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RANDOM OUTPUT SELECTOR FOR THE LABORATORY[1]

ABSTRACT

A random selector, whose output is in the form of switch closures, is described. On each activation one of N outputs is selected and remains closed until the next activation. Each output is equally probable and independent of the previously selected output. The selector can be constructed from the off-the-shelf components of one manufacturer in approximately 1 hr.

DESCRIPTORS: Randomicity, Programming (C. T. Tart).

There are many research designs that call for random alterations of conditions. Typically there are N switches or relays, each controlling a different stimulus condition. One of the N switches is closed on each trial, the *S* of measuring device responds, the switch is shut off, and again one of the N switches must be randomly selected and turned on for the next trial. The control of such switches is typically a two-step process. Random digits are either looked up in a printed table or generated by some hand procedure (shuffling cards, rolling dice, etc.). The program made up from this is then turned into actual switching operations by throwing the appropriate switch on each trial by hand or by punching a paper tape in accordance with the random sequence and allowing the moving paper tape to switch stimuli with a tape reader and relay system.

These procedures are tedious, and often lead to a dubious "short cut" where a random series is programmed once and then repeated across *Ss*, or even repeated later in a continuous experimental series on one *S*, with the (hopeful) assumption that *S* does not remember the series.

This report describes an electronic device which randomly closes one switch out of N such switches[2] each time that it is activated. In other words, it is an electronic random digit generator whose output is in the form of switch closures. Although it is designed with psychological experiments in mind, it can be used in a multitude of disciplines.

The selector has the following features: its output is truly random, as determined by statistical tests of randomicity, described below; and it randomly selects its next output faster than *Ss* can respond, with the result that there is no "lag."

This article will describe the operation of the general circuit of the selector in such a way that an *E* with a good background in electronics can construct it from a variety of commercially available components. The selector actually constructed in my laboratory, on which the actual performance figures described below are based, was constructed from off-the-shelf components of one manufacturer,[3] and requires approximately

[1] The author wishes to thank Robert Bello, J. G. Pratt, and William Wulf for assistance in designing and testing the selector. The device was built and tested while the author was affiliated with the Department of Neurology and Psychiatry of the University of Virginia, School of Medicine, with support from the Carlson fund.

[2] Most available counter-steppers will limit N to a maximum of 10, but two or more counter-steppers could be connected together to raise N.

[3] The selector was constructed from components manufactured by the Massey-Dickinson Company, 9 Elm Street, Saxon-

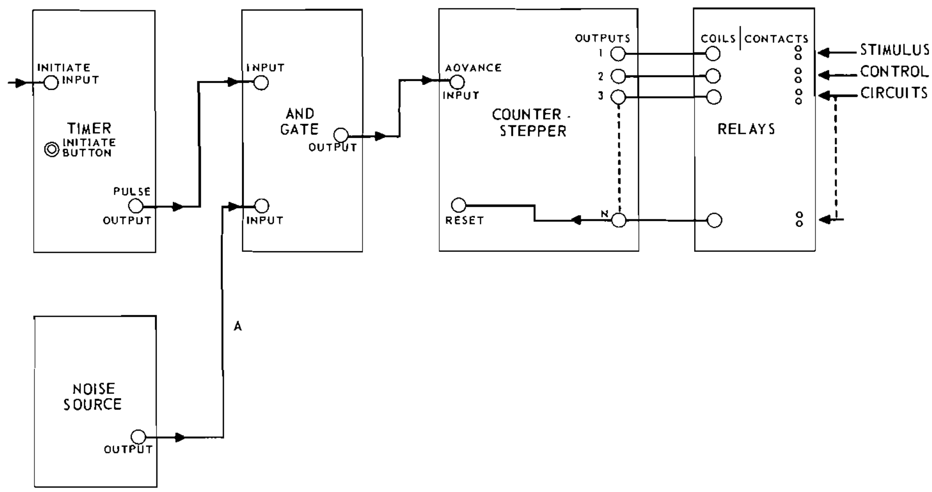


FIG. 1. Block diagram of the random selector

1 hr of time and virtually no technical knowledge to construct.

The general circuit of the random selector is called an "electronic roulette wheel," and is similar, in principle, to that used by Rand Corporation to generate their book of 1,000,000 random digits (Rand, 1955). It is diagrammed in Fig. 1, except for power supply connections. The first unit to consider is a noise source. An electronic white noise generator is desirable here, if its output voltage is high enough to activate the counter-stepper and its noise output band width is less than the maximum counting rate of the counter-stepper. A less expensive alternative, used in the present device, is a SPDT (single pole double throw) relay connected to oscillate, i.e., closure of the relay interrupts the source of power. The contact then recloses through spring tension, and the cycle repeats. The circuit is a buzzer circuit. It buzzes at an *average* frequency of several hundred cycles/sec, but if you inspect the voltage across the coil with equipment capable of responding to very brief pulses, one finds several thousand pulses of varying durations and interpulse intervals being generated per second as a result of contact bounce.

The randomly varying pulse train from this noise source is connected to one input of an AND gate, which may be the normally open contacts of a relay. The coil of this relay or the other leg of the AND gate is activated by the output of a timer. This timer should have the property that when the activate button on it is pressed it puts out a fixed duration pulse[4]

ville, Mass. Cost was about $1300. Users with sufficient electronic knowledge should be able to bring this cost down if they wire some units themselves. A pictorial wiring diagram of the selector built from the Massey-Dickinson units is shown in Fig. 2.

[4] It is possible to eliminate the timer altogether and use a hand-pressed button to close the AND gate or relay. A human button press is a long and highly variable event compared to the rate of noise pulse generation, and so adds another source of randomicity. Indeed, it should be possible to use a regular pulse source instead of a noise source and depend on the variability of the button press as the randomizer, as long as the rate of pulse generation is rapid. One investigator (Cutten, 1961) has suggested using 60-cps line pulses for this application, but as far as I know this method has never been empirically tested to see if the outputs meet satisfactory criteria of randomicity.

(set at 50 msec in the model built). When this activation pulse closes the AND gate or relay, the pulse train from the noise source is connected to the advance (count) input of an electronic counter-stepper. This counter-stepper advances one step for each input pulse. Most commercially available counter-steppers have a maximum of 10 steps available, with an output signal for each step. Fewer steps may be used by connecting the reset line of the counter-stepper to the desired output, so the counter-stepper advances to that output and then automatically begins recounting from the start position. Thus a long train of pulses entering the counter-stepper cause it to "cycle around," and at the end of a fixed time period (generated by the timer) the final position (the active output of the counter-stepper) varies randomly over the N alternatives. The counter-stepper used should generate a fixed output voltage sufficient to close a relay until the next train of pulses is fed in for the next selection.

The outputs of the counter-stepper are shown connected to a set of relays which can then operate suitable stimulus presentation equipment such as slide projectors, tone generators, and shockers. By connecting these relays to switch into different taps on an attenuator, the selector could be used to change the amplitude of some stimulus from trial to trial randomly instead of selecting between qualitatively discrete outputs, or the two functions could be combined. If heavy loads are to be switched, contact suppression should be used on these relays.

Each succeeding trial can be automatically set up as the *S* finishes making his response by connecting a switch to the *S's* response device and using the termination of this switching action to trigger the timer unit. An example of this has been presented elsewhere (Tart, 1966). Various delay units could also be interposed here so that the *S*'s response would randomly select the next stimulus after a fixed delay, or a recycling clock could be connected to activate the selection process every x seconds.

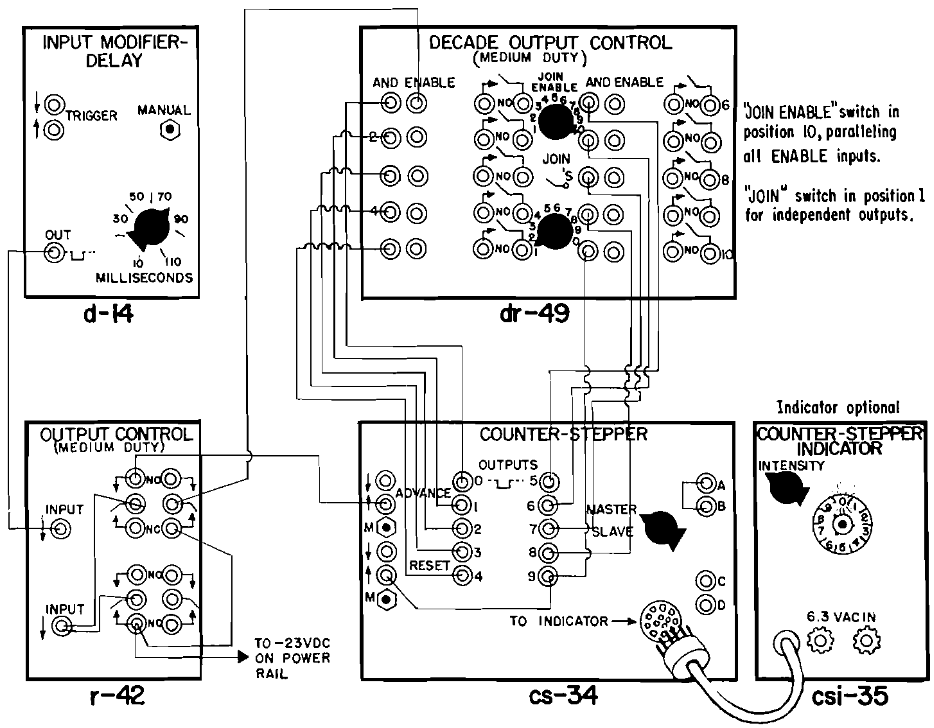
An automatic record of the selection sequence can be obtained by having the outputs activate marking pens on a polygraph, a paper tape punch, or a similar device.

A pictorial circuit diagram of the unit constructed from Massey-Dickinson equipment is shown in Fig. 2, and the performance data discussed below refer to this unit.

With respect to performance, the selector was designed so that all N outputs would have an equal probability of being selected, and the output selected on the kth + 1 trial would be independent of the output selected on the kth trial. There is no technical reason why the unit should develop bias,[5] i.e., select one output more frequently than another output in the long run, or "stick" on a particular output. In some applications, however, complete randomicity is critical, so the output of the selector was checked empirically.

The random selector was set up to select the five outputs, 0, 1, 2, 3, and 4, with equal probability. Three blocks of 1000 outputs each were generated, and tested with a computer program specifically developed for this purpose. In order to test the hypothesis that each output was selected with

[5] By paralleling several outputs, one could purposely make one output more probable than others, e.g. one could set up five possible outputs, four with a probability of $\frac{1}{10}$ each of being selected and the fifth with a probability of $\frac{6}{10}$ of being selected. Many such combinations are possible.



Power supply and rails not shown : use Massey Dickinson type p-4A. power supply.

FIG. 2. Pictorial circuit diagram of the random selector tested by the author

equal frequency (i.e., that the probability of selection was 0.2 for each output), the actual proportions within each 1000 trial block were subjected to a χ^2 goodness of fit test. To test the hypothesis that the selection on each trial was independent of the selection on the previous trial, the frequency of appearance of all possible pairs of outputs was compared with the theoretical expectation that this would be equal for all pairs, i.e., 1–1 is as probable as 1–2, 1–3, 3–1, 3–5, etc. Similarly, the frequency of all possible triplets should be equal. None of the nine χ^2 tests approached statistical significance: seven of the nine resulted in p greater than 0.5, so the actual performance of the random selector passed these standard tests of randomicity. Observed proportions for the five outputs over the 3000 trials were 0.197, 0.203, 0.201, 0.201, and 0.198, respectively.

The possibility of component drift, with consequent shifts in probability of some of the outputs being selected, must be considered, however. After the device had been used to make approximately 20,000 selections over the course of several months, another three blocks of 1000 trials each were subjected to the same analysis. The observed proportions over the 3000 trials were now 0.198, 0.191, 0.221, 0.216, and 0.174. Although these are of no practical significance in some laboratory applications, they do show statistically significant departures from equiprobable output selection which could be unacceptable in some applications. The goodness of fit tests for doublets and triplets were also affected by this drift.

This drift was checked again 2 weeks and several thousand intervening trials later. Only the first block of 1000 trials showed statistically significant deviation ($p = 0.02$, two-tailed), and the following two blocks showed essentially equal probability of selection again, with the mean proportions over this total sample of 3000 trials being 0.200, 0.195, 0.211, 0.210, and 0.184, respectively. In applications where *complete* randomness is essential, this drift should be controlled. It probably resulted from component aging within the counter-stepper unit in conjunction with the fact that the input pulses from the oscillating relay (noise source) varied in *amplitude* as well as duration and interpulse spacing. This could be cured by using a noise source that had constant amplitude of pulse output[6] or by inserting a clipping amplifier at the point marked A in Fig. 1 to equalize the amplitude of all pulses. Further, the higher the average pulse frequency from the noise generator, the less this should be a problem, as far more pulses will be counted in the same time sampling period, so that an electronic white noise generator would be preferable to an oscillating relay in critical applications.

[6] Massey-Dickinson makes a noise generator with constant amplitude output and wide output frequency that satisfies both these requirements.

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