high Q .

A resistance in the LC tank circuit will cause it to broaden; that is, to lower its Q . The loaded Q (i.e., Q when a resistance is present, as in Fig. 2-34A) is always less than the unloaded Q . Some radios use a switched resistor (Fig. 2-34B) to allow the user to broaden or narrow the bandwidth. This switch might be labeled *fidelity* or *tone* or something similar on radio receivers.

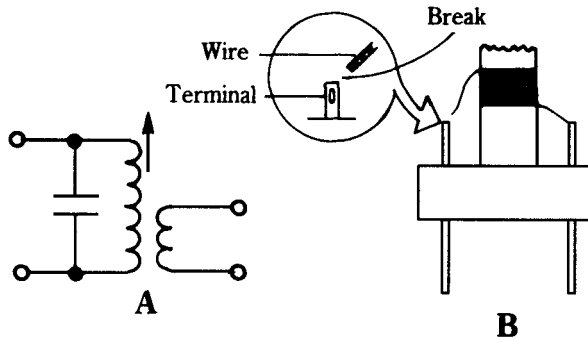


2-34 Resistor loading to broaden response.
(A) Parallel method; (B) hi-fi switch.

Problems with RF/IF transformers

The IF and RF transformers represent a high potential for intermittent problems in radio receivers. There are two basic forms of problems with the IF transformer: intermittent operation and intermittent noise. The best cure for a bad IF or RF transformer is replacement, but because old IF and RF transformers are not always available today, more emphasis must be placed on repair of the transformer.

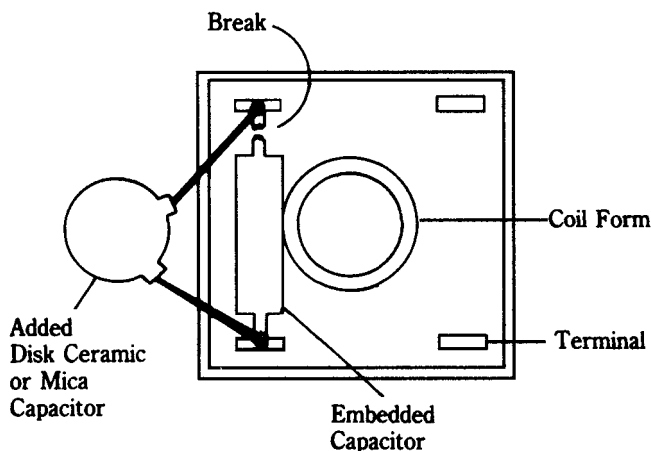
Figure 2-35A shows the basic circuit for a single-tuned IF transformer (others might have a tuned secondary winding). If one of the very-fine wires making up the coil breaks (Fig. 2-35B), then operation is interrupted. The problem can usually be diagnosed by lightly tapping on the shield can of the transformer or by using a signal



2-35 (A) IF transformer circuit; (B) typical defect.

tracer or signal generator to find where the signal is interrupted. In some cases, the plate voltage of the IF amplifier is interrupted when the transformer opens. This can be spotted using a dc voltmeter.

Repairing the IF transformer is a delicate operation. Examine the shield to determine how it is assembled. If it is secured with a screw or nut, simply remove the screw (or nut). If the IF transformer is sealed by metal tabs, then you must very carefully pry the tabs open (do not break them or bend them too far). Slide the base and coil assembly out of the shield. If there is enough slack on the broken wire, simply solder the wire back onto the terminal. The heat of the soldering iron tip will burn away the enamel insulation. If the wire does not have enough slack, then add a little length to the terminal by soldering a short piece of solid wire to the terminal and then solder the IF transformer wire to the added wire. In some cases, it is possible to remove a portion of one turn of the transformer winding in order to gain extra length, but this procedure will change the tuning.



2-36 Replacement of the embedded capacitor with a disk ceramic or silvered mica fixed capacitor.

A noisy IF transformer needs replacement, but the problem is the lack of original or replacement components. The capacitor can be replaced on many IF transformers. If the capacitor is a discrete component soldered to the base, it is simple to replace it with another similar (if not identical) capacitor. But if the IF transformer uses an embedded mica capacitor (Fig. 2-36), then the job becomes more complex.

If the capacitor element is visible (as in Fig. 2-36), then clip one end of the capacitor where it is attached to the terminal. Bridge a disk ceramic or mica capacitor between the two terminals. The value of the capacitor must be found experimentally—it is the value that will resonate the coil to the IF.

If the capacitor is embedded and not visible, it might become necessary to install a new terminal and solder the added capacitor to that terminal (with appropriate external circuit modifications).

3 CHAPTER

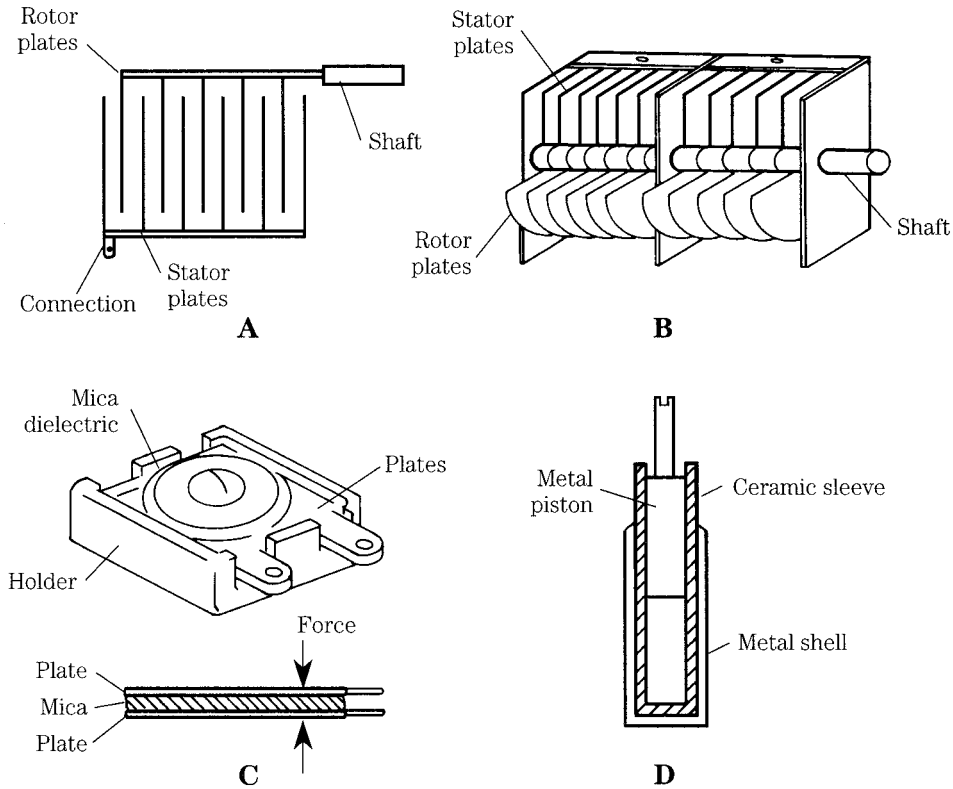
Variable capacitors in RF circuits

Like all capacitors, variable capacitors are made by placing two sets of metal plates parallel to each other (Fig. 3-1A) separated by a dielectric of air, mica, ceramic, or a vacuum. The difference between variable and fixed capacitors is that, in variable capacitors, the plates are constructed in such a way that the capacitance can be changed. There are two principal ways to vary the capacitance: either the spacing between the plates is varied or the cross-sectional area of the plates that face each other is varied. Figure 3-1B shows the construction of a typical variable capacitor used for the main tuning control in radio receivers. The capacitor consists of two sets of parallel plates. The stator plates are fixed in their position and are attached to the frame of the capacitor. The rotor plates are attached to the shaft that is used to adjust the capacitance.

Another form of variable capacitor used in radio receivers is the compression capacitor shown in Fig. 3-1C. It consists of metal plates separated by sheets of mica dielectric. In order to increase the capacitance, the manufacturer may increase the area of the plates and mica or the number of layers (alternating mica/metal) in the assembly. The entire capacitor will be mounted on a ceramic or other form of holder. If mounting screws or holes are provided then they will be part of the holder assembly.

Still another form of variable capacitor is the piston capacitor shown in Fig. 3-1D. This type of capacitor consists of an inner cylinder of metal coaxial to, and inside of, an outer cylinder of metal. An air, vacuum, or (as shown) ceramic dielectric separates the two cylinders. The capacitance is increased by inserting the inner cylinder further into the outer cylinder.

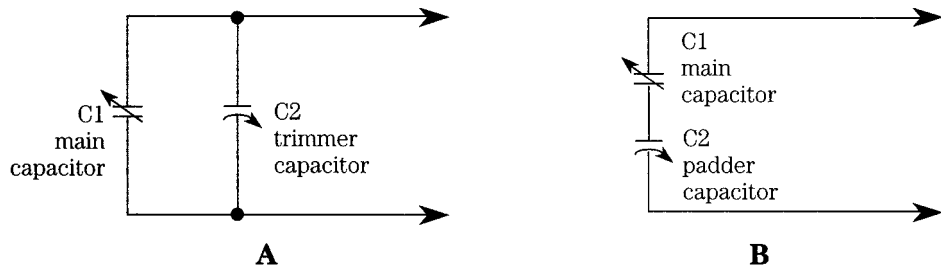
The small-compression or piston-style variable capacitors are sometimes combined with air variable capacitors. Although not exactly correct word usage, the smaller capacitor used in conjunction with the larger air variable is called a trimmer capacitor. These capacitors are often mounted directly on the air variable frame or very close by in the circuit. In many cases, the “trimmer” is actually part of the air variable capacitor.

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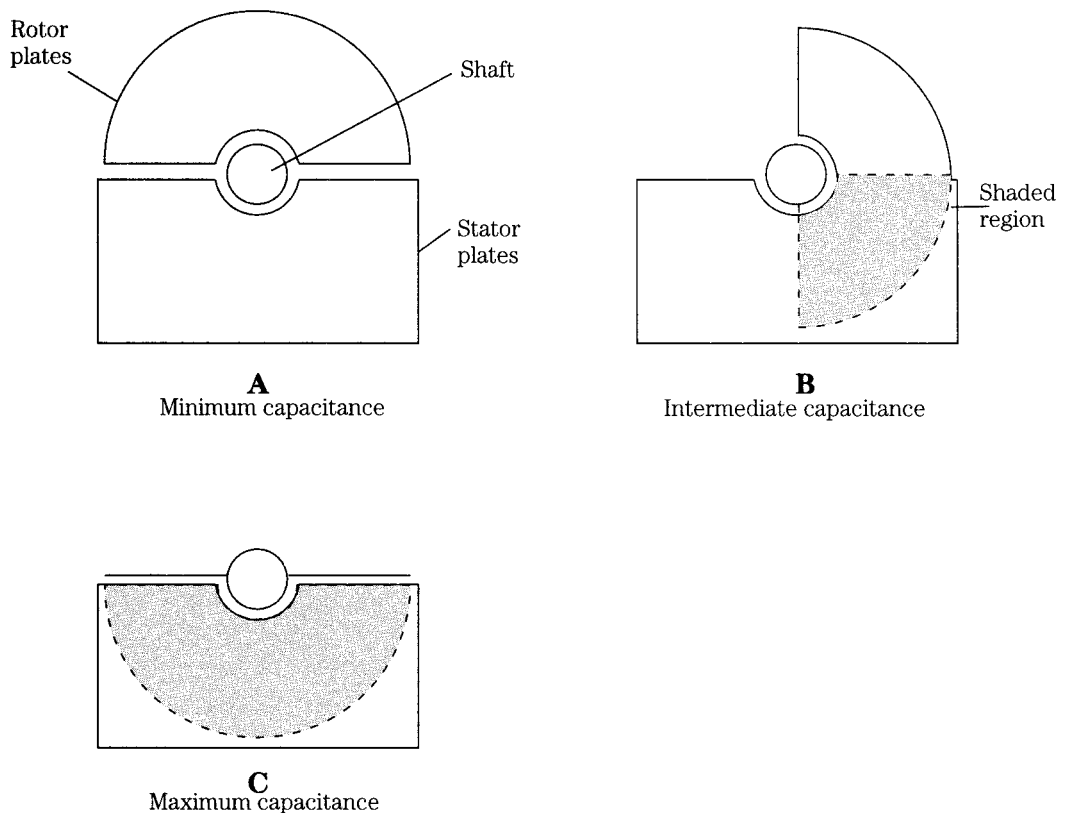
3-1 Air dielectric variable capacitors consists of interleaved stator and rotor plates. (A) Schematic view; (B) construction; (C) mica compression variable capacitor; (D) piston variable capacitor.

There are actually two uses for small variable capacitors in conjunction with the main tuning capacitor in radios. First, there is the true “trimmer,” i.e., a small-valued variable capacitor in parallel with the main capacitor (Fig. 3-2A). These trimmer capacitors (C_2) are used to trim the exact value of the main capacitor (C_1). The other form of small capacitor is the padder capacitor (Fig. 3-2B), which is connected in series with the main capacitor. This error in terminology is calling both series and parallel capacitors “trimmers,” when only the parallel connected capacitor is properly so-called.

The capacitance of an air variable capacitor at any given setting is a function of how much of the rotor plate set is shaded by the stator plates. In Fig. 3-3A, the rotor plates are completely outside of the stator plate area. Because the shading is zero, the capacitance is minimum. In Fig. 3-3B, however, the rotor plate set has been slightly meshed with the stator plate, so some of its area is shaded by the stator. The capacitance in this position is at an intermediate-value. Finally, in Fig. 3-3C, the rotor is completely meshed with the stator so the cross-sectional area of the rotor that is shaded by the stator is maximum. Therefore, the capacitance is also maximum. Remember these two rules:



3-2 (A) Trimmer capacitor connected in parallel with the main tuning capacitor; (B) padder capacitor is connected in series with the main tuning capacitor.



3-3 The capacitance of the air variable capacitor is determined by how much of the rotor plate is shaded by the stator plates. (A) Minimum capacitance; (B) intermediate capacitance; (C) maximum capacitance.

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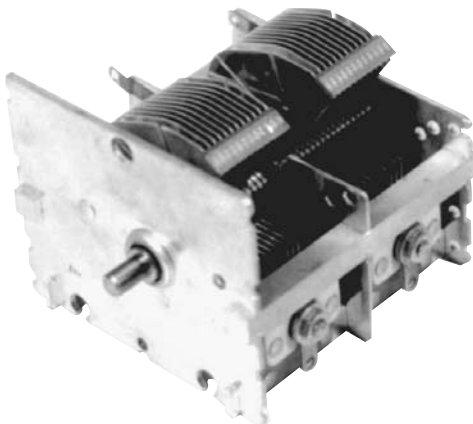
1. Minimum capacitance is found when the rotor plates are completely unmeshed with the stator plates; and
2. Maximum capacitance is found when the rotor plates are completely meshed with the stator plates.

Figure 3-4 shows a typical single-section variable capacitor. The stator plates are attached to the frame of the capacitor, which in most radio circuits is grounded. Front and rear mounts have bearing surfaces to ease the rotor's action. The ganged variable capacitor (Fig. 3-5) was invented to provide tracking between two related LC-tuned circuits, as in a radio receiver. Such capacitors are basically two (in the case of Fig. 3-5) or more variable capacitors mechanically ganged on the same rotor shaft.



3-4
Small air variable capacitor.

In Fig. 3-5, both sections of the variable capacitor have the same capacitance, so they are identical to each other. If this capacitor is used in a superheterodyne radio, the section used for the local oscillator (LO) tuning must be padded with a series capacitance in order to reduce the overall capacitance. This trick is done to permit the higher-frequency LO to track with the RF amplifiers on the dial.



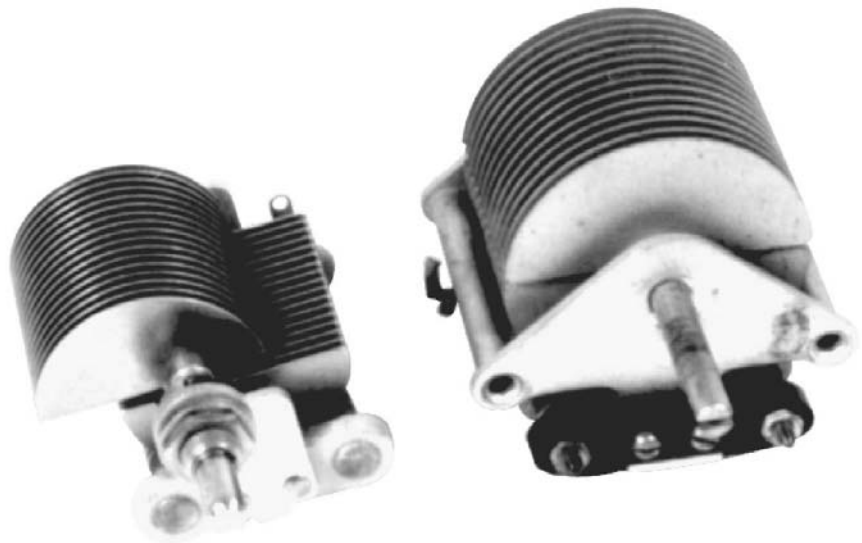
3-5
Dual section air variable capacitor.

In many superheterodyne radios, you will find variable tuning capacitors in which one section (usually the front section) has fewer plates than the other section.

One section tunes the RF amplifier of the radio, and the other tunes the local oscillator. These capacitors are sometimes called *cut-plate capacitors* because the LO section plates are cut to permit tracking of the LO with the RF.

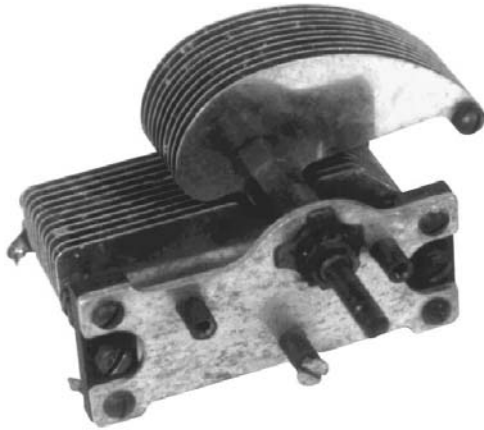
Straight-line capacitance vs straight-line frequency capacitors

The variable capacitor shown in Fig. 3-5 has the rotor shaft in the geometric center of the rotor plate half-circle. The capacitance of this type of variable capacitor varies directly with the rotor shaft angle. As a result, this type of capacitor is called a *straight-line capacitance model*. Unfortunately, as you will see in a later section, the frequency of a tuned circuit based on inductors and capacitors is not a linear (straight line) function of capacitance. If a straight line capacitance unit is used for the tuner, then the frequency units on the dial will be cramped at one end and spread out at the other (you've probably seen such radios). But some capacitors have an offset rotor shaft (Fig. 3-6A) that compensates for the nonlinearity of the tuning circuit. The shape of the plates and the location of the rotor shaft are designed to produce a linear relationship between the shaft angle and the resonant frequency of the tuned circuit in which the capacitor is used. A comparison between straight-line capacitance and straight-line frequency capacitors is shown in Fig. 3-6B.



A

3-6 (A) Straight-line frequency capacitor; (B) comparison of straight-line capacitance with straight-line frequency capacitor.



3-6

*Continued***B**

Special variable capacitors

In the preceding sections, the standard forms of variable capacitor were covered. These capacitors are largely used for tuning radio receivers, oscillators, signal generators, and other variable-frequency LC oscillators. This section covers some special forms of variable capacitor.

Split-stator capacitors

The split-stator capacitor is one in which two variable capacitors are mounted on the same shaft. The split-stator capacitor normally uses a pair of identical capacitors, each the same value, turned by the same shaft. The rotor is common to both capacitors. Thus, the capacitor will tune either two tuned circuits at the same time or both halves of a balanced-tuned circuit (i.e., one in which the inductor is center-tapped and grounded).

Differential capacitors

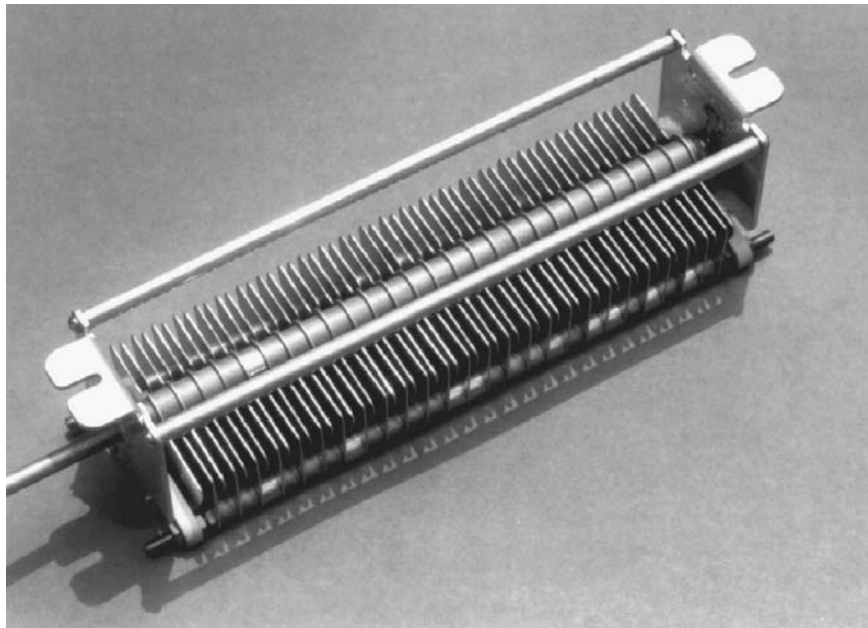
Although some differential capacitors are often mistaken for split-stator capacitors, they are actually quite different. The split-stator capacitor is tuned in tandem, i.e., both capacitor sections have the same value at any given shaft setting. The differential capacitor, on the other hand, is arranged so that one capacitor section increases in capacitance and the other section decreases in exactly the same proportion.

Differential capacitors are used in impedance bridges, RF resistance bridges, and other such instruments. If you buy or build a high-quality RF impedance bridge for antenna measurements, for example, it is likely that it will have a differential capacitor as the main adjustment control. The two capacitors are used in two arms of a Wheatstone bridge circuit. Be careful of planning to build such a bridge, however. I recently bought the differential capacitor for such an instrument, and it cost nearly \$50!

“Transmitting” variable capacitors

The one requirement of transmitting variable capacitors (and certain antenna tuning capacitors) is the ability to withstand high voltages. The high-power ham radio or AM broadcast transmitter will have a dc potential of 1500 to 7500 V on the RF amplifier anode, depending on the type of tube used. If amplitude-modulated, the potential can double. Also, if certain antenna defects arise, then the RF voltages in the circuit can rise quite high. As a result, the variable capacitor used in the final amplifier anode circuit must be able to withstand these potentials.

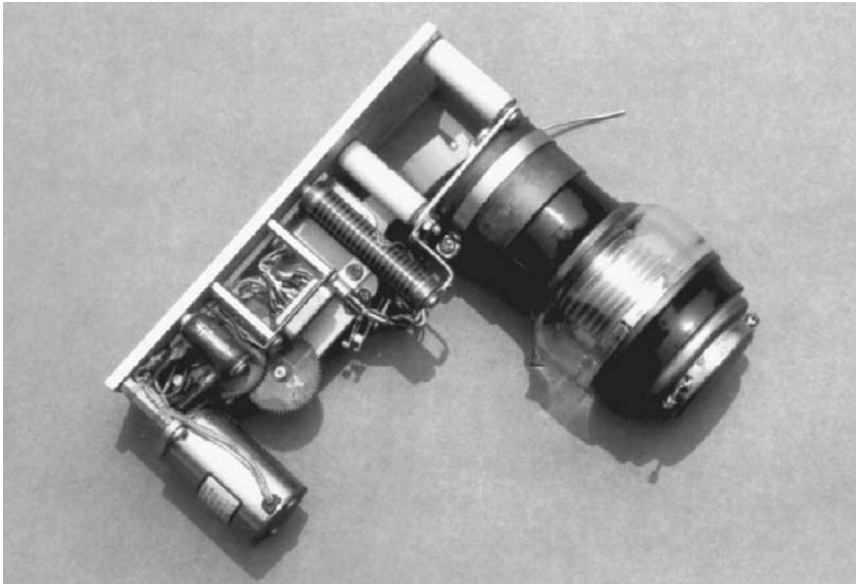
Two forms of transmitting variables are typically used in RF power amplifiers and antenna tuners. Figure 3-7 shows a transmitting air variable capacitor. The shaft of this particular capacitor is nylon, so it can be mounted either with the frame grounded or with the frame floating at high voltage. The other form of transmitting variable is the vacuum variable. This type of capacitor is a variation of the piston capacitor, but it has a vacuum dielectric (K factor = 1.0000). The model shown in Fig. 3-8 is a 18- to 1000-pF model that is driven from a 12-Vdc electric motor. Other vacuum variables are manually driven.



3-7 Transmitting air variable capacitor.

Solid-state capacitors

One of the problems with variable capacitors is that they are large, bulky things (look at all the photos) that must be mechanically operated. Modern electronic circuits, including most radios today, are electrically tuned using a varicap diode for the capacitor function. These “capacitors” operate because the junction capacitance

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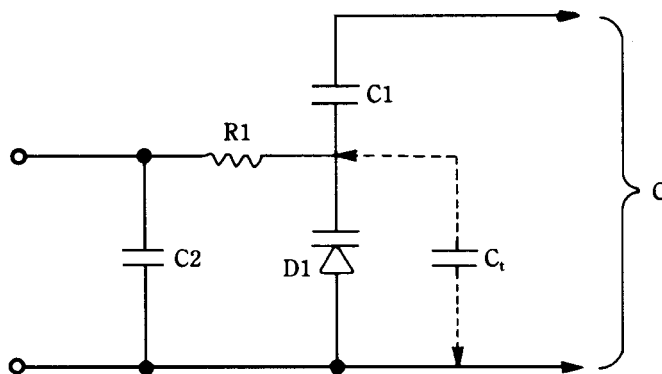
3-8 Vacuum variable capacitor.

(C_t) of a PN junction diode is a function of the reverse bias voltage applied across the diode. The varicap (a.k.a. “varactor”) is therefore a variable capacitor in which the capacitor is a function of an applied voltage. Maximum capacitances run from 15 to 500 pF, depending on the type.

Figure 3-9 shows the usual circuit for a varicap diode. D_1 is the varactor, and capacitor C_1 is a dc-blocking capacitor. Normally, the value of C_1 is set many times higher than the capacitance of the diode. The total capacitance is as follows:

$$C = \frac{C_1 C_t}{C_1 + C_t} \quad (3-1)$$

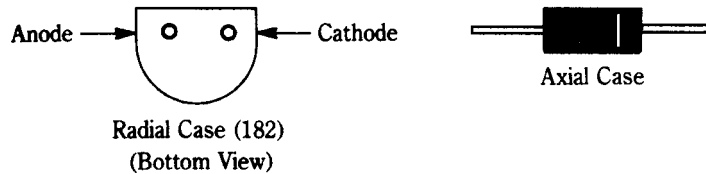
Capacitor C_1 will affect the total capacitance only negligibly if $C_1 > C_t$.



3-9 Variable-capacitance diode (varactor) in a typical circuit.

The control circuit for the varactor is series current-limiting resistor R_1 . This resistor is typically 10 to 470 k Ω . The shunt capacitor (C_2) is used to decouple RF from the circuit from getting to other circuits and noise signals from other circuits from affecting the capacitor.

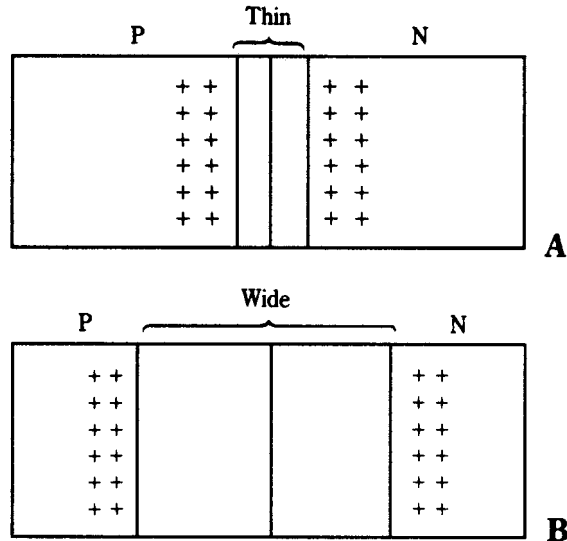
Varactors come in several different standard diode packages, including the two-terminal “similar to 182” package shown in Fig. 3-10. Some variants bevel the edge of the package to denote which is the cathode. In other cases, the package style will be like other forms of diode. Varactors are used in almost every form of diode package, up to and including the package used for 50- to 100-A stud-mounted rectifier diodes.



3-10 Typical varactor cases.

How do varactors work?

Varactors are specially made PN junction diodes that are designed to enhance the control of the PN junction capacitance with a reverse bias voltage. Figure 3-11 shows how this capacitance is formed. A PN junction consists of P- and N-type semi-



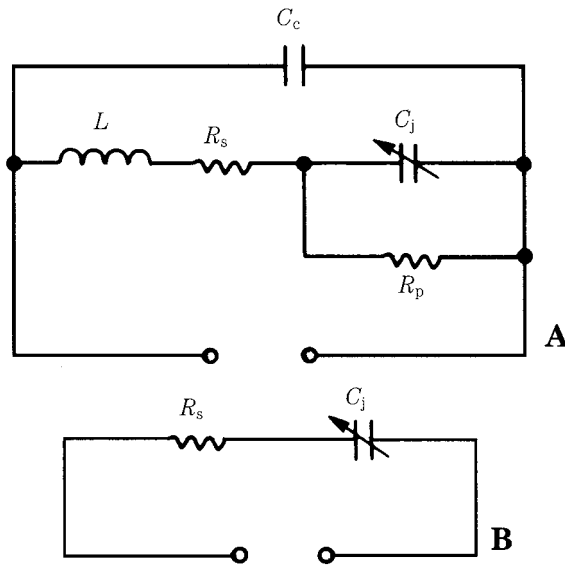
3-11 Varactor diode operation. (A) Thin depletion zone means maximum capacitance; (B) wider depletion zone means less capacitance.

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conductor material placed in juxtaposition with each other, as shown in Fig. 3-11. When the diode is forward-biased, the charge carriers (electrons and holes) are forced to the junction interface, where positively charged holes and negatively charged electrons annihilate each other (causing a current to flow). But under reverse bias situations (e.g., those shown in Fig. 3-11), the charges are drawn away from the junction interface.

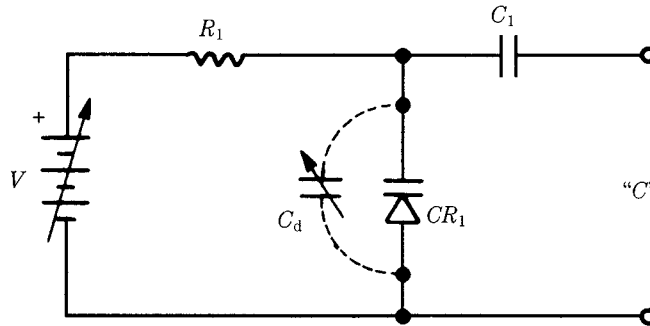
Figure 3-11A shows the situation where the reverse bias is low. The charge carriers are drawn only a little way from the junction, creating a thin insulating depletion zone. This zone is an insulator between the two charge-carrying P- and N-regions, and this situation fulfills the criterion for a capacitor: two conductors separated by an insulator. Figure 3-11B shows the situation where the reverse bias is increased. The depletion zone is increased, which is analogous to increasing the separation between plates.

The varactor is not an ideal capacitor (but then again, neither are “real” capacitors). Figure 3-12 shows the equivalent circuit for a varactor. Figure 3-12A shows the actual model circuit, and Fig. 3-12B shows one that is simplified, but nonetheless is valuable to understanding the varactor's operation. The equivalent circuit of Fig. 3-12B assumes that certain parameter shown in Fig. 3-12A are negligible.



3-12 (A) Equivalent circuit of a varactor diode; (B) simplified circuit.

Figure 3-13 shows a typical test circuit for the varactor. A variable dc voltage is applied as a reverse bias across the diode. A series resistor serves both to limit the current should the voltage exceed the avalanche or zener points (which could destroy the diode) and also to isolate the diode from the rest of the circuitry. Without a high-value resistor (10 to 470 k Ω is the normal range; 100 k Ω is typical) in series with the dc supply, stray circuit capacitances and the power-supply output capaci-



3-13 Varactor diode-control circuit.

tance would swamp the typically low value of varactor capacitance. The capacitor at the output (C_1) is used to block the dc from affecting other circuits or the dc in other circuits from affecting the diode. The value of this capacitor must be very large in order to prevent it from affecting the diode capacitance (C_d).

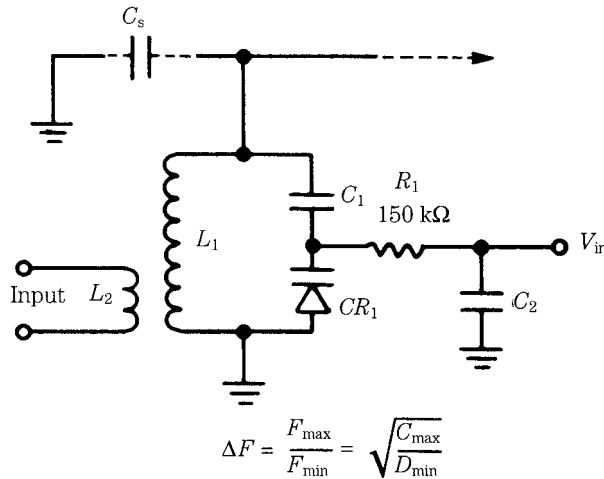
Varactor-tuning voltage sources The capacitance of a varactor is a function of the applied reverse bias potential. Because of this, it is essential that a stable, noise-free source of bias is provided. If the diode is used to tune an oscillator, for example, frequency drift will result if the dc potential is not stable. Besides ordinary dc drift, noise affects the operation of varactors. Anything that varies the dc voltage applied to the varactor will cause a capacitance shift.

Electronic servicers should be especially wary of varactor-tuned circuits in which the tuning voltage is derived from the main regulated power supply without an intervening regulator that serves only the tuning voltage input of the oscillator. Dynamic shifts in the regulator's load, variations in the regulator voltage, and other problems can create local oscillator drift problems that are actually power-supply problems and have nothing at all to do with the tuner (despite the apparent symptoms).

The specifications for any given varactor are given in two ways. First is the nominal capacitance taken at a standard voltage (usually 4 Vdc, but 1 and 2 Vdc are also used). The other is a capacitance ratio expected when the dc reverse bias voltage is varied from 2 to 30 Vdc (whatever the maximum permitted applied potential is for that diode). Typical is the NTE replacement line type 614. According to the *NTE Service Replacement Guide and Cross-Reference*, the 614 has a nominal capacitance of 33 pF at 4 Vdc reverse bias potential and a " C_2/C_{30} " capacitance ratio of 3:1.

Varactor applications

Varactors are electronically variable capacitors. In other words, they exhibit a variable capacitance that is a function of a reverse bias potential. This phenomenon leads to several common applications in which capacitance is a consideration. Figure 3-14 shows a typical varactor-tuned LC tank circuit. The link-coupled inductor (L_2) is used to input RF to the tank when the circuit is used for RF amplifiers (etc.). The

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3-14 Varactor diode-tuned circuit.

principal LC tank circuit consists of the main inductor (L_1) and a capacitance made up from the series equivalent of C_1 and varactor CR_1 . In addition, you must also take into account the stray capacitance (C_s) that exists in all electronic circuits. The blocking capacitor and series-resistor functions were covered in the preceding paragraphs. Capacitor C_2 is used to filter the tuning voltage, V_{in} .

Because the resonant frequency of an LC-tuned tank circuit is a function of the square root of the inductance-capacitance product, we find that the maximum/minimum frequency of the varactor-tuned tank circuit varies as the square root of the capacitance ratio of the varactor diode. This value is the ratio of the capacitance at minimum reverse bias over capacitance at maximum reverse bias. A consequence of this is that the tuning characteristic curve (voltage vs frequency) is basically a parabolic function.

Note and Warning!

Cleaning Variable Capacitors

The main tuning capacitors in old radios are often full of crud, grease, and dust. Similarly, ham radio operators working the hamfest circuit looking for linear amplifier and antenna tuner parts often find just what they need, but the thing is all gooped-up. Several things can be done about it. First, try using dry compressed air. It will remove dust, but not grease. Aerosol cans of compressed air can be bought from a lot of sources, including automobile parts stores and photography stores.

Another method, if you have the hardware, is to ultrasonically clean the capacitor. The ultrasonic cleaner, however, is expensive; unless you have one, do not rush out to lay down the bucks.

Still another way is to use a product, such as Birchwood Casey Gun Scrubber. This product is used to clean firearms and is available in most gun shops. Firearms

goop-up because gun grease, oil, unburned powder, and burned powder residue combine to create a crusty mess that is every bit as hard to remove as capacitor gunk. A related product is the degunking compound used by auto mechanics.

At one time, carbon tetrachloride was used for this purpose . . . and you will see it listed in old radio books. However, carbon tet is now well-recognized as a health hazard. DO NOT USE CARBON TETRACHLORIDE for cleaning, despite the advice to the contrary found in old radio books.

4 CHAPTER

Winding your own coils

Inductors and capacitors are the principal components used in RF tuning circuits. The resonant frequency of a tank circuit is the frequency to which the inductor-capacitor combination is tuned and is found from:

$$F = \frac{1}{2\pi\sqrt{LC}} \quad (4-1)$$

or, if either the inductance (L) or capacitance (C) is known or preselected then the other can be found by solving Eq. (4-1) for the unknown, or:

$$C = \frac{1}{39.5 F^2 L} \quad (4-2)$$

and

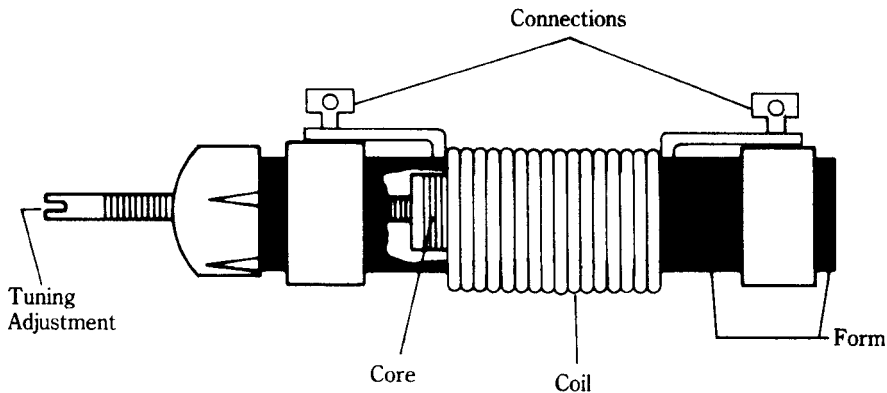
$$L = \frac{1}{39.5 F^2 C}. \quad (4-3)$$

In all three equations, L is in henrys, C is in farads, and F is in hertz (don't forget to convert values to microhenrys and picofarads after calculations are made).

Capacitors are easily obtained in a wide variety of values. But tuning inductors are either unavailable or are available in other people's ideas of what you need. As a result, it is often difficult to find the kinds of parts that you need. This chapter will look at how to make your own slug-tuned adjustable inductors, RF transformers, and IF transformers (yes, you can build your own IF transformers).

Tuning inductors can be either air-, ferrite-, or powdered-iron-core coils. The air-core coils are not adjustable unless either an expensive roller-contact mechanism or clumsy taps on the winding of the coil are provided. However, the ferrite- and powdered-iron slug-tuned core coils are adjustable.

Figure 4-1 shows one form of slug-tuned adjustable coil. The form is made of plastic, phenolic, fiberglass, nylon, or ceramic materials and is internally threaded. The windings of the coil (or coils in the case of RF/IF transformers) are wound onto the form. The equation for calculating the inductance of a single-layer air-core coil



4-1 Variable inductor on open coil form.

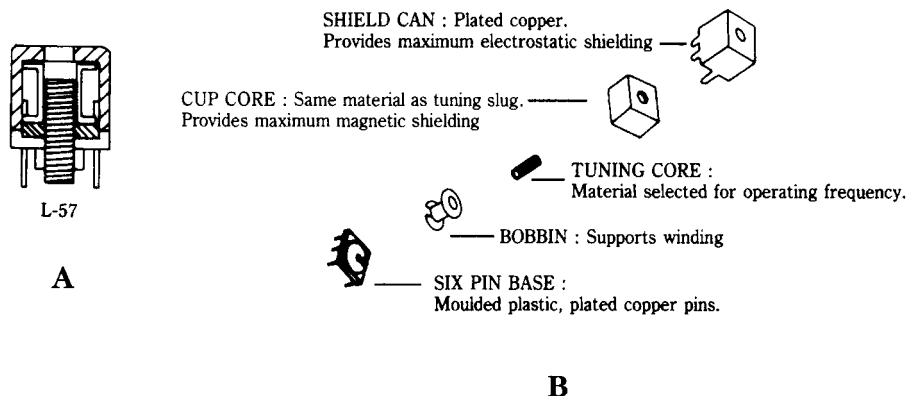
was discussed in Chapter 2. For non-air-core coils, the inductance is multiplied by a factor that is determined by the properties of the core material.

The tuning slug is a ferrite- or powdered-iron-core coil that mates with the internal threads in the coil form. A screwdriver slot or hex hole in either (or both) end allows you to adjust it. The inductance of the coil depends on how much of the core is inside the coil windings.

Amidon Associates coil system

It was once difficult to obtain coil forms to make your own project inductors. Amidon Associates Inc. makes a series of slug-tuned inductor forms that can be used to make any-value coil that you are likely to need. Figure 4-2A shows an Amidon form, and Fig. 4-2B shows an exploded view.

L-57 COIL FORM - - typical assembly



4-2 Shielded slug-tuned variable inductor.

Table 4-1 gives the type numbers, frequency ranges (in megaHertz), and other specifications for the coil forms made by Amidon. Three sizes of coil form are offered. The L-33s are 0.31" square and 0.40" high, the L-43s are 0.44" square and 0.50" high, and the L-57s are 0.56" square and 0.50" high. The last number (e.g., -1, -6, -10) in each type number indicates the type of material, which in turn translates to the operating frequency range (see Table 4-1). Now, see how the coil forms are used.

Table 4-1. Amidon coil form specifications

Part number	Frequency range (MHz)	A_L value	Ratio	$Q_{\max}$
L-33-1	0.30–1.0	76	1.7:1	80
L-33-2	1.00–10	68	1.5:1	90
L-33-3	0.01–0.5	80	1.8:1	70
L-33-6	10–50	60	1.5:1	100
L-33-10	25–100	54	1.4:1	120
L-33-17	50–200	48	1.3:1	130
L-43-1	0.30–1.00	115	1.6:1	110
L-43-2	1.00–10	98	1.6:1	120
L-43-3	0.01–0.5	133	1.8:1	90
L-43-6	10–50	85	1.4:1	130
L-43-10	25–100	72	1.3:1	150
L-43-17	50–200	56	1.2:1	200
L-57-1	0.30–1.00	175	3:1	*
L-57-2	1.00–10	125	2:1	*
L-57-3	0.01–0.5	204	3:1	*
L-57-6	10–50	115	2:1	*
L-57-10	25–100	100	2:1	*
L-57-17	50–200	67	1.5:1	*

Determine the required inductance from Eq. (4-3). For an experiment to see how this coil system works, I decided to build a 15-MHz WWV converter that reduced the WWV radio station frequency to an 80- to 75-m ham-band frequency. Thus, I needed a circuit that would tune 15 MHz. It is generally a good idea to have a high capacitance-to-inductance ratio in order to maintain a high Q factor. I selected a 56-pF NPO capacitor for the tuned circuit because it is in the right range, and a dozen or so were in my junk box. According to Eq. (4-3), therefore, I needed a 2- μ H inductor.

To calculate the number of turns (N) required to make any specific inductance, use the following equation:

$$N = 100 \sqrt{\frac{L}{0.9A_L}}, \quad (4-4)$$

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where

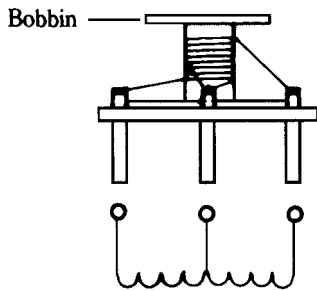
L = inductance in microhenrys (μH)

N = the number of turns.

The A_L factor is a function of the properties of the core materials and is found in Table 4-1; the units are microhenrys per 100 turns ($\mu\text{H}/100$ turns). In my case, I selected an L-57-6, which covers the correct frequency range and has an A_L value of $115 \mu\text{H}/100$ turns. According to Eq. (4-4), therefore, I need 14 turns of wire.

The coil is wound from no. 26 to no. 32 wire. Ideally, Litz wire is used, but that is both hard to find and difficult to solder. For most projects ordinary enamel-coated magnet wire will suffice. A razor knife (such as X-acto) and soldering iron tip can be used to remove the enamel from the ends of the wire. Because the forms are small, I recommend using the no. 32 size.

Winding the coil can be a bit tricky if your vision needs augmentation as much as mine. But, using tweezers, needlenose pliers, and a magnifying glass on a stand made it relatively easy. Figure 4-3 shows the method for winding a coil with a tapped winding. Anchor one end of the wire with solder on one of the end posts and use this as the reference point. In my case, I wanted a 3-turn tap on the 14-turn coil, so I wound 3 turns then looped the wire around the center post. After this point was soldered, the rest of the coil was wound and then anchored at the remaining end post. A dab of glue or clear fingernail polish will keep the coil windings from moving.



4-3

Construction of a custom coil using Fig. 4-2.

If you make an RF/IF transformer, then there will be two windings. Try to separate the primary and secondary windings if both are tuned. If one winding is not tuned, then simply wind it over the “cold” (i.e., ground) end of the tuned winding—no separation is needed.

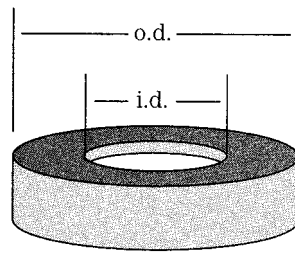
The Amidon coil forms are tight, but they do have sufficient space for very small disk ceramic capacitors inside. The 56-pF capacitors that I selected fit nicely inside the shielded can of the coil, so I elected to place it there. Thus, I’ve basically made a 15-MHz RF/IF transformer.

After constructing the 15-MHz RF coil, I tested it and found that the slug tuned the coil to 15 MHz with a nice tolerance on either side of the design resonant frequency. It worked!

Although slug-tuned inductors are sometimes considered a bit beyond the hobbyist or ham, that is not actually true. The Amidon L-series coil forms can easily be used to make almost any inductor that you are likely to need.

Making your own toroid-core inductors and RF transformers

A lot of construction projects intended for electronic hobbyists and amateur radio operators call for inductors or radio-frequency (RF) transformers wound on toroidal cores. A toroid is a doughnut-shaped object, i.e., a short cylinder (often with rounded edges) that has a hole in the center (see Fig. 4-4). The toroidal shape is desirable for inductors because it permits a relatively high inductance value with few turns of wire, and, perhaps most important, the geometry of the core makes it self-shielding. That latter attribute makes the toroid inductor easier to use in practical RF circuits. Regular solenoid-wound cylindrical inductors have a magnetic field that goes outside the immediate vicinity of the windings and can thus intersect nearby inductors and other objects. Unintentional inductive coupling can cause a lot of serious problems in RF electronic circuits so they should be avoided wherever possible. The use of a toroidal shape factor, with its limited external magnetic field, makes it possible to mount the inductor close to other inductors (and other components) without too much undesired interaction.



4-4

(A) Trifilar wound transformer circuit; (B) actual windings; (C) glue or silicone seal is used to hold the ends of the windings.

Materials used in toroidal cores

Toroid cores are available in a variety of materials that are usually grouped into two general classes: powdered iron and ferrite. These groups are further subdivided.

Powdered-iron materials

Powdered-iron cores are available in two basic formulations: carbonyl irons and hydrogen-reduced irons. The carbonyl materials are well-regarded for their temperature stability; they have permeability (μ) values that range from 1μ to about 35μ . The carbonyls offer very good Q values to frequencies of 200 MHz. Carbonyls are used in high-power applications as well as in variable-frequency oscillators and wherever temperature stability becomes important. However, notice that no powdered-iron material or ferrite is totally free of temperature variation, so oscillators using these cores must be temperature compensated for proper operation. The hydrogen-reduced iron devices offer permeabilities up to 90μ , but are lower Q than carbonyl devices. They are most used in electromagnetic interference (EMI) filters. The powdered-iron materials are the subject of Table 4-2.

Table 4-2. Powdered-iron core materials

Material	Permeability (μ)	Comments
0	1	Used up to 200 MHz; inductance varies with method of winding
1	20	Made of carbonyl C; similar to mixture no. 3 but is more stable and has a higher volume resistivity
2	10	Made of carbonyl E; high Q and good volume resistivity over range of 1 to 30 MHz
3	35	Made of carbonyl HP; very good stability and good Q over range of 0.05 to 0.50 MHz
6	8	Made of carbonyl SF; similar to mixture no. 2 but has higher Q over range 20 to 50 MHz
10	6	Type W powdered iron; good Q and high stability from 40 to 100 MHz
12	3	Made of a synthetic oxide material; good Q but only moderate stability over the range 50 to 100 MHz
15	25	Made of carbonyl GS6; excellent stability and good Q over range 0.1 to 2 MHz; recommended for AM BCB and VLF applications
17	3	Carbonyl material similar to mixture no. 12 but has greater temperature stability but lower Q than no. 12
26	75	Made of hydrogen reduced iron; has very high permeability; used in EMI filters and DC chokes

Ferrite materials

The name *ferrite* implies that the materials are iron-based (they are not), but ferrites are actually grouped into nickel-zinc and manganese-zinc types. The nickel-zinc material has a high-volume resistivity and high Q over the range 0.50 to 100 MHz. The temperature stability is only moderate, however. The permeabilities of nickel-zinc materials are found in the range 125 to 850 μ . The manganese-zinc materials have higher permeabilities than nickel-zinc and are on the order of 850 to 5000 μ . Manganese-zinc materials offer high Q over 0.001 to 1 MHz. They have low volume resistivity and moderate saturation flux density. These materials are used in switching power supplies from 20 to 100 kHz and for EMI attenuation in the range 20 to 400 MHz. See Table 4-3 for information on ferrite materials.

Toroid-core nomenclature

Although there are several different ways to designate toroidal cores, the one used by Amidon Associates is perhaps that most commonly found in electronic hobbyist and amateur radio published projects.

Although the units of measure are the English system, which is used in the United States and Canada and formerly in the UK, rather than SI units, their use with respect to toroids seems widespread. The type number for any given core will consist of three elements: xx-yy-zz. The “xx” is a one- or two-letter designation of the

Table 4-3. Ferrite materials

Material	Permeability (μ)	Remarks ¹
33	850	M-Z; used over 0.001 to 1 MHz for loopstick antenna rods; low volume resistivity
43	850	N-Z; medium-wave inductors and wideband transformers to 50 MHz; high attenuation over 30 to 400 MHz; high volume resistivity
61	125	N-Z; high Q over 0.2 to 15 MHz; moderate temperature stability; used for wideband transformers to 200 MHz
63	40	High Q over 15 to 25 MHz; low permeability and high volume resistivity
67	40	N-Z; high Q operation over 10 to 80 MHz; relatively high flux density and good temperature stability; similar to Type 63, but has lower volume resistivity; used in wideband transformers to 200 MHz
68	20	N-Z; excellent temperature stability and high Q over 80 to 180 MHz; high volume resistivity
72	2000	High Q to 0.50 MHz but used in EMI filters from 0.50 to 50 MHz; low volume resistivity
J/75	5000	Used in pulse and wideband transformers from 0.001 to 1 MHz and in EMI filters from 0.50 to 20 MHz; low volume resistivity and low core losses
77	2000	0.001 to 1 MHz; used in wideband transformers and power converters and in EMI and noise filters from 0.5 to 50 MHz
F	3000	Is similar to Type 77 above but offers a higher volume resistivity, higher initial permeability, and higher flux saturation density; used for power converters and in EMI/noise filters from 0.50 to 50 MHz

¹ N-Z: nickel-zinc;
M-Z: manganese-zinc.

general class of material, i.e., powdered iron (xx = “T”) or ferrite (xx = “TF”). The “yy” is a rounded-off approximation of the outside diameter (*o.d.* in Fig. 4-4) of the core in inches; “37” indicates a 0.375" (9.53 mm) core, while “50” indicates a 0.50" (12.7 mm) core. The “zz” indicates the type (mixture) of material. A mixture no. 2 powdered-iron core of 0.50" diameter would be listed as a T-50-2 core. The cores are color-coded to assist in identification.

Inductance of toroidal coils

The inductance of the toroidal core inductor is a function of the permeability of the core material, the number of turns, the inside diameter (*i.d.*) of the core, the outside diameter (*o.d.*) of the core, and the height (*h*) (see Fig. 4-1) and can be approximated by:

$$L = 0.011684 h N^2 \mu_r \log_{10} \left(\frac{o.d.}{i.d.} \right) H. \quad (4-5)$$

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This equation is rarely used directly, however, because toroid manufacturers provide a parameter called the A_L *value*, which relates inductance per 100 or 100 turns of wire. Tables 4-4 and 4-5 show the A_L values of common ferrite and powdered-iron cores.

Table 4-4. Common powdered-iron A_L values

Core size	Core material type (mix)								
	26	3	15	1	2	6	10	12	0
12	—	60	50	48	20	17	12	7	3
16	—	61	55	44	22	19	13	8	3
20	—	90	65	52	27	22	16	10	3.5
37	275	120	90	80	40	30	25	15	4.9
50	320	175	135	100	49	40	31	18	6.4
68	420	195	180	115	57	47	32	21	7.5
94	590	248	200	160	84	70	58	32	10.6
130	785	350	250	200	110	96	—	—	15
200	895	425	—	250	120	100	—	—	—

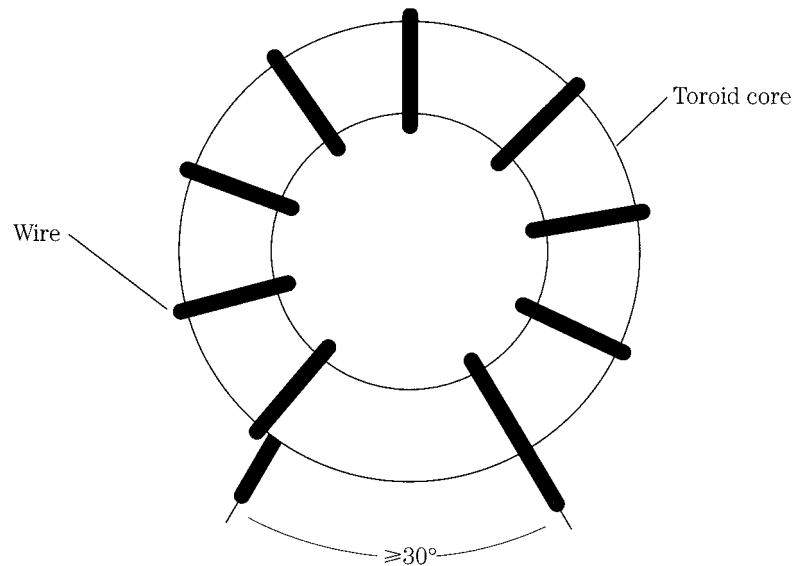
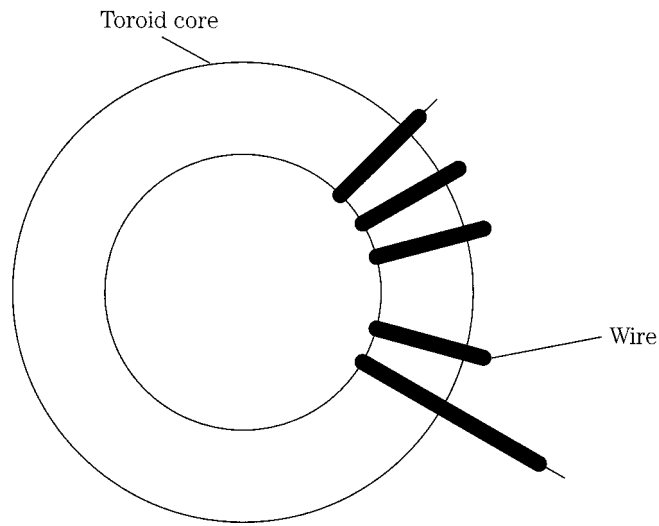
Table 4-5. Common ferrite-core A_L values

Core size ¹	Material type					
	43	61	63	72	75	77
23	188	24.8	7.9	396	990	356
37	420	55.3	17.7	884	2210	796
50	523	68	22	1100	2750	990
50A	570	75	24	1200	2990	1080
50B	1140	150	48	2400	—	2160
82	557	73.3	22.8	1170	3020	1060
114	603	79.3	25.4	1270	3170	1140
114A	—	146	—	2340	—	—
240	1249	173	53	3130	6845	3130

¹ Core type no. prefix: TF-yy-zz.

Winding toroid inductors

There are two basic ways to wind a toroidal core inductor: distributed (Fig. 4-5A) and close-spaced (Fig. 4-5B). In distributed toroidal inductors, the turns of wire that are wound on the toroidal core are spaced evenly around the circumference of the core, with the exception of a gap of at least 30° between the ends (see Fig. 4-5A). The gap ensures that stray capacitance is kept to a minimum. The winding covers 270° of the core. In close winding (Fig. 4-5B), the turns are made so that adjacent turns of wire touch each other. This practice raises the stray capacitance of the winding, which affects the resonant frequency, but can be done in many cases with little or no ill effect (especially where the capacitance and resonant point shift are negli-

**A****B****4-5** Toroid winding styles: (A) distributed; (B) close wound.

gible). In general, close winding is used for inductors in narrowband-tuned circuits, and distributed winding is used for broadband situations, such as conventional and balun RF transformers. The method of winding has a small effect on the final inductance of the coil. Although this makes calculating the final inductance less pre-

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dictable, it also provides a means of final adjustment of actual inductance in the circuit as-built.

Calculating the number of turns

As in all inductors, the number of turns of wire determines the inductance of the finished coil. In powdered-iron cores, the A_L rating of the core is used with fair confidence to predict the number of turns needed.

For powdered-iron cores:

$$N = 100 \frac{\sqrt{L_{\mu H}}}{A_L} \quad (4-6)$$

For ferrite cores:

$$N = 1000 \sqrt{\frac{L_{mH}}{A_L}}, \quad (4-7)$$

where

N = the number of turns

$L_{\mu H}$ = inductance in microhenrys (μH)

L_{mH} = inductance in millihenrys (mH)

A_L is a property of the core material.

Building the toroidal device

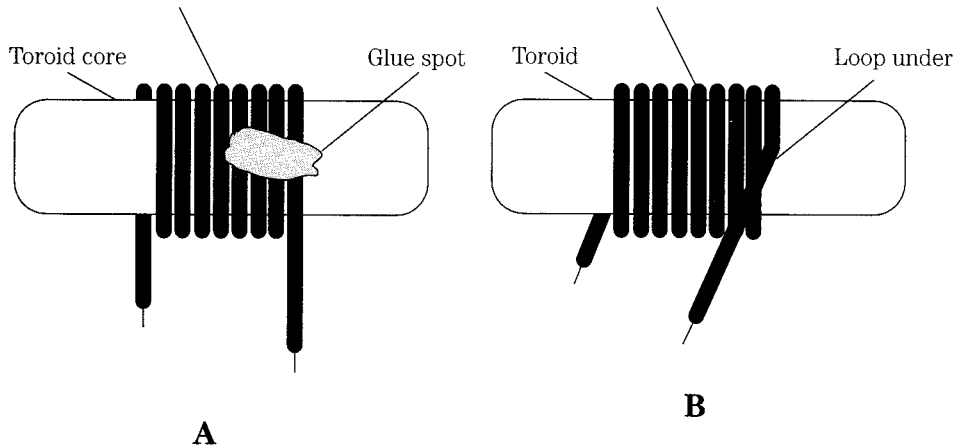
The toroid core or transformer is usually wound with enameled or formvar-insulated wire. For low-powered applications (receivers, VFOs, etc.) the wire will usually be no. 22 through no. 36 (with no. 26 being very common) AWG. For high-power applications, such as transmitters and RF power amplifiers, a heavier grade of wire is needed. For high-power RF applications, no. 14 or no. 12 wire is usually specified, although wire as large as no. 6 has been used in some commercial applications. Again, the wire is enameled or formvar-covered insulated wire.

In the high-power case, it is likely that high voltages will exist. In high-powered RF amplifiers, such as used by amateur radio operators in many countries, the potentials present across a 50- Ω circuit can reach hundreds of volts. In those cases, it is common practice to wrap the core with a glass-based tape, such as Scotch 27.

High-powered applications also require a large-area toroid rather than the small toroids that are practical at lower power levels. Cores in the FT-150-zz to FT-240-zz or T-130-zz to T-500-zz are typically used. In some high-powered cases, several identical toroids are stacked together and wrapped with tape to increase the power-handling capacity. This method is used quite commonly in RF power amplifier and antenna tuner projects.

Binding the wires

It sometimes happens that the wires making up the toroidal inductor or transformer become loose. Some builders prefer to fasten the wire to the core using one of the two methods shown in Fig. 4-6. Figure 4-6A shows a dab of glue, silicone adhesive, or the high-voltage sealant Glyptol (sometimes used in television receiver high-voltage circuits) to anchor the end of the wire to the toroid core.



4-6 Methods for fastening the wire on a toroid winding: (A) glue spot and (B) “tuck under” method.

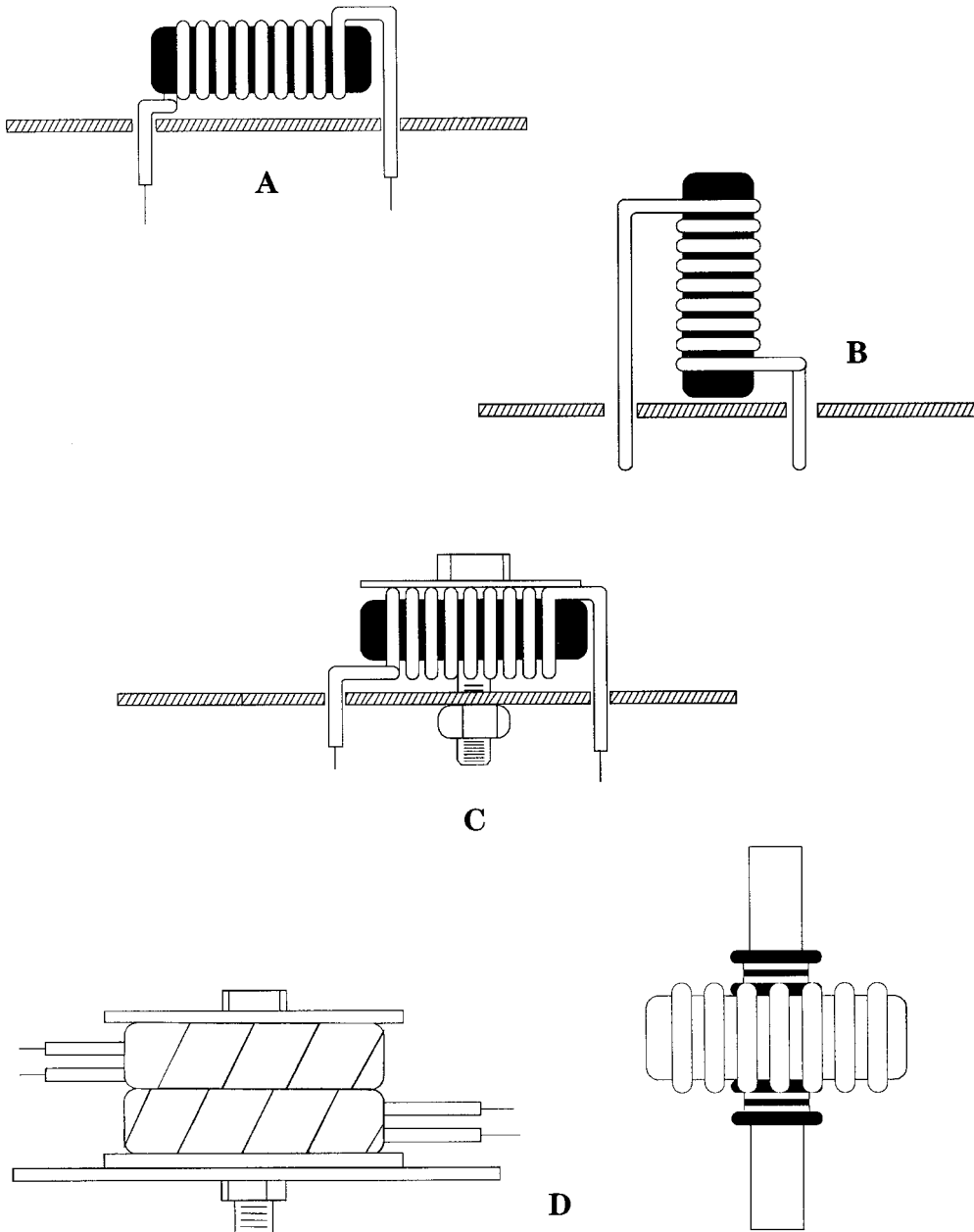
Other builders prefer the method shown in Fig. 4-6B. In this method, the end of the wire is looped underneath the first full turn and pulled taut. This method will effectively anchor the wire, but some say it creates an anomaly in the magnetic situation that might provoke interactions with nearby components. In my experience, that situation is not terribly likely, and I use the method regularly with no observed problems thus far.

When the final coil is ready, and both the turns count and spacing are adjusted to yield the required inductance, the turns can be anchored to the coil placed in service. A final sealant method is to coat the coil with a thin layer of clear lacquer, or “Q-dope” (this product is intended by its manufacturer as an inductor sealant).

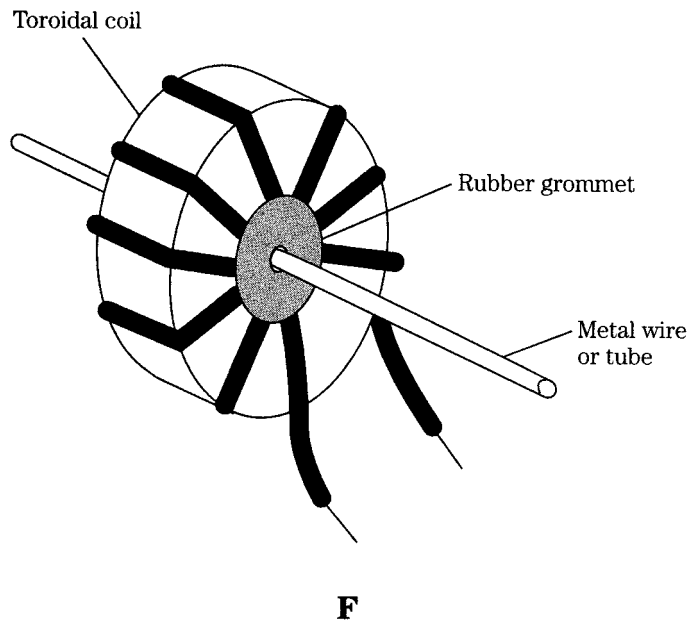
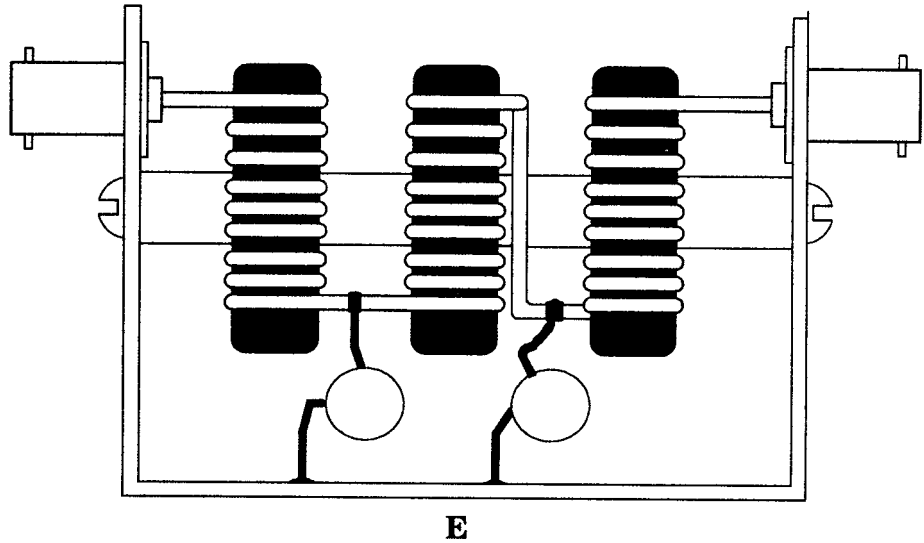
Mounting the toroidal core

Toroids are a bit more difficult to mount than solenoid-wound coils (cylindrical coils), but the rules that one must follow are not as strict. The reason for loosening of the mounting rules is that the toroid, when built correctly, is essentially self-shielding, so less attention (not *no* attention!) can be paid to the components that surround the inductor. In the solenoid-wound coil, for example, the distance between adjacent coils and their orientation is important. Adjacent coils, unless well shielded, must be placed at right angles to each other to lessen the mutual coupling between the coils. However, toroidal inductors can be closer together and either coplanar or adjacent planar can be placed with respect to each other. Although some spacing must be maintained between toroidal cores (the winding and core manufacture not being perfect), the required average distance can be less than for solenoid-wound cores.

Mechanical stability of the mounting is always a consideration for any coil (indeed, any electronic component). For most benign environments, the core can be mounted directly to a printed wiring board (PWB) in the manner of Figs. 4-7A and 4-7B. In Fig. 4-7A, the toroidal inductor is mounted flat against the board; its leads

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4-7 (A) Flat mounting; (B) on-end mounting; (C) secured mounting (use nylon machine screws); (D) mounting high-power or high-voltage toroidal inductors or transformers; (E) suspending toroid inductors on a dowel; (F) mounting method for a “single-turn primary” transformer in RF watt-meters or VSWR meters.



4-7 Continued

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are passed through holes in the board to solder pads underneath. The method of Fig. 4-7B places the toroid at right angles to the board, but it still uses the leads soldered to copper pads on the PWB to anchor the coil. It is wise to use a small amount of RTV silicone sealant or glue to held the coil to the board once it is found to work satisfactorily.

If the environment is less benign with respect to vibration levels, then a method similar to Fig. 4-7C can be used. Here, the toroid is fastened to the PWB with a set of nylon machine screw and nut hardware and a nylon or fiber washer. In high-powered antenna tuning units, it is common to see an arrangement similar to that in Fig. 4-7D. In this configuration, several toroidal cores are individually wrapped in glass tape, then the entire assembly is wrapped as a unit with the same tape. This assembly is mounted between two insulators, such as plastics, ceramic, or fiberboard, which are held together as a “sandwich” by a nylon bolt and hex nut.

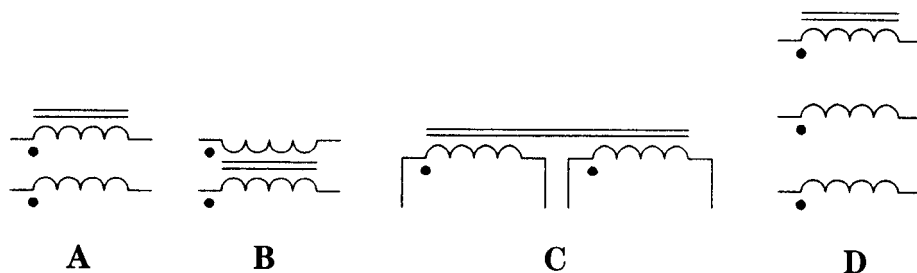
Figure 4-7E shows a method for suspending toroidal cores in a shielded enclosure. I’ve used this method to make five-element low-pass filters for use in my basement laboratory. The toroidal inductors are mounted on a dowel, which is made of some insulating material, such as wood, plastic, plexiglass, Lexan, or other synthetic. If the dowel is sized correctly, then the inductors will be a tight slip fit and there will be no need for further anchoring. Otherwise, a small amount of glue or RTV silicone sealant can be used to stabilize the position of the inductor.

Some people use a pair of undersized rubber grommets over the dowel, one pressed against either side of the inductor (see inset to Fig. 4-7E). If the grommets are taut enough, then no further action is needed. Otherwise, they can be glued to the rod.

A related mounting method is used to make current transformers in home-made RF power meters (Fig. 4-7F). In this case, a rubber grommet is fitted into the center of the toroid, and a small brass or copper rod is passed through the center hole of the grommet. The metal rod serves as a one-turn primary winding. A sample of the RF current flowing in the metal rod is magnetically coupled to the secondary winding on the toroid, where it can be fed to an oscilloscope for display or rectified, filtered, and displayed on a dc current meter that is calibrated in watts or VSWR units.

Torodial RF transformers

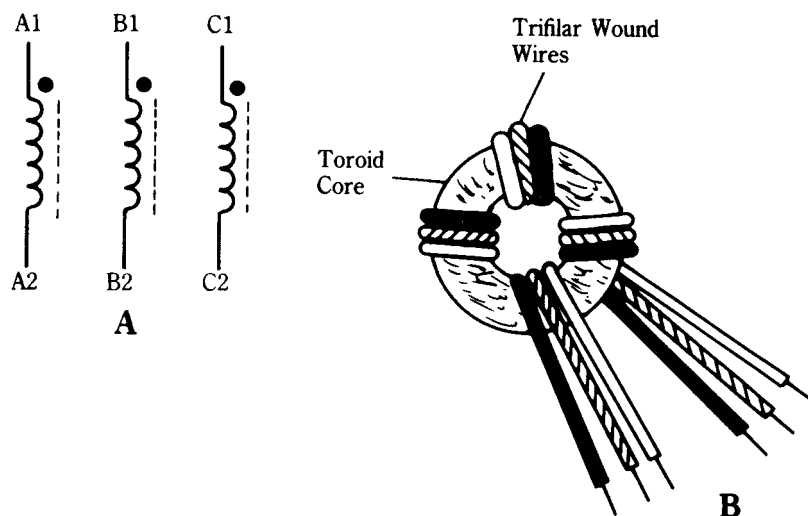
Both narrowband-tuned and broadband RF transformers can be accommodated by toroidal powdered-iron and ferrite cores. The schematic symbols used for transformers are shown in Fig. 4-8. These symbols are largely interchangeable and are all seen from time to time. In Fig. 4-8A, the two windings are shown adjacent to each other, but the core is shown along only one of them. This method is used to keep the drawing simple and does not imply in any way that the core does not affect one of the windings. The core can be represented either by one or more straight lines, as shown, or by dotted lines. The method shown in Fig. 4-8B is like the conventional transformer representation in which the windings are juxtaposed opposite each other with the core between them. In Fig. 4-8C, the core is extended and the two windings are along one side of the core bars.



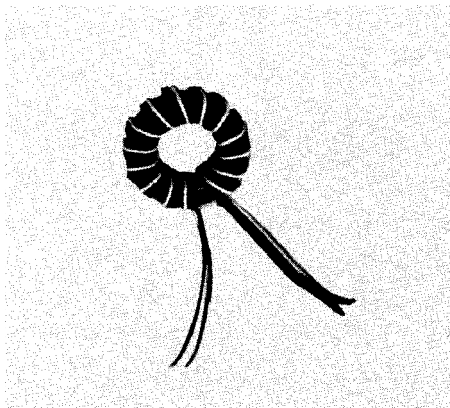
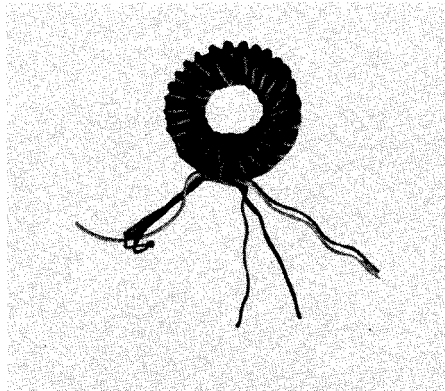
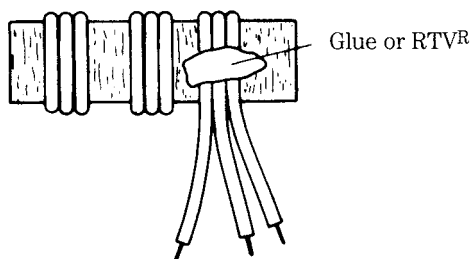
4-8 Transformer schematic styles.

In each of the transformer representations of Fig. 4-8, dots are on the windings. These dots show the “sense” of the winding and represent the same end of the coils. Thus, the wires from two dotted ends are brought to the same location, and the two coils are wound in the same direction. Another way of looking at it is that if a third winding were used to excite the core from an RF source, the phase of the signals at the dot end will be the same; the phase of the signal at the undotted ends will also be the same, but will be opposite that of the dotted ends.

I was once questioned by a reader concerning the winding protocol for toroidal transformers, as shown in books and magazine articles. My correspondent included a partial circuit (Fig. 4-9A) as typical of the dilemma. The question was How do you wind it? and a couple of alternative methods were proposed. At first I thought it was a silly question because the answer was obvious, and then I realized that perhaps I was wrong; to many people, the answer was not that obvious. The answer to this question is that all windings are wound together in a multifilar manner.



4-9 Trifilar wound transformer: (A) circuit symbol; (B) winding details; (C) using parallel wires; (D) using twisted wires; and (E) glue spot for securing windings.

**C****D****E**4-9 *Continued.*

Because there are three windings, in this case, we are talking about trifilar windings. Figure 4-9B shows the trifilar winding method. For the sake of clarity, I have colored all the three wires differently so that you can follow it. This practice is also a good idea for practical situations. Because most of my projects use nos. 26, 28, or 30 enameled wire to wind coils, I keep three colors of each size on hand and wind each winding with a different color. That makes it a whole lot easier to identify which ends go with each other.

The dots in the schematic and on the pictorial are provided to identify one end of the coil windings. Thus, the dot and no-dot ends are different from each other; in circuit operation, it usually makes a difference which way the ends are connected into the circuit (the issue is signal phasing).

Figures 4-9C and 4-9D shows two accepted methods for winding a multifilar coil on a toroidal core. Figure 4-9C is the same method as in Fig. 4-9B, but on an actual toroid instead of a pictorial representation. The wires are laid down parallel to each other as shown previously. The method in Fig. 4-9D uses twisted wires. The three wires are chunked up in a drill and twisted together before being wound on the core.

With one end of the three wires secured in the drill chuck, anchor the other end of the three wires in something that will hold it taut. I use a bench vise for this purpose. Turn the drill on the slow speed and allow the wires to twist together until the desired pitch is achieved.

Be very careful when performing this operation. If you don't have a variable-speed electric drill (so that it can be run at very low speeds), then use an old-fashioned manual hand drill. If you use an electric drill, wear eye protection. If the wire breaks or gets loose from its mooring, it will whip around wildly until the drill stops. That whipping wire can cause painful welts on your skin, and it can easily cause permanent eye damage.

Of the two methods for winding toroids, the method shown in Figs. 4-9B and 4-9C is preferred. When winding toroids, at least those of relatively few windings, pass the wire through the doughnut hole until the toroid is about in the middle of the length of wire. Then, loop the wire over the outside surface of the toroid and pass it through the hole again. Repeat this process until the correct number of turns are wound onto the core. Be sure to press the wire against the toroid form and keep it taut as you wind the coils.

Enameled wire is usually used for toroid transformers and inductors, and that type of wire can lead to a problem. The enamel can chip and cause the copper conductor to contact the core. On larger cores, such as those used for matching transformers and baluns used at kilowatt power levels, the practical solution is to wrap the bare toroid core in a layer of fiberglass packing tape. Wrap the tape exactly as if it were wire, but overlap the turns slightly to ensure that the entire circumference of the core is covered.

On some projects, especially those in which the coils and transformers use very fine wire (e.g., no. 30), I have experienced a tendency for the wire windings to unravel after the winding is completed. This problem is also easily curable. At the ends of the windings place a tiny dab of rubber cement or RTV silicone sealer (see Fig. 4-5E).

Conventional RF transformers

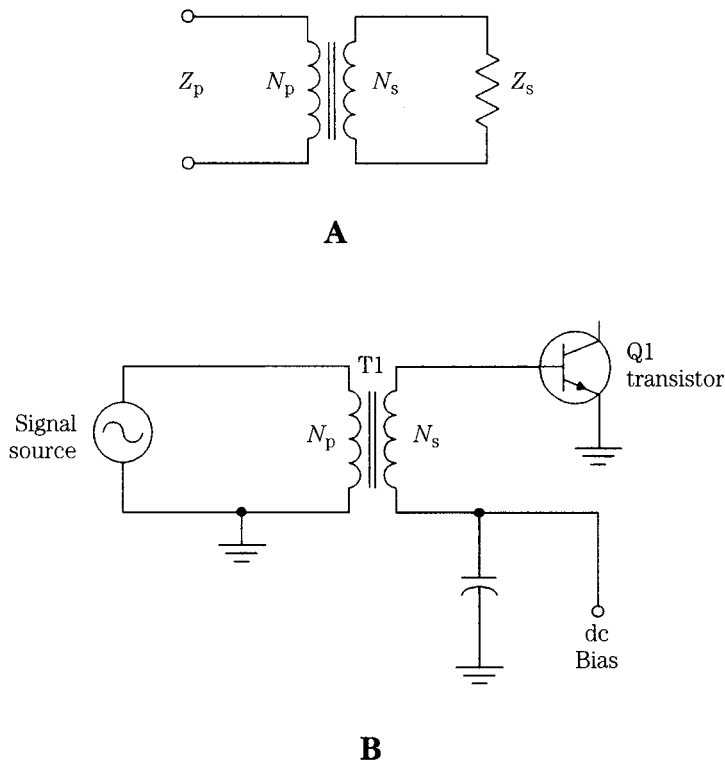
One of the principal uses of transformers in RF circuits is impedance transformation. When the secondary winding of a transformer is connected to a load impedance, the impedance seen "looking into" the primary will be a function of the load impedance and the turns ratio of the transformer (see Fig. 4-10A). The relationship is:

$$\frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s}} \quad (4-8)$$

With the relationship of Eq. (4-8), you can match source and load impedances in RF circuits.

Example

Assume that you have a 3- to 30-MHz transistor RF amplifier with a base input impedance of $4\ \Omega$ (Z_s), and that transistor amplifier has to be matched to a $50\text{-}\Omega$

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4-10 (A) A transformer with primary and secondary labels; (B) typical transformer circuit with transistor load.

source impedance (Z_p), as shown in Fig. 4-10B. What turns ratio is needed to effect the impedance match? Let's calculate:

$$\begin{aligned}\frac{N_p}{N_s} &= \sqrt{\frac{Z_p}{Z_s}} \\ \frac{N_p}{N_s} &= \sqrt{\frac{50\Omega}{4\Omega}} \\ \frac{N_p}{N_s} &= \sqrt{12.5} = 3.53:1.\end{aligned}\tag{4-9}$$

A general design rule for the value of inductance used in transformers is that the inductive reactance at the lowest frequency must be 4 times ($4\times$) the impedance connected to that winding. In the case of the $50\text{-}\Omega$ primary of this transformer, the inductive reactance of the primary winding should be $4 \times 50 = 200\text{ }\Omega$. The inductance should be:

$$L = \frac{200\Omega 10^6}{2\pi F}$$

$$L = \frac{200 \Omega 10^6}{(2)(3.1415)(3,000,000 \text{ Hz})} = 10.6 \mu\text{H}.$$

Now that you know that a 10.6- μH inductance is needed, you can select a toroidal core and calculate the number of turns needed. The T-50-2 (RED) core covers the correct frequency range and is of a size that is congenial to easy construction. The T-50-2 (RED) core has an A_L value of 49, so the number of turns required is as follows:

$$N = 100 \sqrt{\frac{10.6 \mu\text{H}}{49}} = 46.5 \text{ turns} \approx 47 \text{ turns}.$$

The number of turns in the secondary must be such that the 3.53:1 ratio is preserved when 47 turns are used in the primary:

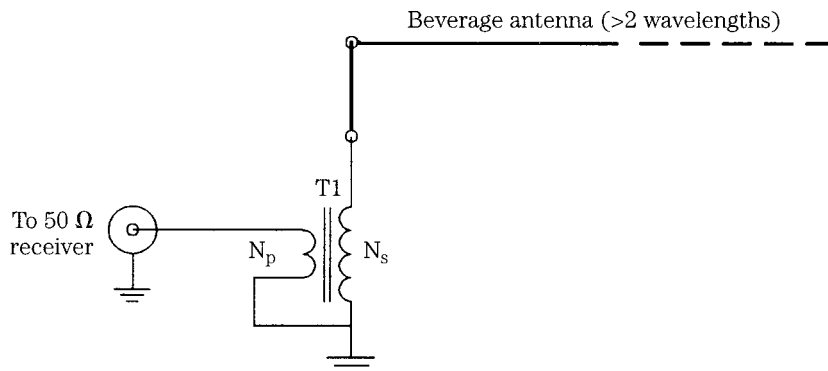
$$N_s = \frac{47}{3.53} = 13.3 \text{ turns}.$$

If you wind the primary with 47 turns and the secondary with 13 turns, then you can convert the 4- Ω transistor base impedance to the 50- Ω systems impedance.

Example

A beverage antenna can be constructed for the AM broadcast band (530 to 1700 kHz). By virtue of its construction and installation, it exhibits a characteristic impedance, Z_o , of 600 Ω . What is the turns ratio required of a transformer at the feed end (Fig. 4-11) to match a 50- Ω receiver input impedance?

$$\frac{N_s}{N_p} = \sqrt{\frac{600 \Omega}{50 \Omega}} = 3.46:1.$$



4-11 Coupling transformer used to feed a Beverage antenna.

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The secondary requires an inductive reactance of $4 \times 600 \Omega = 2400 \Omega$. To obtain this inductive reactance at the lowest frequency of operation requires an inductance of:

$$L = \frac{(2400 \Omega)(10^6)}{(2)(\pi)(530,000 \text{ Hz})} = 721 \mu\text{H}.$$

Checking a table of powdered-iron toroid cores, you will find that the -15 (RED/WHT) mixture will operate over 0.1 to 2 MHz (see Table 4-6.). Selecting a T-106-15 (Red/White) core provides an A_L value of 345. The number of turns required to create an inductance of 721 μH is:

$$N = 100 \sqrt{\frac{721 \mu\text{H}}{345}} = 145 \text{ turns}.$$

The primary winding must have:

$$N_p = \frac{145}{3.46} \text{ turns} = 42 \text{ turns}.$$

Winding this transformer, as designed, should provide adequate service.

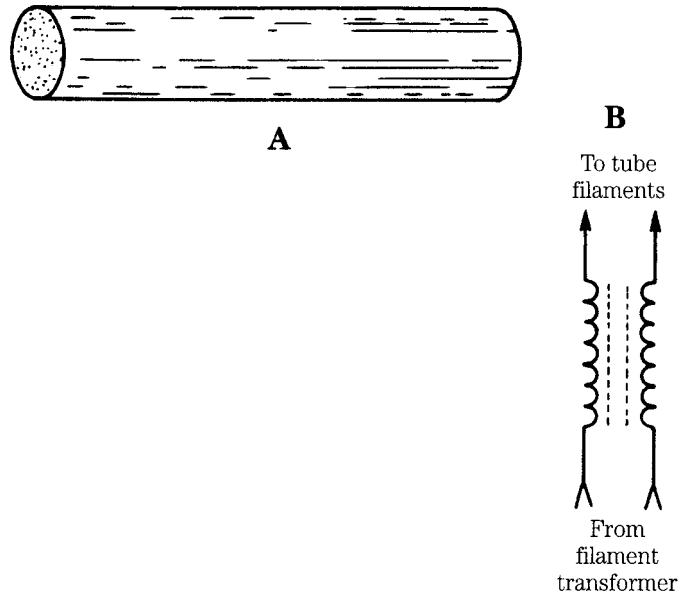
Table 4-6. Properties of powdered-iron core types

Material type	Color code	Mu (μ)	Frequency (MHz)
41	Green	75	—
3	Grey	35	0.05–0.5
15	Red/white	25	0.1–2
1	Blue	20	0.5–5
2	Red	10	1–30
6	Yellow	8	10–90
10	Black	6	60–150
12	Green/white	3	100–200
0	Tan	1	150–300

Ferrite and powdered-iron rods

Ferrite rods (Fig. 4-12A) are used in the low-frequency medium wave, AM broadcast band, and LF/VLF receivers to form “loopstick” antennas. These antennas are often used in radio-direction finders because they possess a “figure-8” reception pattern that counterposes two deep nulls with a pair of main lobes. Another application of ferrite rods is to make balun transformers (Fig. 4-12B) or filament transformers in vacuum-tube high-power RF amplifiers. Ferrite rod inductors are also used in any application, up to about 10 MHz, where a high inductance is needed.

Two permeability figures are associated with the ferrite rod, but only one of them is easily available (see Table 4-7): the initial permeability. This figure is used in the equations for inductance. The effective permeability is a little harder to pin down and is dependent on such factors as (a) the length/diameter ratio of the rod, (b) location of the coil on the rod (centered is most predictable), (c) the spacing between turns of wire, and (d) the amount of air space between the wire and the rod. In general, maximizing effective A_L and inductance requires placing the coil in the center of the rod. The best Q , on the other hand, is achieved when the coil runs nearly the entire length of the rod.



4-12 (A) Ferrite rod; (B) filament transformer RF choke.

Table 4-7. Properties of some common ferrite rods

Part no. turns	Permeability	Approx. A_L ¹	Ampere
R61-025-400	125	26	110
R61-033-400	125	32	185
R61-050-400	125	43	575
R61-050-750	125	49	260
R33-037-400	800	62	290
R33-050-200	800	51	465
R33-050-400	800	59	300
R33-050-750	800	70	200

¹ Approximate value for coil centered on rod, covering nearly the entire length, made of no. 22 wire. Actual A_L may vary with situation.

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Several common ferrite rods available from Amidon Associates are shown in Table 4-7. The “R” indicates “rod” while the number associated with the “R” (e.g., R61) indicates the type of ferrite material used in the rod. The following numbers (e.g., 025) denote the diameter (025 = 0.25”, 033 = 0.33”, and 050 = 0.50”); the length of the rod is given by the last three digits (200 = 2”, 400 = 4”, and 750 = 7.5”). The Type 61 material is used from 0.2 to 10 MHz, and the Type 33 material is used in VLF applications.

In some cases, the A_L rating of the rod will be known, and in others, only the permeability (μ) is known. If either is known, you can calculate the inductance produced by any given number of turns.

For the case where the A_L is known:

$$L_{\mu H} = N_p^2 A_L \times 10^{-4} \quad (4-10)$$

For the case where μ is known:

$$L_{\mu H} = (4 \times 10^{-9}) \pi N_p^2 \mu \left(\frac{A_e (\text{cm}^2)}{l_e (\text{cm})} \right), \quad (4-11)$$

where

N_p is the number of turns of wire

μ is the core permeability

A_e is the cross-sectional area of the core (cm^2)

l_e is the length of the rod's flux path (cm)

Example

Find the number of turns required on an R61-050-750 ferrite rod to make a 220- μH inductor for use in the AM receiver with a 10- to 365-pF variable capacitor.

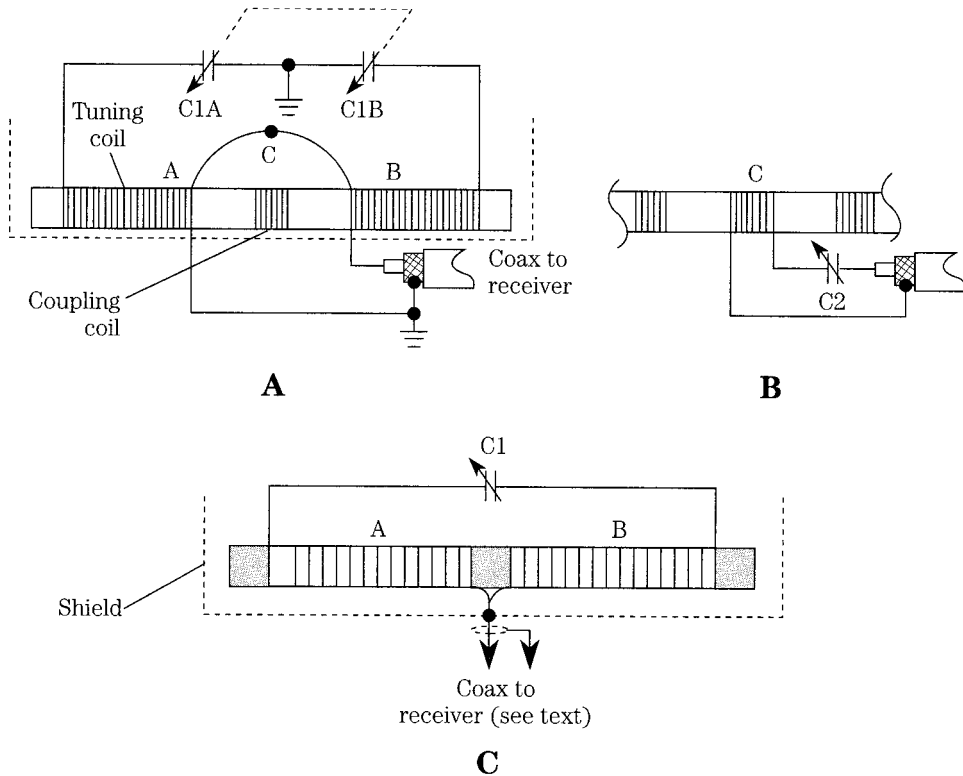
Solution

Solving Eq. (4-11) for N :

$$N = \sqrt{\frac{L_{\mu H}}{A_L \times 10^{-4}}}$$

$$N = \sqrt{\frac{220 \mu\text{H}}{(43)(10^{-4})}} = 226.$$

Figure 4-13 shows several popular ways for ferrite rod inductors to be wound for service as loopstick antennas in radio receivers. Figure 4-13A shows a transformer circuit in which the main tuned winding is broken into two halves, A and B. These windings are at the end regions of the rod but are connected together in series at the center. The main coils are resonated by a dual capacitor, C_{1A} and C_{1B} . A coupling winding, of fewer turns, is placed at the center of the rod and is connected to the coaxial cable going to the receiver. In some cases, the small coil is also tuned but usually with a series capacitor (see Fig. 4-13B). Capacitor C_2 is usually a much larger value than C_1 because the coupling winding has so many fewer turns than the main tuning windings. The antenna in Fig. 4-13C is a little different. The two halves of the



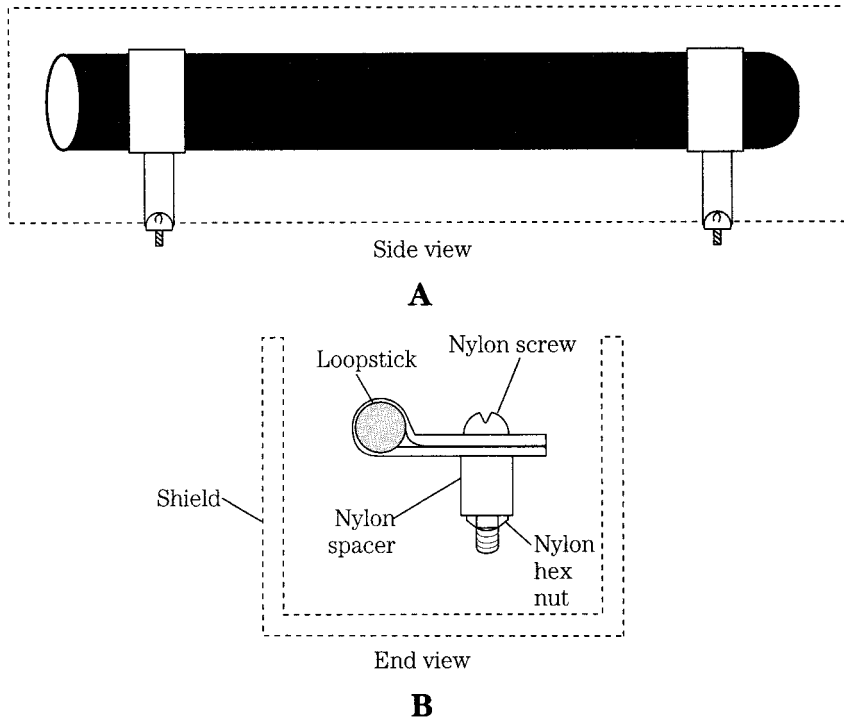
4-13 Loopstick antenna: (A) overall circuit for doubled-tuned winding; (B) tuning the coupling loop; and (C) singled tuned variety.

tuning winding are connected together at the center and connected directly to the center conductor of the coaxial cable or to a single download. A single capacitor is used to resonate the entire winding (both halves).

Project 4-1

A radio direction-finding antenna can be used for a number of purposes, only one of which is finding the direction from which a radio signal arrives. Another use is in suppressing cochannel and adjacent-channel interference. This becomes possible when the desired station is in a direction close to right angles from the line between the receiver and the desired transmitter. Reduction of the signal strength of the interfering signal is possible because the loopstick antenna has nulls off both ends.

Figure 4-14 shows a loopstick antenna mounted in a shielded compartment for radio direction finding. The shield is used to prevent electrical field coupling from nearby sources, such as power lines and other stations, yet doesn't affect the reception of the magnetic field of radio stations. The aluminum can be one-half of an electronic hobbyist's utility box, of appropriate dimensions, or can be built custom from



4-14 Mounting the loopstick antenna in a shielded enclosure.

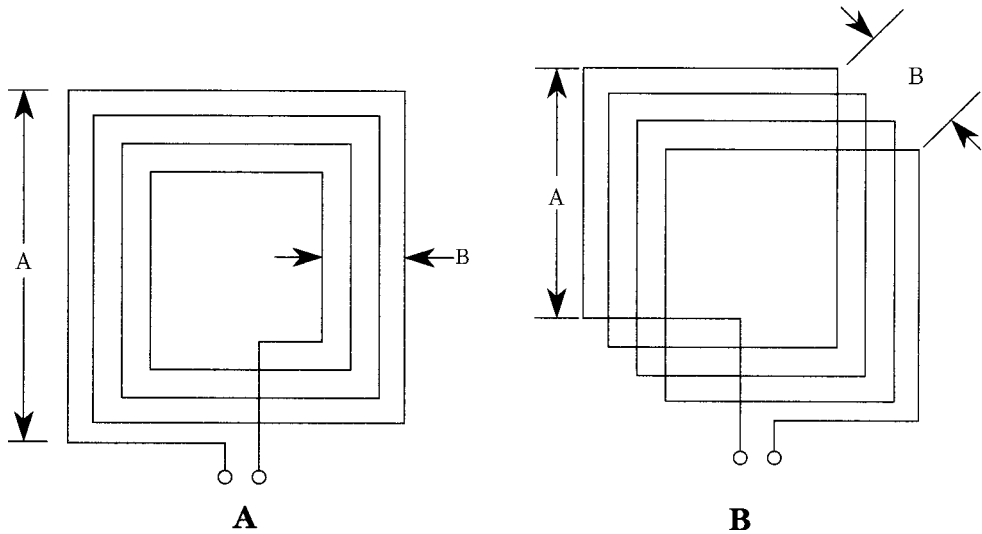
Harry & Harriet Homeowner Do-It-Yourself hardware stores. The loopstick antenna is mounted by nonmetallic cable ties to nylon spacers that are, in turn, fastened to the aluminum surface with nylon hardware.

The number of turns required for the winding can be found experimentally, but starting with the number called for by the preceding formula. The actual number of turns depends in part on the frequency of the band being received and the value of the capacitors used to resonate the loopstick antenna.

Noncylindrical air-core inductors

Most inductors used in radio and other RF circuits are either toroidal or solenoid-wound cylindrical. There is, however, a class of inductors that are neither solenoidal nor toroidal. Many loop antennas are actually inductors fashioned into either triangle, square, hexagon, or octagon shapes. Of these, the most common is the square-wound loop coil (Fig. 4-15). The two basic forms are: flat wound (Fig. 4-15A) and depth wound (Fig. 4-15B). The equation for the inductance of these shaped coils is a bit difficult to calculate, but the equation provided by F. W. Grover of the U.S. National Bureau of Standards in 1946 is workable:

$$L_{\mu\text{H}} = K_1 N^2 A \left(L n \left(\frac{K_2 A N}{(N + 1) B} \right) + K_3 + \left(\frac{K_4 (N + 1) B}{A N} \right) \right), \quad (4-12)$$



4-15 Inductive-loop direction-finding antenna.

where

A is the length of each side in centimeters (cm)

B is the width of the coil in centimeters (cm)

N is the number of turns in the coil (close wound)

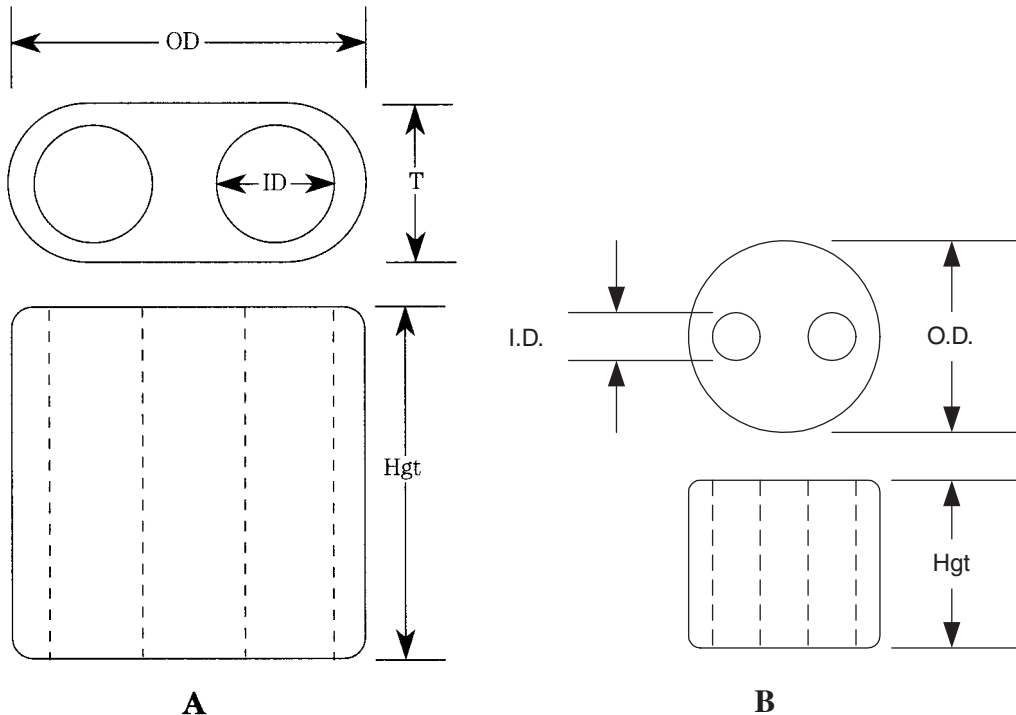
K_1, K_2, K_3 , and K_4 are 0.008, 1.4142, 0.37942, and 0.3333 respectively.

Whenever conductors are placed side by side, as in the case of the loop-wound coil, there is a capacitance between the conductors (even if formed by a single loop of wire, as in a coil). This capacitance can be significant when dealing with radio circuits. The estimate of distributed loop capacitance (in picofarads) for square loops is given by Bramslev as about $60A$, where A is expressed in meters (m). The distributed capacitance must be accounted for in making calculations of resonance. Subtract the distributed capacitance from the total capacitance required in order to find the value of the capacitor required to resonate the loop-wound coil.

Binocular- (“balun” or “bazooka”) core inductors

The toroidal core has a certain charm because it is easy to use, is predictable, and is inherently self-shielding because of its geometry. But there is another core shape that offers very high inductance values in a small volume. The binocular core (Fig. 4-16) offers very high A_L values in small packages, so you can create very high inductance values without them being excessively large. A binocular core that uses type 43 ferrite, and is about the same weight and size as the T-50-43 ($A_L = 523$), has an A_L value of 2890. Only 8.8 turns are required to achieve 225 μH on this core.

There are actually two different types of binocular core in Fig. 4-16. The Type 1 binocular core is shown in Fig. 4-16A. It is larger than the Type 2 (Fig. 4-16B) and has larger holes. It can, therefore, be used for larger-value inductors and transformers. The Type 2 core can be considered as a two-hole ferrite bead.



4-16 Bazooka balun cores: (A) Type 1 and (B) Type 2.

Table 4-8 shows several popular-sized binocular cores and their associated A_L values. The center two digits of each part number is the type of ferrite material used to make the core (e.g., BN-xx-202), and the last digits refer to the size and style of the core.

Three different ferrite materials are commonly used in binocular cores. The type 43 material is a nickel-zinc ferrite and has a permeability of 850. It is used for wide-band transformers up to 50 MHz and has high attenuation, from 30 to 400 MHz. It can be used in tuned RF circuits from 10 to 1000 kHz. The type 61 material is also nickel-

Table 4-8. Binocular cores

Part no.	Material	A_L value	Size	Style
BN-43-202	43	2890	A	1
BN-43-2302	43	680	B	1
BN-43-2402	43	1277	C	1
BN-43-3312	43	5400	D	1
BN-43-7051	43	6000	E	1
BN-61-202	61	425	A	1
BN-61-2302	61	100	B	1

zinc and has a permeability of 125. It offers moderate to good thermal stability and a high Q over the range 200 kHz to 15 MHz. It can be used for wideband transformers up to 200 MHz. The type 73 material has a permeability of 2500 and offers high attenuation from 500 kHz to 50 MHz.

The binocular core can be used for a variety of different RF inductor devices. Besides the single, fixed inductor, it is also possible to wind conventional transformers and balun transformers of various types on the core.

Figure 4-17 shows Type 1 binocular cores wound in various ways. The normal manner of winding the turns of the inductor is shown in Fig. 4-17A; the wire is passed from hole to hole around the central wall between the holes. The published A_L values for each core are based on this style of winding, and it is the most commonly used.

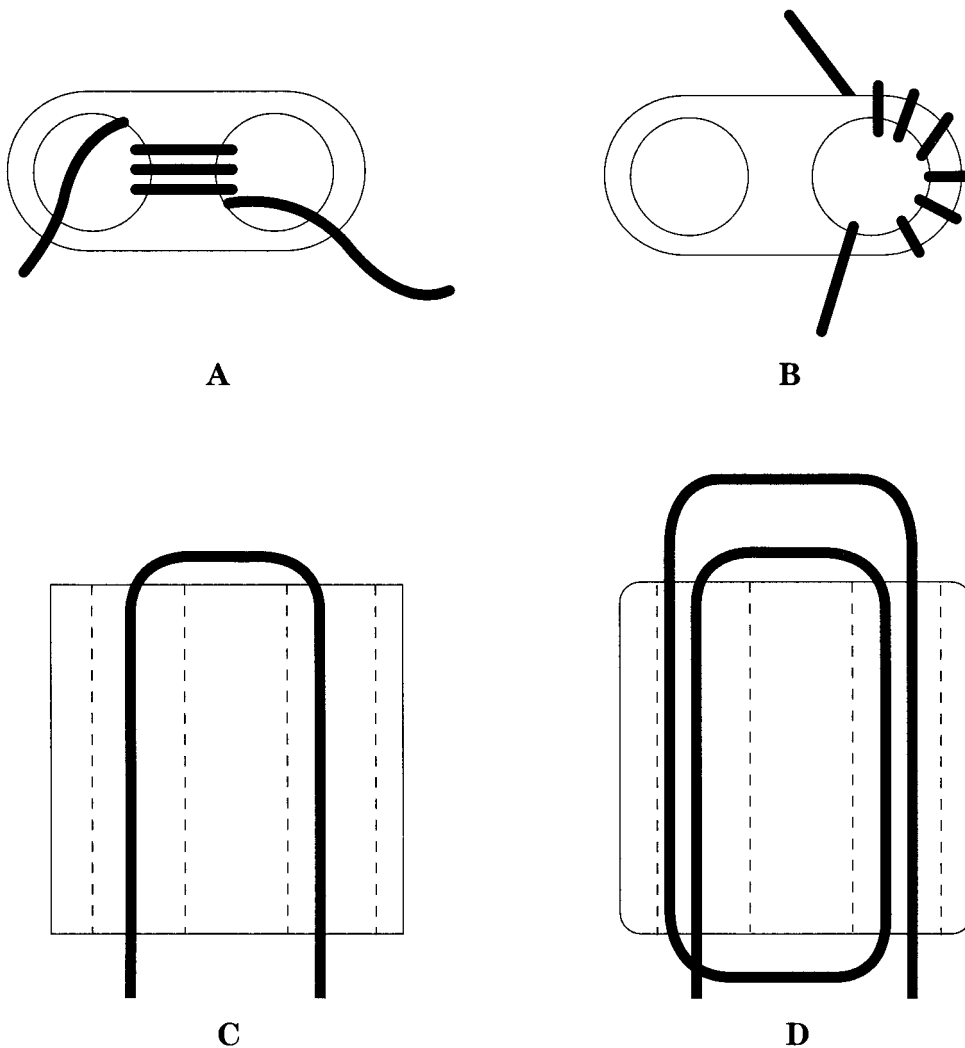
An edge-wound coil is shown in Fig. 4-17B. In this coil, the turns are wound around the outside of the binocular core. To check the difference, I wound a pair of BN-43-202 cores with 10 turns of no. 26 wire; one in the center (Fig. 4-17A) and one around the edge (Fig. 4-17B). The center-wound version produced 326 μH of inductance, and the edge-wound version produced 276 μH with the same number of turns.

Counting the turns on a binocular core is a little different than you might expect. A single U-shaped loop that enters and exits the core on the same side (Fig. 4-17C) counts as one turn. When the wire is looped back through a second time (Fig. 4-17D), there are two turns.

Winding the binocular core

Some people think that it is easier to use these cores than toroids, and after spending a rainy weekend winding LF and AM BCB coils (after pumping groundwater out of the basement workshop!), I am inclined to agree partially. The “partially” means that they are easier to work than toroids if you do it correctly. It took me some experimenting to figure out a better way than holding the core in one hand and the existing wires already on the core in another hand and then winding the remaining coils with a third hand. Not being a Martian, I don’t have three hands, and my “Third Hand” bench tool didn’t seem to offer much help. Its alligator clip jaws were too coarse for the no. 36 enameled wire that I was using for the windings. So, enter a little “mother of invention” ingenuity (it’s amazing how breaking a few wires can focus one’s attention on the problem). In fact, I came up with two related methods between gurgles of my portable sump pump.

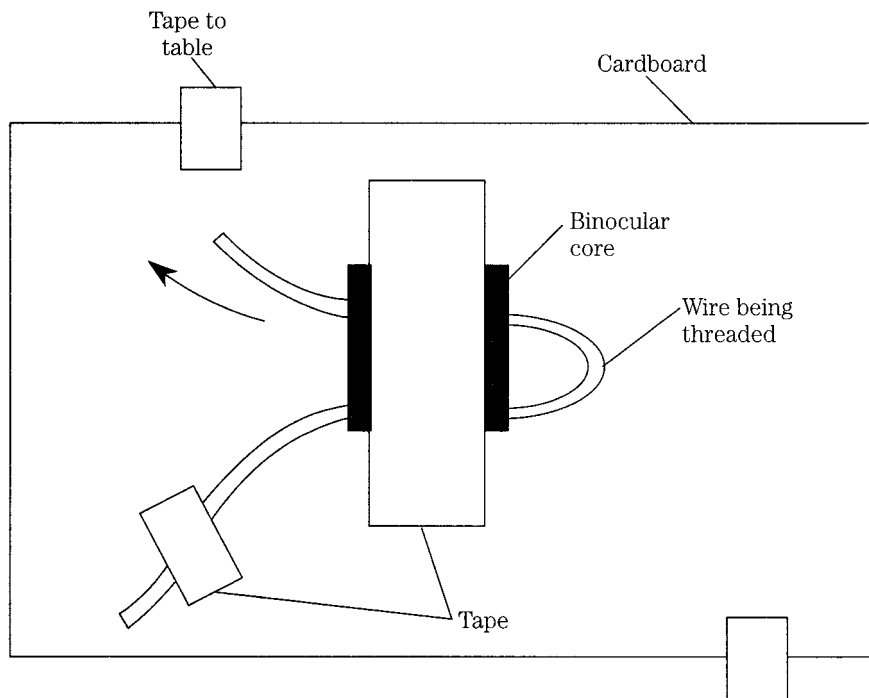
The first method is shown in Fig. 4-18. The binocular core is temporarily affixed to a stiff piece of cardboard stock such as a 5×7 ” card or a piece cut from the stiffener used in men’s shirts at the laundry. The cardboard is taped to the work surface, and the core is taped to the cardboard. One end of the wire that will be used for the winding is taped to the cardboard with enough leader to permit working the end of the coil once it is finished (2 to 3”). Pass the wire through the holes enough times to make the coil needed and then anchor the free end to the cardboard with tape. If the device has more than one winding, make each one in this manner, keeping the ends taped down as you go. Once all of the windings are in place, seal the assembly



4-17 Winding style for Bazooka balun cores: (A) through the center; (B) around the edge (less-predictable inductance); (C) single turn winding (note: no doubling back); and (D) two-turn winding.

with Q-Dope or some other sealant (RTV silicone, rubber cement, etc.). Q-Dope is intended for inductors and can be purchased from G-C dealers or by mail from Ocean State Electronics [P.O. Box 1458, 6 Industrial Drive, Westerly, RI, 02891; phone 1-800-866-6626 (orders only), 401-596-3080 (voice) or 401-596-3590 (fax)].

The second method involves making a header for the binocular core. This header can be permanent and can be installed into the circuit just like any other coil with a header. When built correctly, the header will be spaced on 0.100" centers, so it is compatible with DIP printed circuit boards and perforated wiring board. I used



4-18 Winding “jig” for Bazoooka balun core.

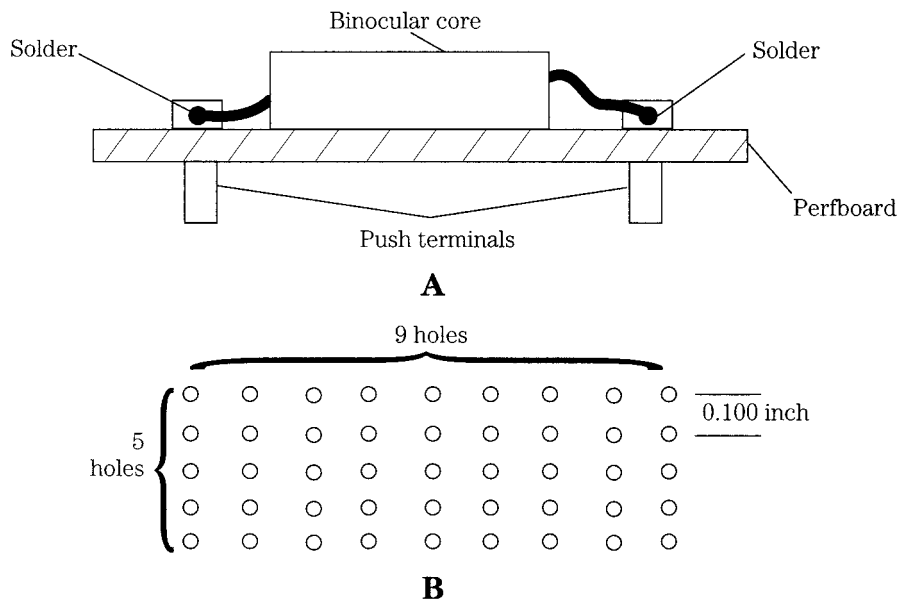
perforated wiring board of the sort that has printed circuit pads (none of which connected to each other) at each hole.

Figure 4-19A shows the basic configuration for my homebrew header (a DIP header can also be used). These connectors are intended to connect wiring or other components to a DIP printed circuit board designed for digital integrated circuits. I found that a small segment of printed perfboard, 0.100" centers on the holes, that contained five rows by nine columns of holes (see inset to Fig. 4-19B) was sufficient for the 0.525×0.550 " BN-xx-202. Larger or smaller hole matrices can be cut for larger or smaller binocular cores.

The connections to the header are perfboard push terminals (available any place that perfboard and printed-circuit making supplies are sold). I used the type of perfboard that had solder terminals so that the push terminals can be held to the board with solder. Otherwise, they have a distinct tendency to back out of the board with handling.

When the header is finished, the binocular core is fastened to the top surface of the header with tape, then the pins of the header are pushed into a large piece of perfboard. This step is done to stabilize the assembly on the work surface. It might be a good idea to stabilize the perfboard to the table with tape to keep it from moving as you wind the coils.

Once the header and core are prepared, then it is time to make the windings. Scrape the insulation off one end of the wire for about 1/4". An X-acto knife, scalpel,

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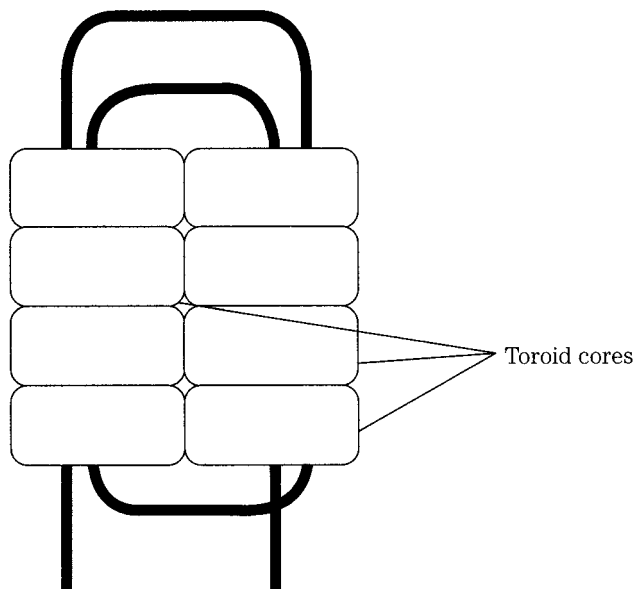
4-19 Construction of a perfboard carrier or header for Bazooka balun cores.

or similar tool can be used to do this job. Turn the wire over several times to make sure that the enamel insulation is scraped around the entire circumference. Some people prefer to burn the insulation off with a soldering iron, which tins the end of the wire as it burns the insulation away. I've found that method to be successful when the smaller gauges are used, but when good-quality no. 26 or larger wire is used, the scraping method seems to work better. If the scraping method is used, then follow the scraping by tinning the exposed end of the wire with solder. Each winding of the transformer can be made by threading the wire through the core as needed. As each winding is finished, the loose end is cleaned, tinned, and soldered to its push terminal. After all windings are completed, then seal the assembly with Q-Dope or equivalent.

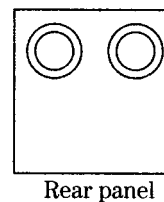
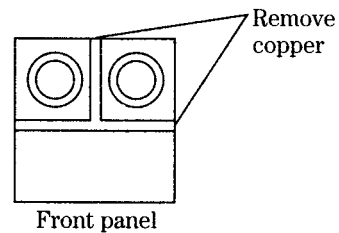
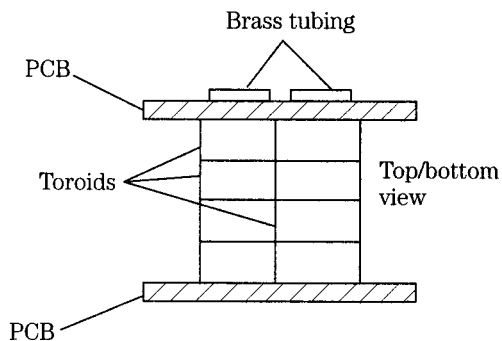
Homebrew binocular cores

You can build custom "binocular cores" from toroidal cores. The toroids are easily obtained from many sources and in many different mixtures of both powdered iron and ferrite. You can also make larger binocular cores using toroids because of the wide range of toroid sizes. Actual binocular cores are available in a limited range of mixtures and sizes. Figure 4-20 shows the common way to make your own binocular core: Stack a number of toroid cores in the manner shown. It is common practice to wrap each stack in tape, then place the two stacks together and wrap the assembly together. Although four toroids are shown on each side, any number can be used.

A variation on the theme is shown in Fig. 4-21. This binocular core is designed to have a single-turn winding consisting of a pair of brass tubes passed through the

**4-20**

Stacking toroid cores to make a higher-power Bazoooka balun.



4-21 Construction of the high-power Bazoooka balun core with stacked toroid cores and copper (PCB material) end plates.

center holes of the toroid stacks. The ends of the stacks are held together with a pair of copper-clad PC boards. The read panel has no copper removed, and the front panel is etched to isolate the two brass tubes. The pads around the brass tubes at the front end are used to make connections to the tubing (which serves as a single-turn winding). The other winding of the transformer is made of ordinary insulated wire, which is passed through the brass tubes the correct number of turns to achieve the desired turns ratio. This type of binocular core was once popular with ham operators who built their own solid-state RF power amplifiers. The higher-power transformers needed to match the impedances of the base and collector terminals of the RF transistors were not easily available on the market, so they had to “roll their own.”

The binocular core is not as well-known as the toroid core, but for many applications, it is the core of choice. This is especially true when low frequencies are used or when large inductances are needed in a small package . . . and you don't want to work your arm off hand-winding the large number of turns that would be required on a solenoid-wound or toroidal core.

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- F. W. Grover, *Inductance Calculation: Working Formulas and Tables*, D. VanNostrand Co., Inc. (New York, 1946).
- G. Bramslev, “Loop Aerial Reception,” *Wireless World*, Nov. 1952, pp. 469–472.