FLUKE

Techniques for Oscilloscope Calibration

Using either dedicated or multiproduct calibrators

Teleconference:
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Welcome

Greetings from –

Fluke Corporation
Everett, Washington, USA

We are very pleased to bring you this presentation on techniques for oscilloscope calibration.

Welcome and Thanks!

This presentation is based on Fluke's extensive experience with:

- Use and design of calibration instruments and oscilloscopes
- Our experience and understanding of the problems faced when performing calibration of oscilloscopes

Thanks for your time, we hope you find it both valuable and useful.

Presented by

Fluke's Precision Measurement
Business Unit

and Jack Somppi

Electrical Calibration Instruments
Product Line Manager

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Fluke Precision Measurement Web Seminar Series

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or directly go to:
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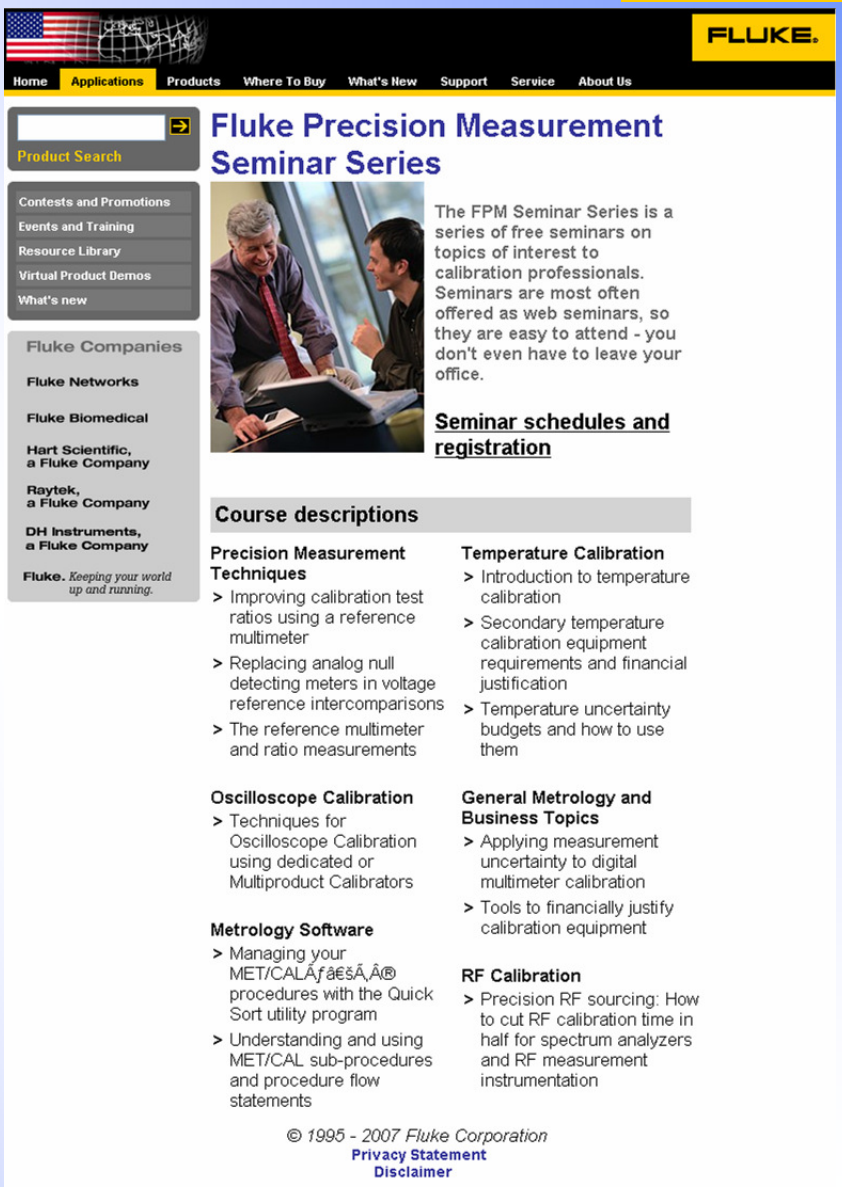
Our Seminar Topics Include:
- Precision Measurement Techniques
- Oscilloscope Calibration
- General Metrology
- Temperature Calibration
- Metrology Software
- RF Calibration



Web seminar etiquette

- Choice of Audio – VOIP or Teleconference
  - **VOIP receives audio only while teleconference is two way sound**
- Don’t mute your phone if you have background music enabled
- Use Q&A or chat to send me questions or request clarification
- There will be an opportunity throughout the discussion to pause and ask questions.
- You can view the material using either full screen or multi window methods

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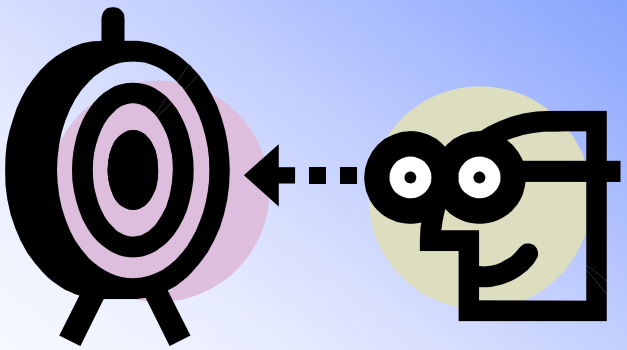
Techniques for Oscilloscope Calibration

Using either dedicated or multiproduct calibrators

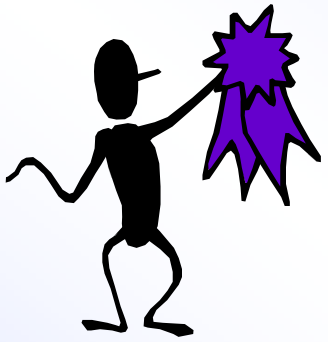
Objectives for today's session



- Review the calibration requirements of oscilloscopes
- Examine the basic calibration techniques for scope calibration
- Study scope calibration instrumentation alternatives
- Consider automation and it's benefits
- Identify additional reference sources for further study

Benefits with modern scope calibration

- Simplify oscilloscope calibration
  - Allow for full automation
  - All signals should be through single output
  - Make procedures available
- Reduce calibration times
- Reduce cost of ownership
  - All functions integrated in a single unit
  - Allow for upgradeability (workloadkeeps changing)
  - Simplify calibrator support

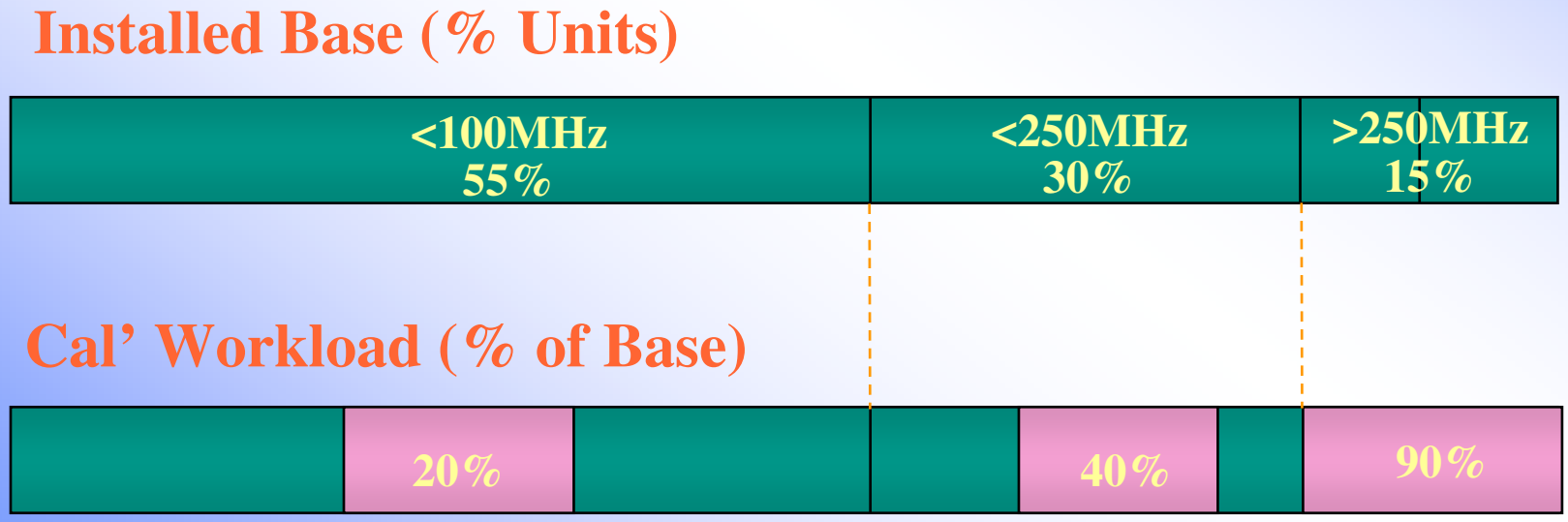


An Introduction to Oscilloscope Calibration

Oscilloscope calibration trends

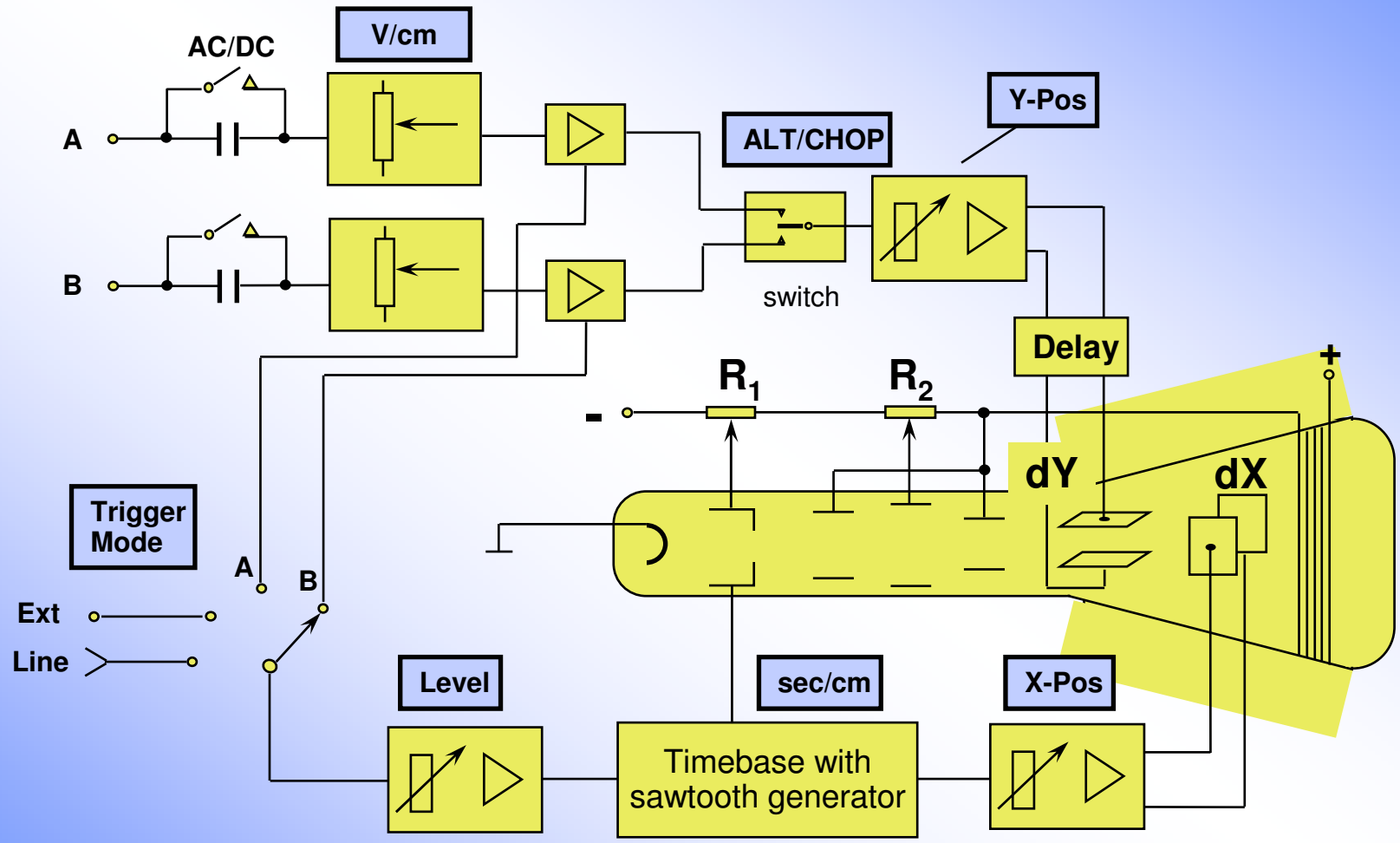
- Perceived as complex
  - Modular based calibration systems
  - Multiple outputs means many lead changes
  - High skill level required
  - Time consuming to calibrate
  - Automated systems still require manual intervention
- ISO9000 driven manufacturing systems
- Newer measurement functions & accuracy require formal calibration
- Increasing bandwidth to 1GHz and beyond

Oscilloscope calibration workload (The Bandwidth Perspective)

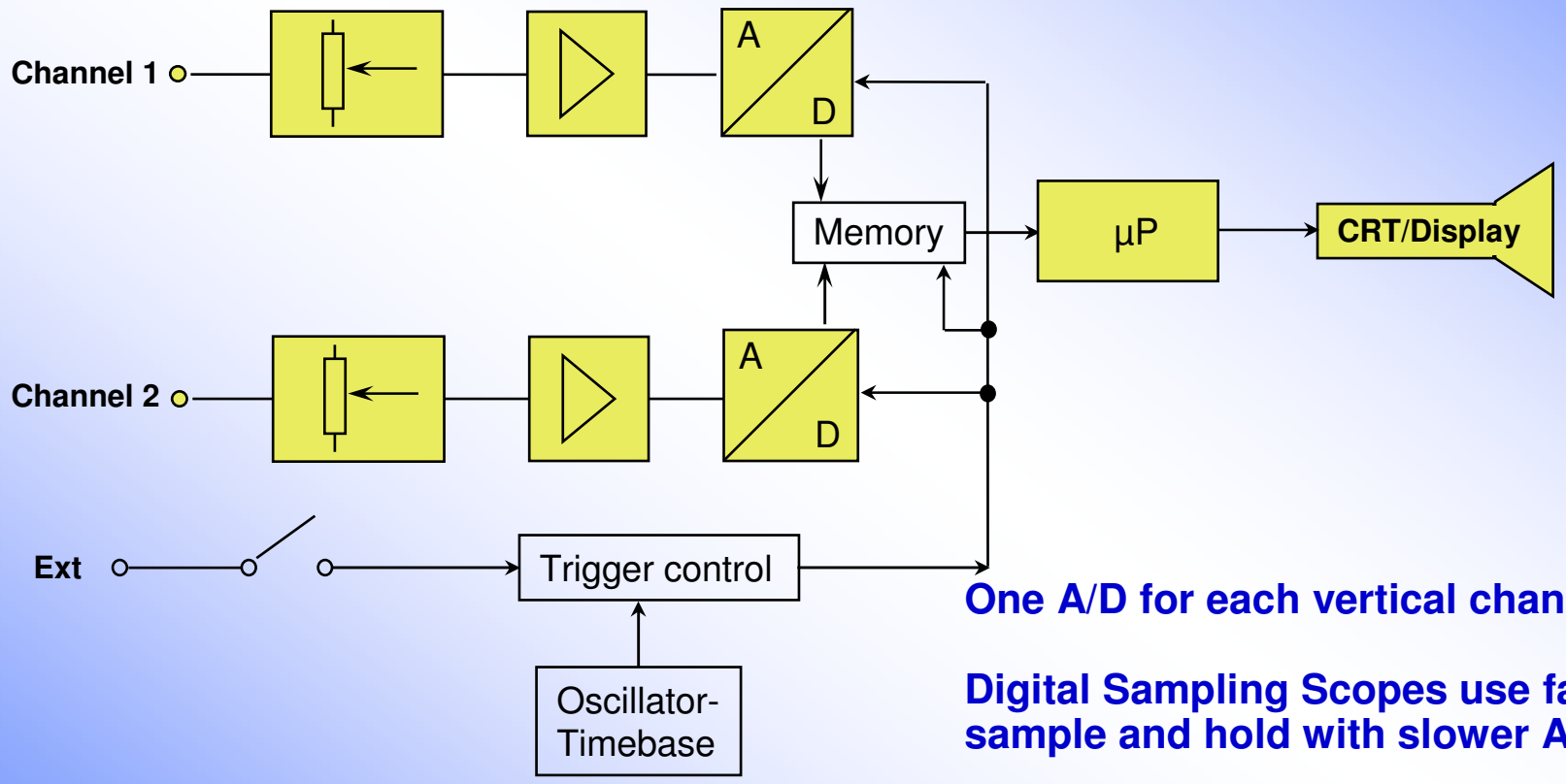



Oscilloscope Architectures
... and what needs to be calibrated

Analog oscilloscope



Digital storage oscilloscope (DSO)

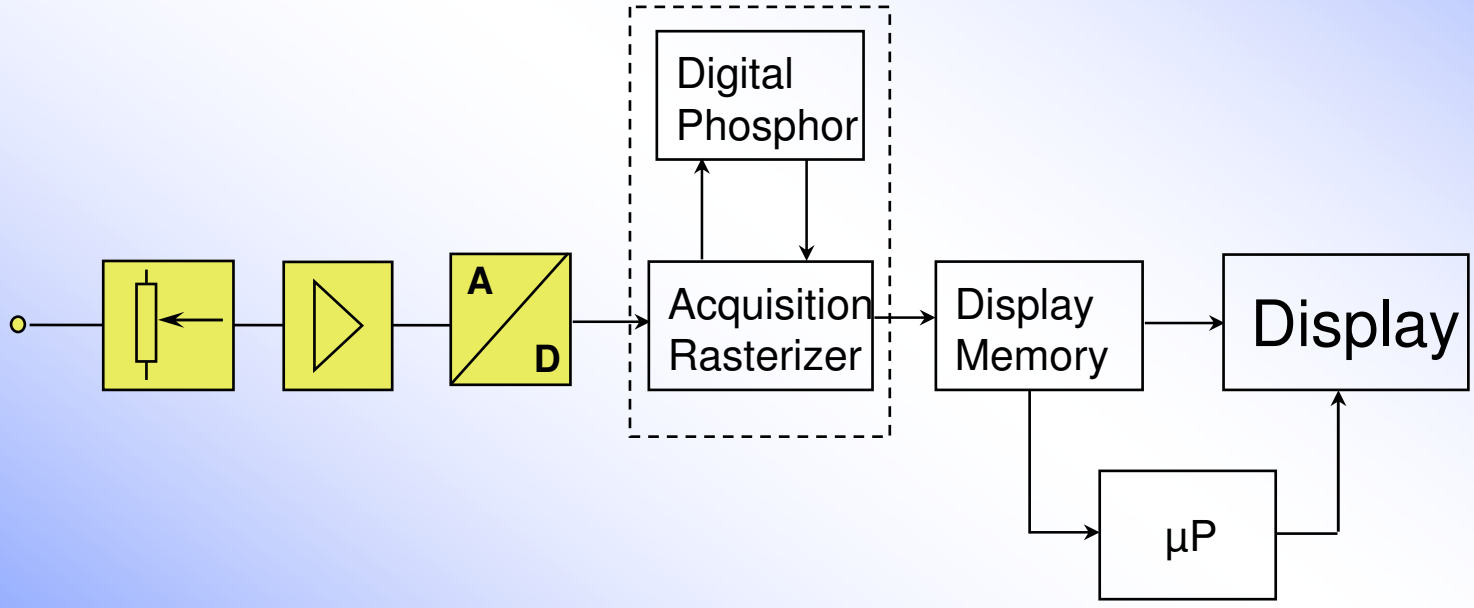


One A/D for each vertical channel

Digital Sampling Scopes use fast sample and hold with slower A/D.

- no ALT/CHOP mode
- channel skew is a common test

Digital phosphor oscilloscope (DPO)

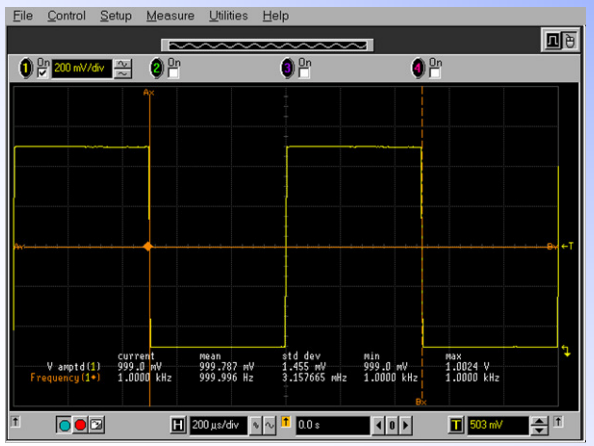


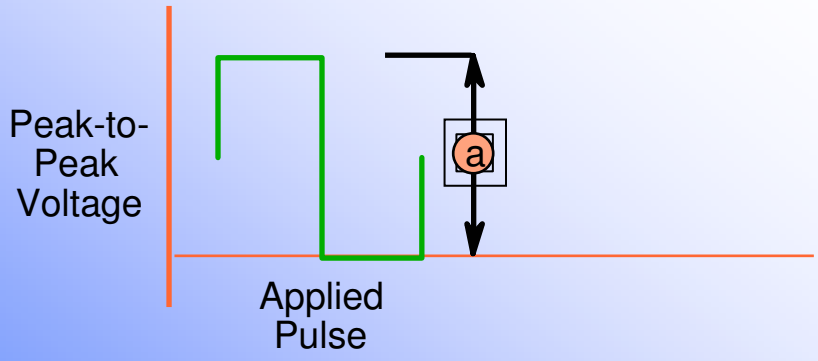
What to calibrate?

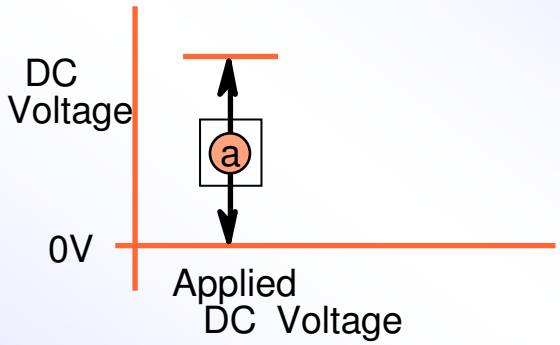
- **Vertical Channels**
  - Channel switching
  - Deflection range and accuracy
  - Bandwidth, pulse response and risetime
- **Horizontal Channels**
  - Timebase accuracy including delay, magnification and jitter
  - Trigger functions
  - X-Axis deflection accuracy and X-Y phasing
- **Internal calibration signals**
- **Cursors and measurement readouts**
- **Z-Axis bandwidth**

Vertical channel accuracy

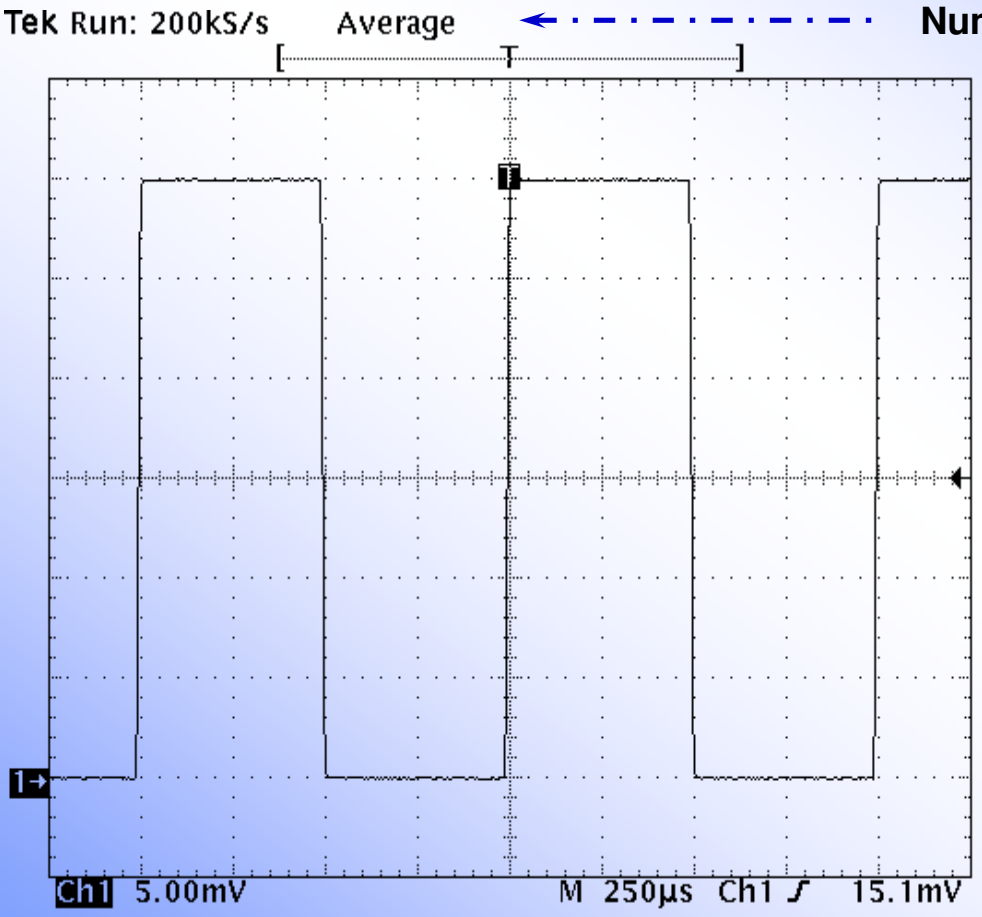
- **Insure the voltage amplitude is measured & displayed properly**







Vertical channels verification



Number of measurements for averaging

C1 Ampl
30.1mV

measurement function V_{pp}

typical frequency 1kHz

DSO

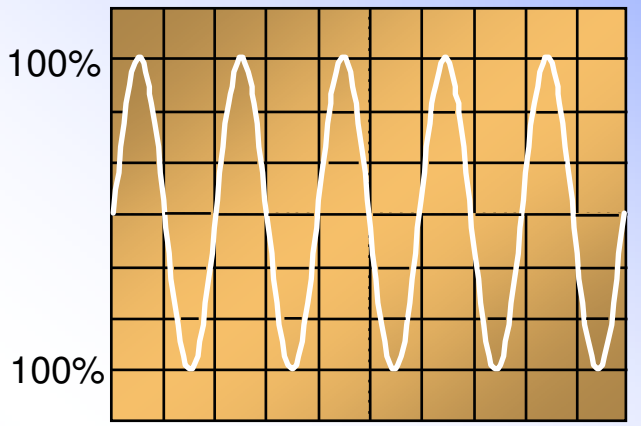
analog & DSO

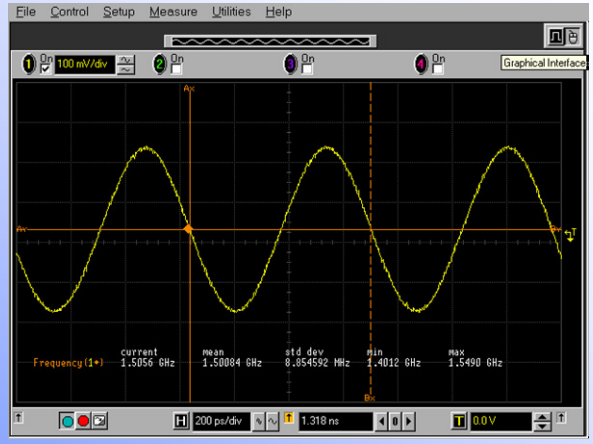
Input coupling DC
Any internal 50Ω
setting also calibrated

Trigger level 50%

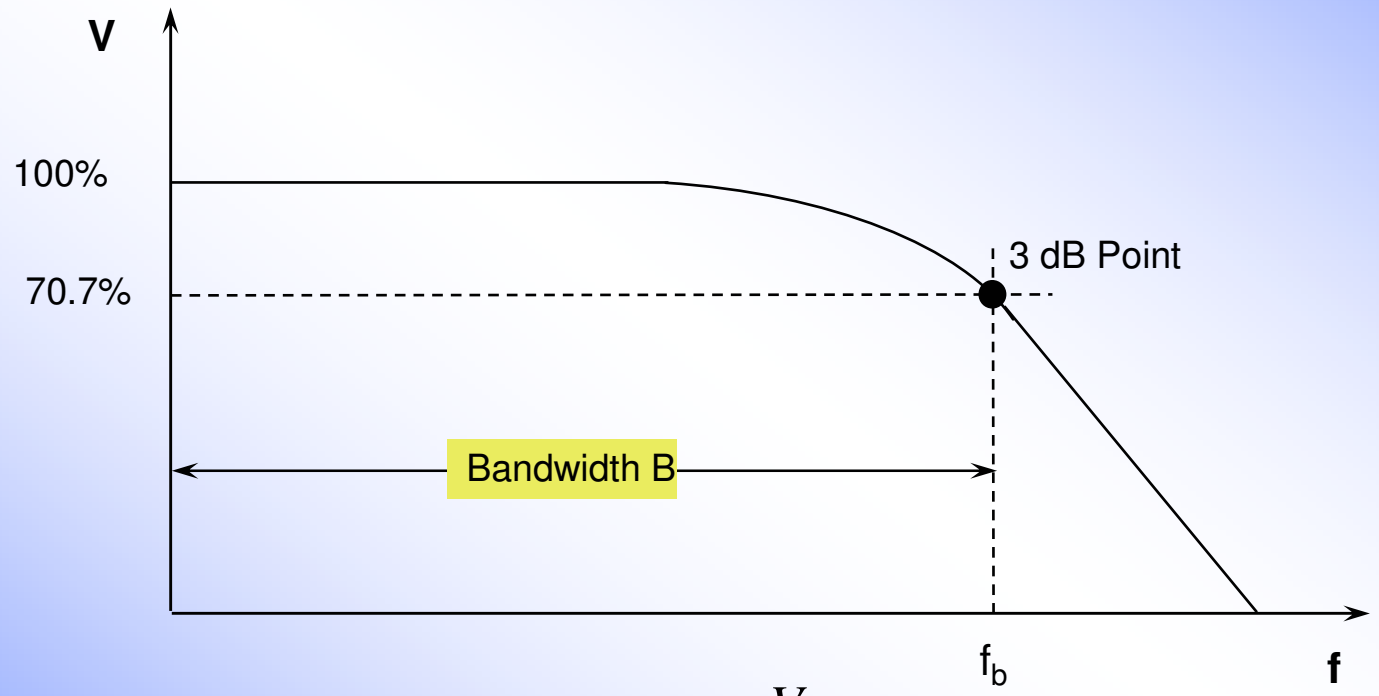
Vertical channel bandwidth

- **Insure all measurable frequencies respond properly**





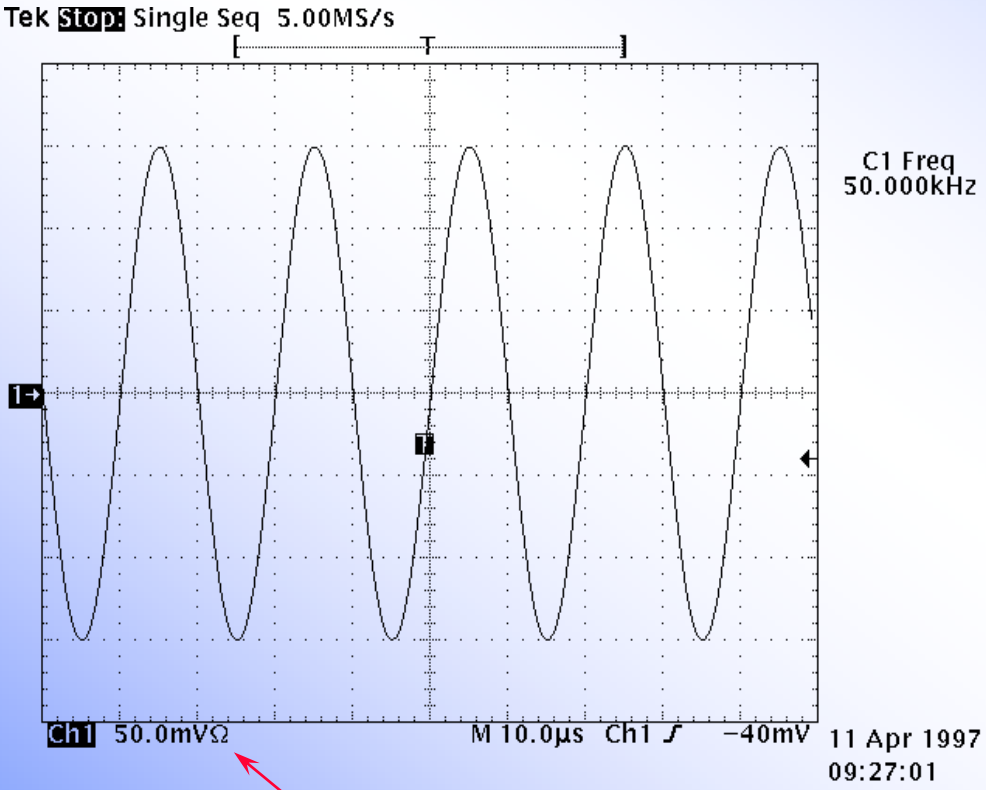
Test response to the 3 dB freq.



Definition of -3dB Point:

$$-3dB = 20\log_{10}\frac{V_{BwFreq}}{V_{Ref}}$$

Bandwidth calibration: LF Reference

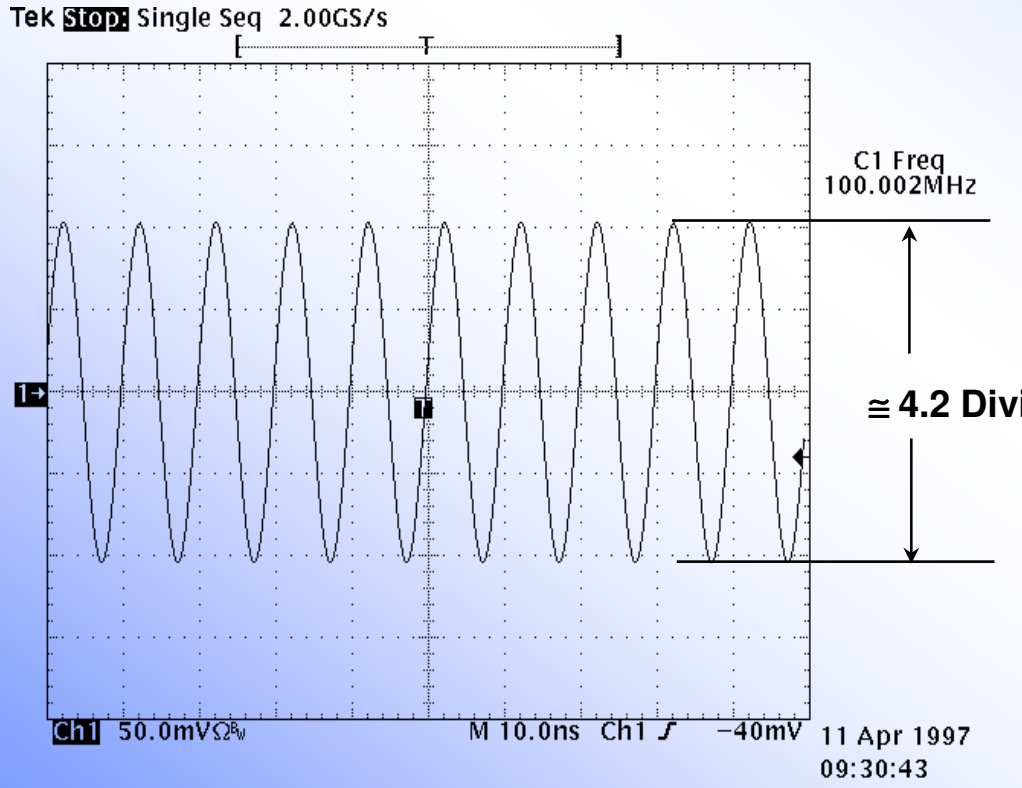


Adjust for 6 Div at ~50 kHz = Reference level

Scopes with selectable internal 50Ω termination calibrated for bandwidth using 50Ω setting and a 50Ω signal source. Good matching is important.

High bandwidth scopes can have selectable or fixed internal 50Ω termination

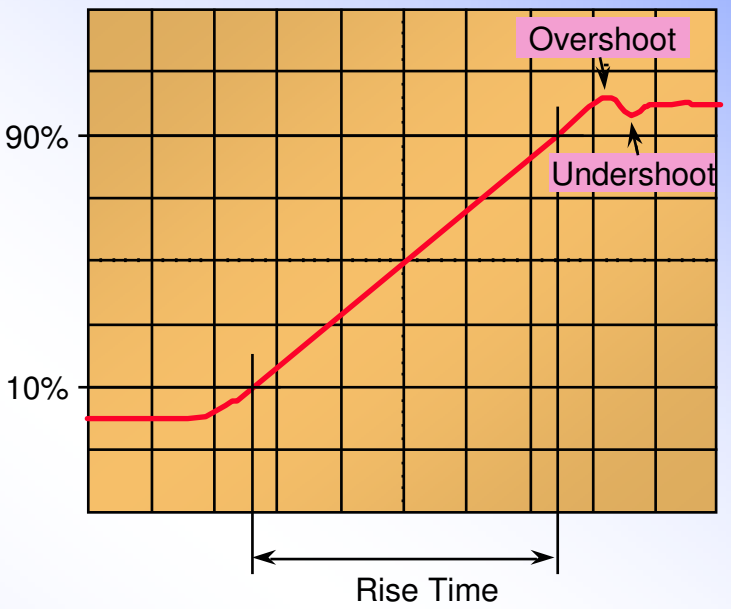
Bandwidth calibration: verify the -3dB point

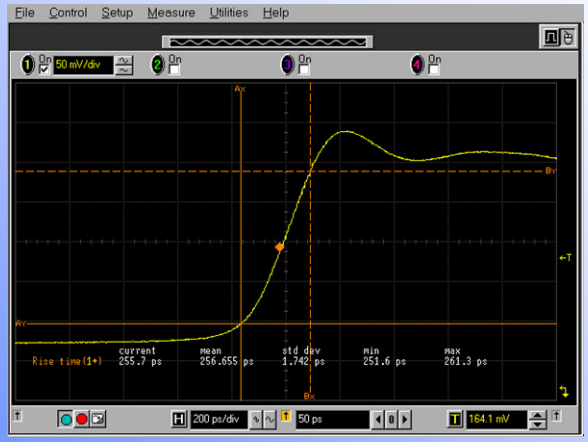


≅ 4.2 Divisions = 70.7% of Reference level at 50kHz

Vertical Channel risetime and pulse response

- Verify vertical channel risetime, abberation distortion, and additionally the maximum bandwidth

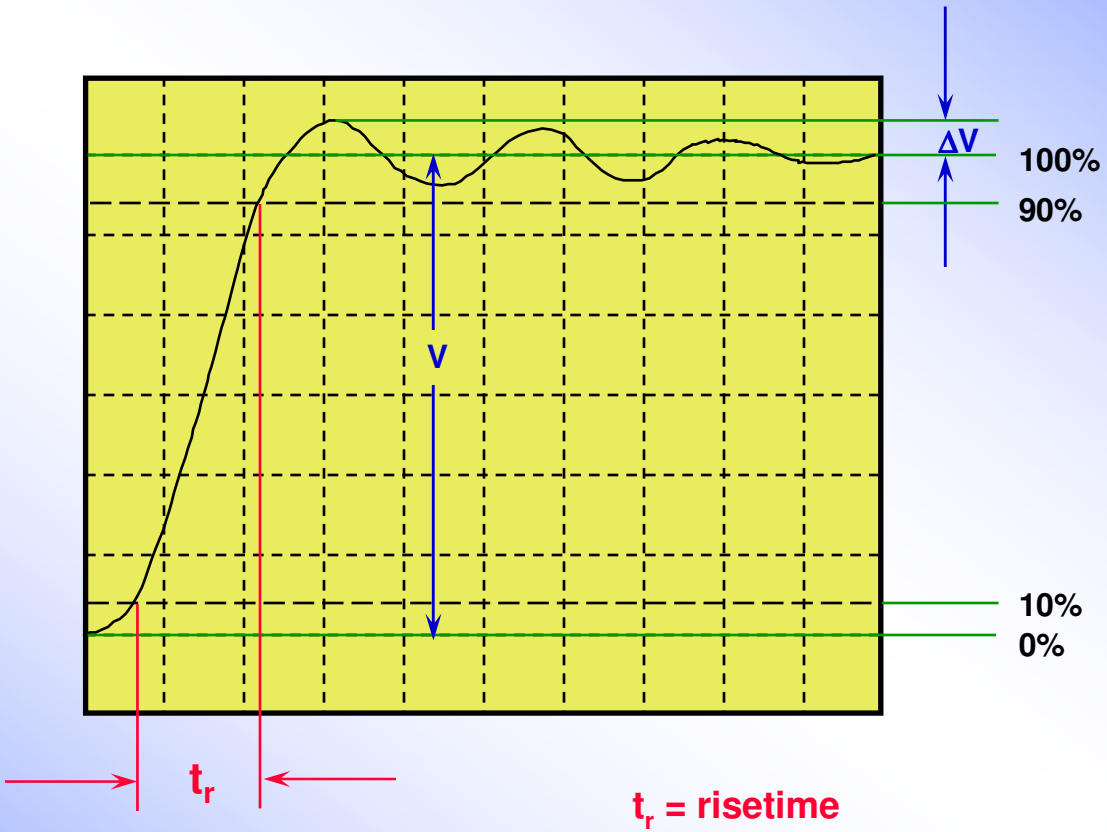




Generally:

Rise Time (ns) = 350/BW(MHz)

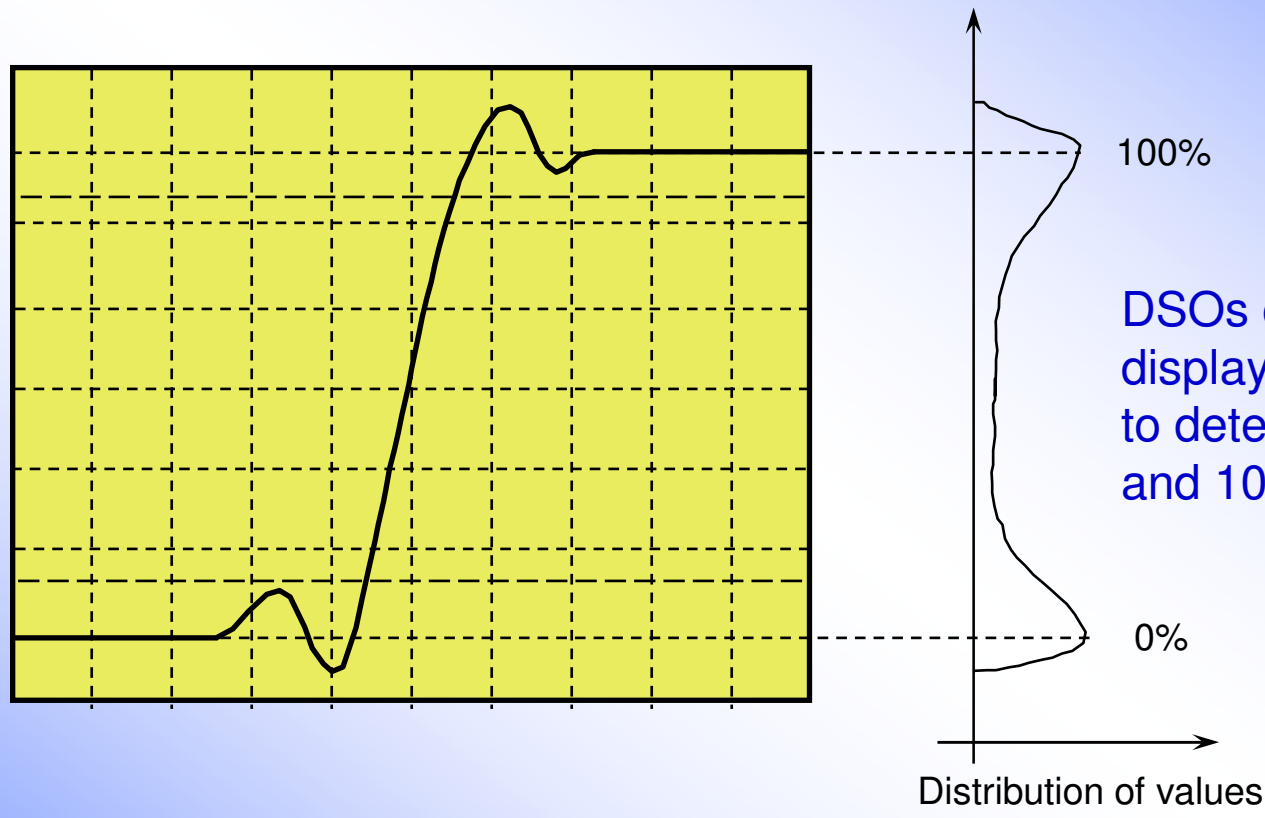
Risetime and pulse response



t_r = risetime

ΔV/V = overshoot/undershoot

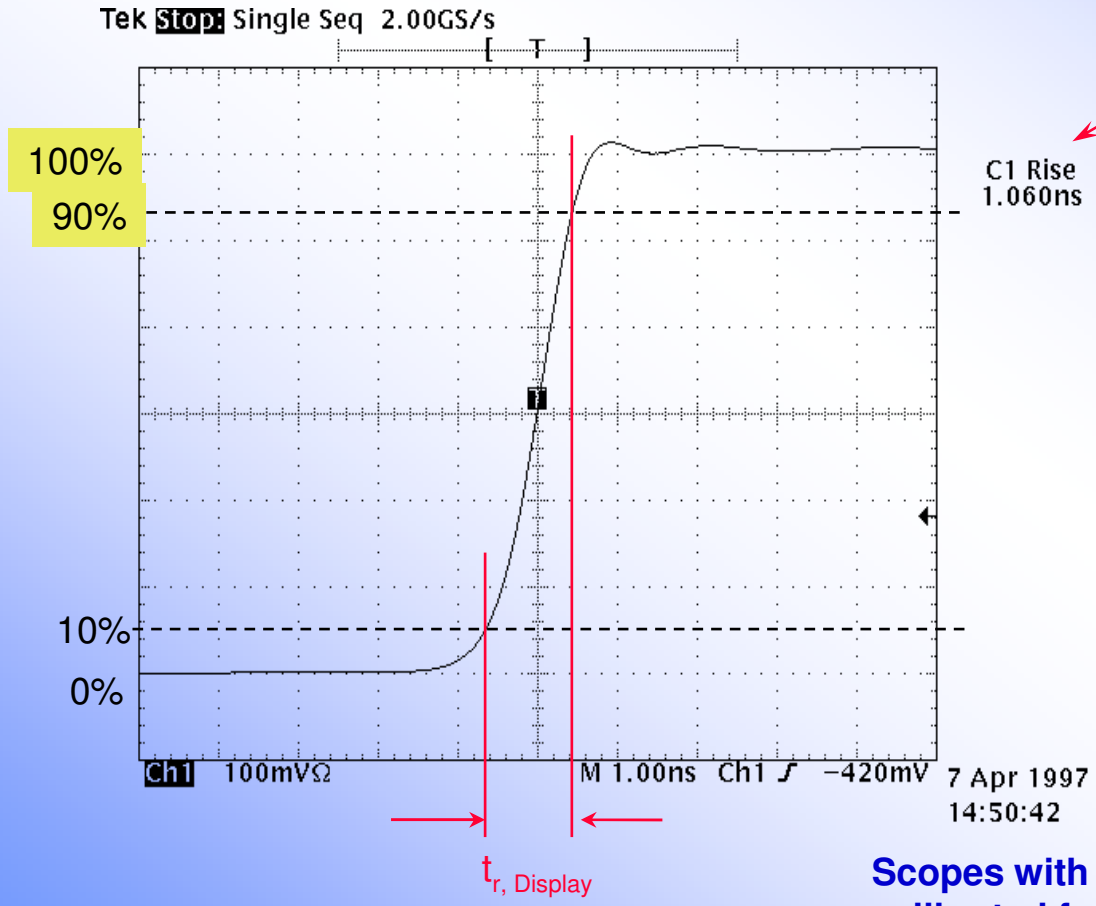
Determining 0% and 100% points



DSOs can display histogram to determine 0% and 100% points

Risetime calibration

Signal = fast pulse 100kHz to 10MHz



Risetime measurement readout

Risetime displayed consists of two components

- **risetime of signal (calibration source)**
- **risetime of oscilloscope**

$$t_{r,UUT} = \sqrt{\left(t_{r,Display}\right)^2 - \left(t_{r,Calibrator}\right)^2}$$

$t_{r,UUT}$ = real risetime of oscilloscope

$t_{r,Display}$ = risetime shown on screen

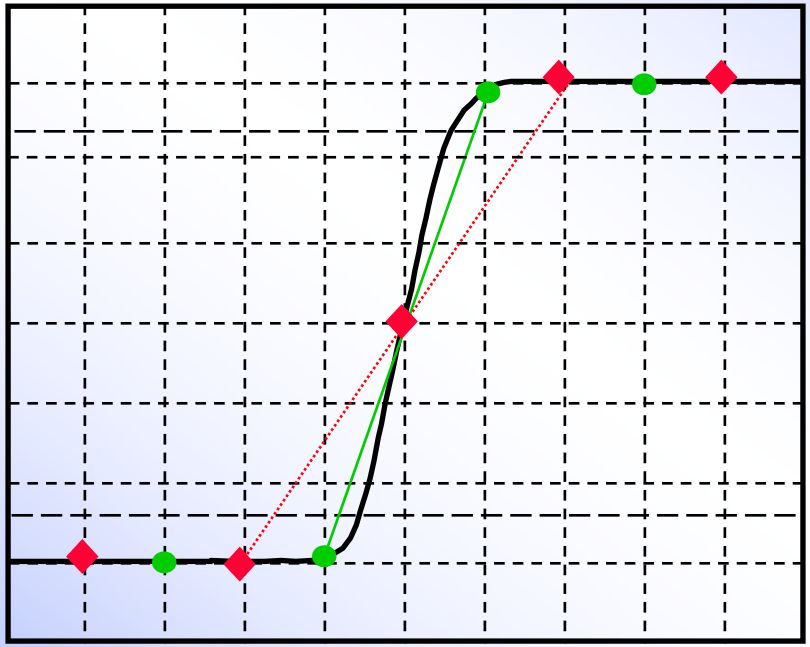
$t_{r,Calibrator}$ = risetime of calibration source

$t_{r,UUT} = t_{r,Display}$ if $t_{r,UUT} > 4t_{r,Calibrator}$

Scope risetime depends on V/div setting.

Scopes with selectable internal 50Ω termination calibrated for bandwidth using 50Ω setting and a 50Ω signal source. Good matching is important.

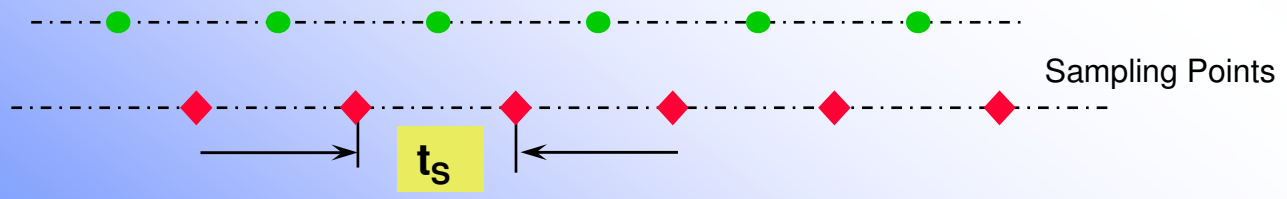
Scope sampling rate and risetime considerations



Input signal

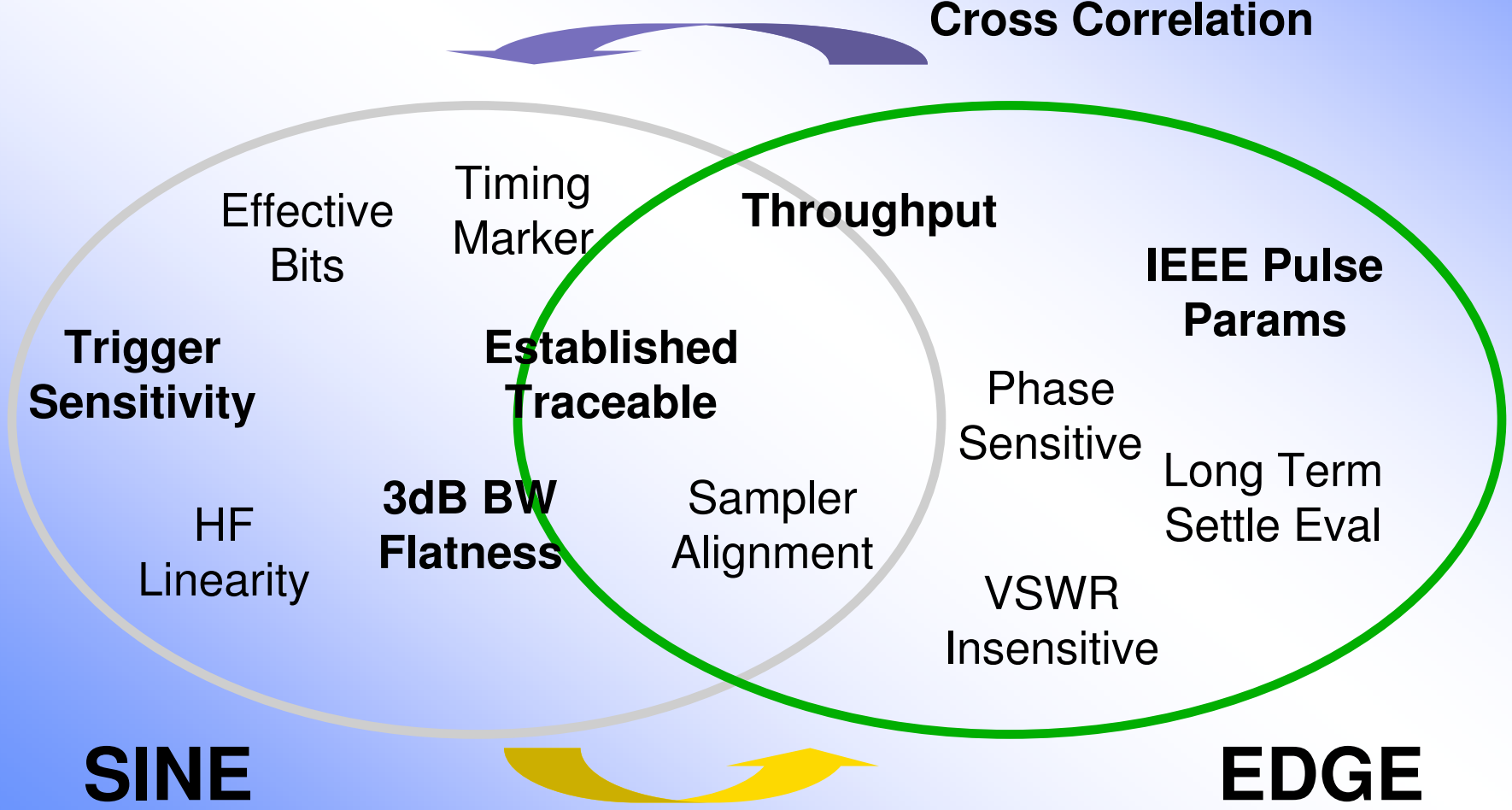
reconstructed Signals

Rise-Time t_r
min: 0.8 t_r
max: 1.6 t_r



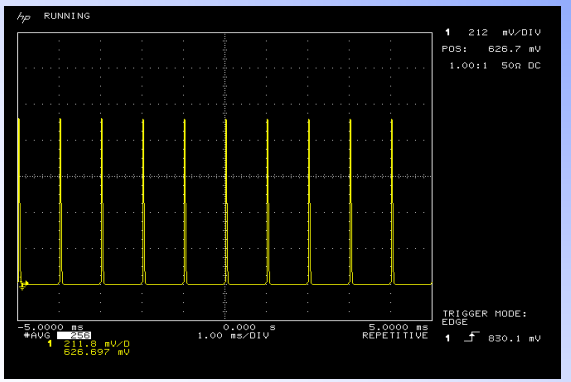
Importance of sine and edge

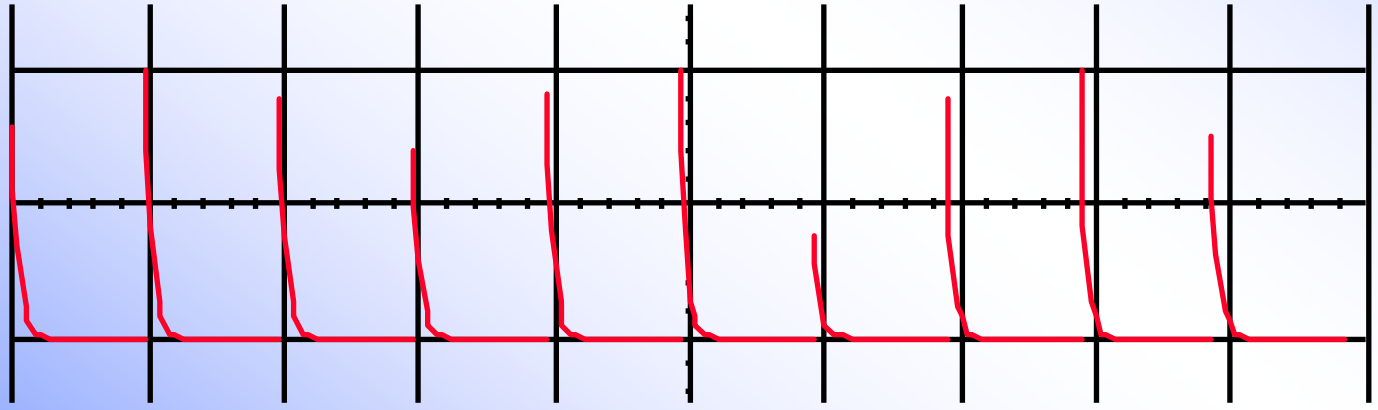
Some overlap in the Calibration Application but both required



Timebase (horizontal) calibration

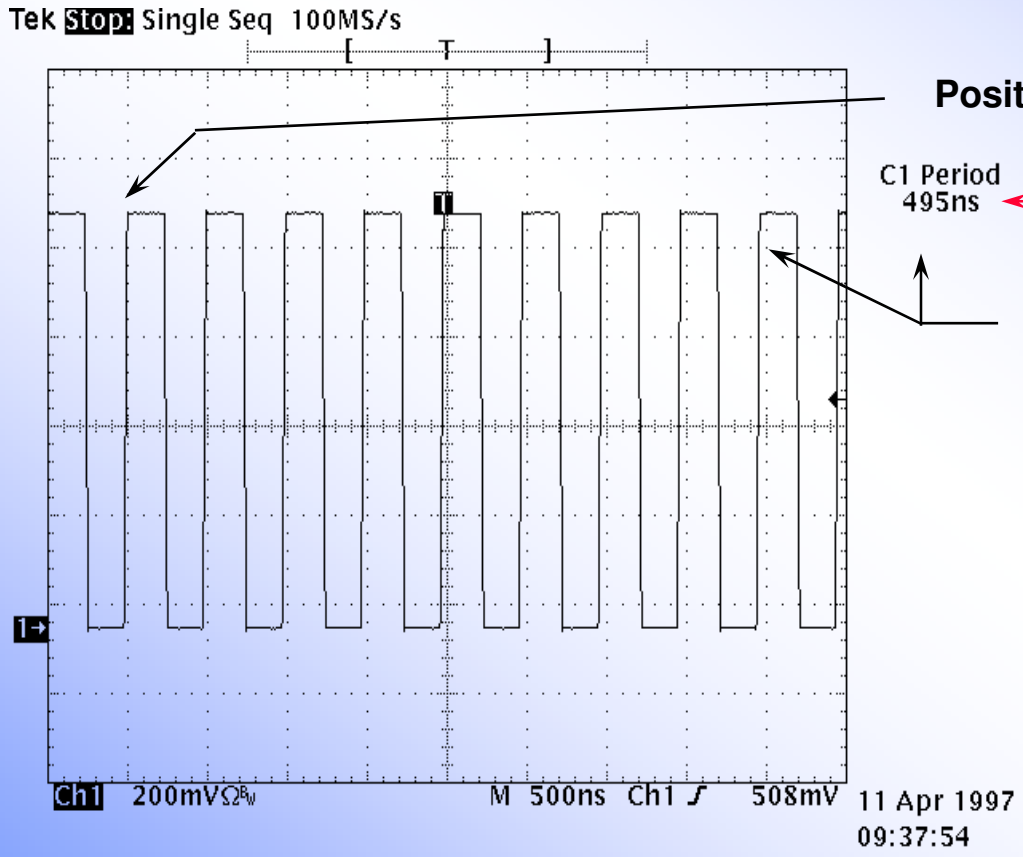
- **Evaluate accuracy of the horizontal time scale**





Comb or triangle waveforms are usually used with analog oscilloscopes

Timebase calibration (1)



Position 2nd Edge on 2nd graticule line

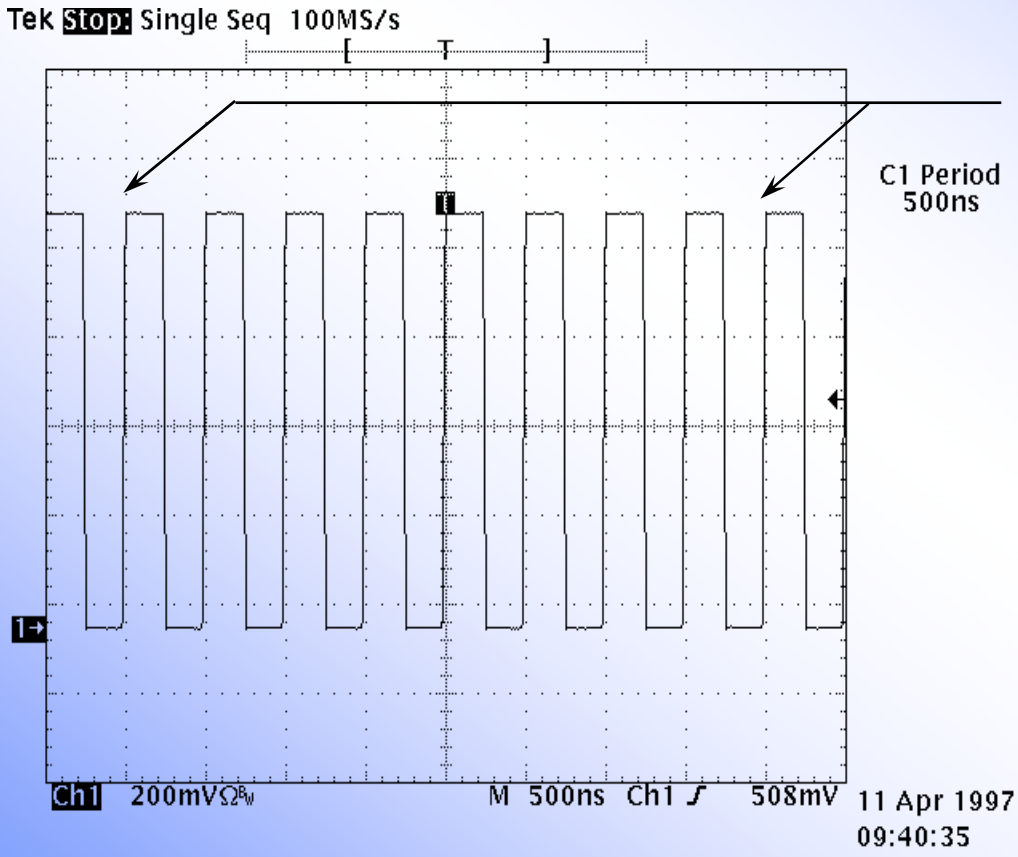
Period measurement readout

Deviation of 10th rising edge at 10th graticule line shows error: -1%

Scopes with dual (delayed) timebases require calibration of both timebases and delay function

Triangle waveform signals used for analog scopes. Square and pulse waveforms avoid edge sampling problems on DSOs.

Timebase calibration (2)

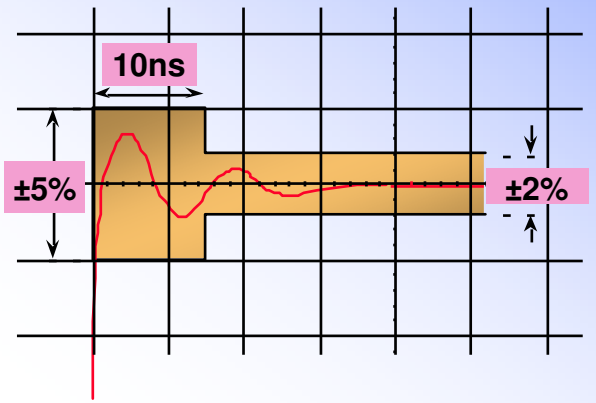


2nd and 10th rising edges aligned with according graticule lines

Period = 500ns; Error : 0%

Other functions & tests

- Fast edge ≤ 25ps pulse
  - Used for Rise Time Pulse Response Tests @ 50Ω
  - Tests BW to 14 GHz
- Other important scope calibrator capabilities:
  - External trigger for all functions
  - Built-in pulse generator with pulse width control
  - Video trigger in NTSC, SECAM, PAL and PAL-M formats with selectable line marker
  - Measure input impedance (resistance & capacitance)
  - Input Overload testing



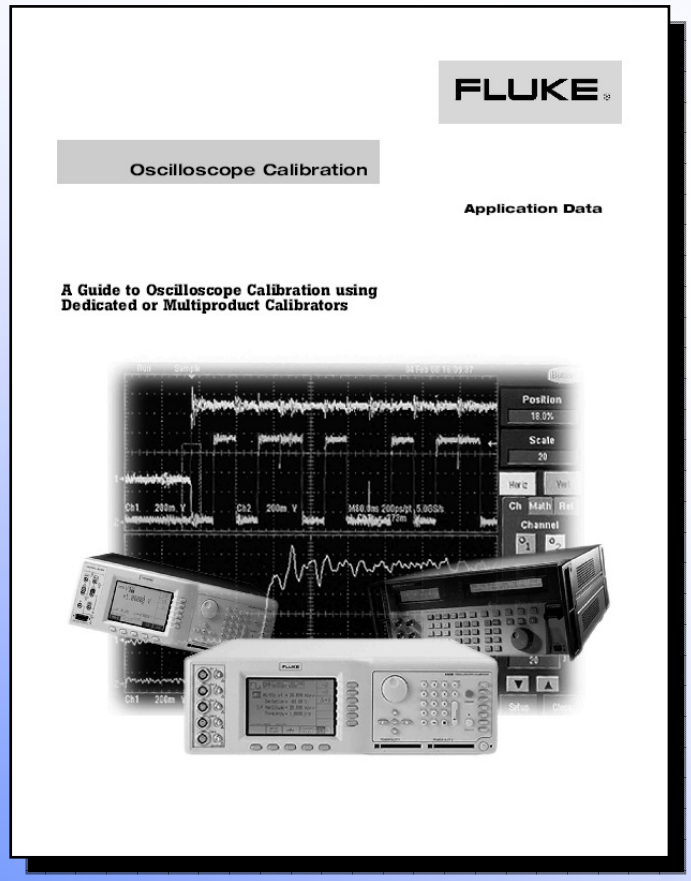
Generic test plan considerations (used in routine calibration)

- Have any Problems been Reported?
- Functional Checks:- Operation of All Controls, Air Filter, Line Voltage, Connectors, Display.
- Measure each vertical channel:
- Measure All Ranges:- Amplitude accuracy, bandwidth, pulse response, 1M ohm and 50 ohm inputs, including cursor and measurement features.
- Measure horizontal channel, including delay and dual timebase features, X-Y mode, cursor and measurement features.
- Check trigger operation and sensitivity.
- Include internal calibrator and any other specific requirements.

Summary and recommendations

- Think Carefully about the Test Plan and User Requirements
- Are appropriate calibration sources available?
- Follow Manufacturer's Recommendations

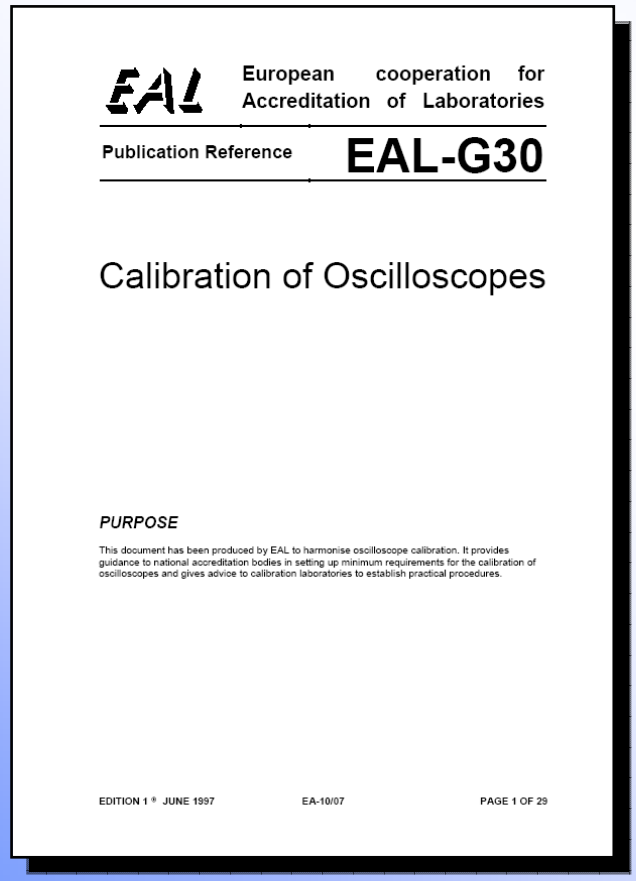
For more detailed information



- Guide Describes
  - Need for Calibration
  - Calibration Requirements
  - Aberration
  - Trigger Operation

  …….and more.
- For your copy –
  - Contact your Fluke sales representative
  - Find it with the scope calibration information on www.fluke.com

More information



EAL European cooperation for Accreditation of Laboratories

Publication Reference **EAL-G30**

Calibration of Oscilloscopes

PURPOSE

This document has been produced by EAL to harmonise oscilloscope calibration. It provides guidance to national accreditation bodies in setting up minimum requirements for the calibration of oscilloscopes and gives advice to calibration laboratories to establish practical procedures.

EDITION 1 © JUNE 1997 EA-10/07 PAGE 1 OF 29

- A European document to harmonize oscilloscope calibration
- Presently named EA-10/07
  - Originally published as EAL-G30 in 1997
  - Now under revision
- For a copy –
  - Search the web for "EAL-G30"
  - **www.euromet.org/docs/calguides/**

Questions?


Instrumenting Scope Calibration

Traditional calibration system

- Calibration Generator
- Time Mark Generator
- DC Calibrator
- AF Signal Generator
- Fast Pulse Generator
- RF Signal Generator & Power Meter
- Multiplexers
- Frequency Standard
- Multimeter
- Video Generator, Power Supply and more !!!

Problems with traditional systems

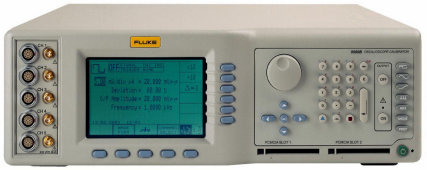
- Complex software to drive many instruments
- Multiplexer and cabling adds errors that need compensation
  - Frequency response
  - Pulse dribble up
  - Signal generator needs characterizing
    - * Poor flatness
    - * Poor VSWR
  - Can still require manual intervention!!
- Cost of calibration

Alternative calibrators

Multi-Product Platforms

BW < 1.1 GHz
>300 ps

Dedicated Scope Cal Platforms



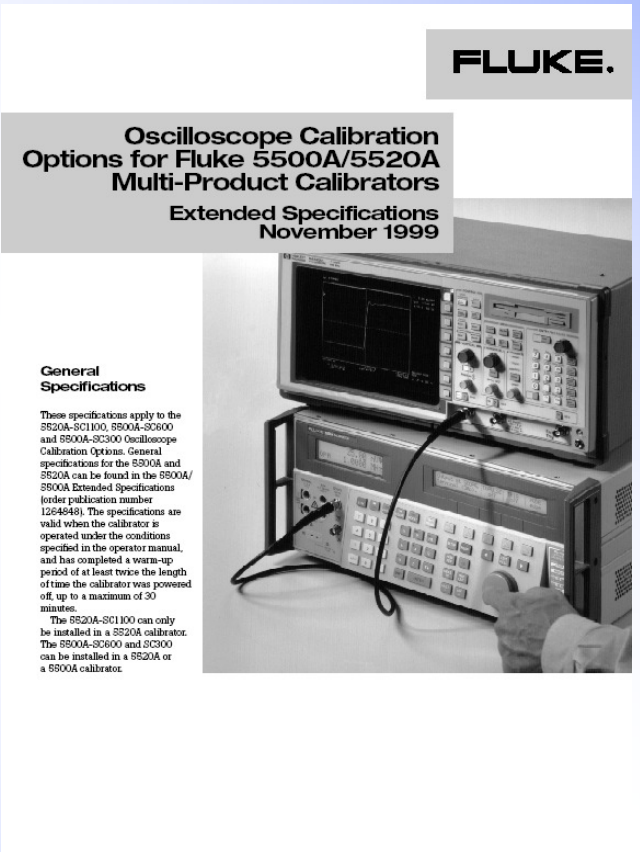
BW < 14 GHz
> 25 ps

Integrated Multi Product Calibrator Solutions

- An easy solution for labs with supporting fewer instruments
- Share total meter & scope work on one calibrator
- Limited bandwidth and edge performance
  - Bandwidths from 250MHz to 1.1GHz
  - Limited edge amplitudes and polarities
- Limited secondary calibration functions
- Not easily or economically expandable as workload grows beyond 1GHz

For more information -

- Refer to brochures with extended specifications
- Download the operators manuals for the calibrators of interest
- Refer to technical articles and white papers
- All available from:
  - www.fluke.com

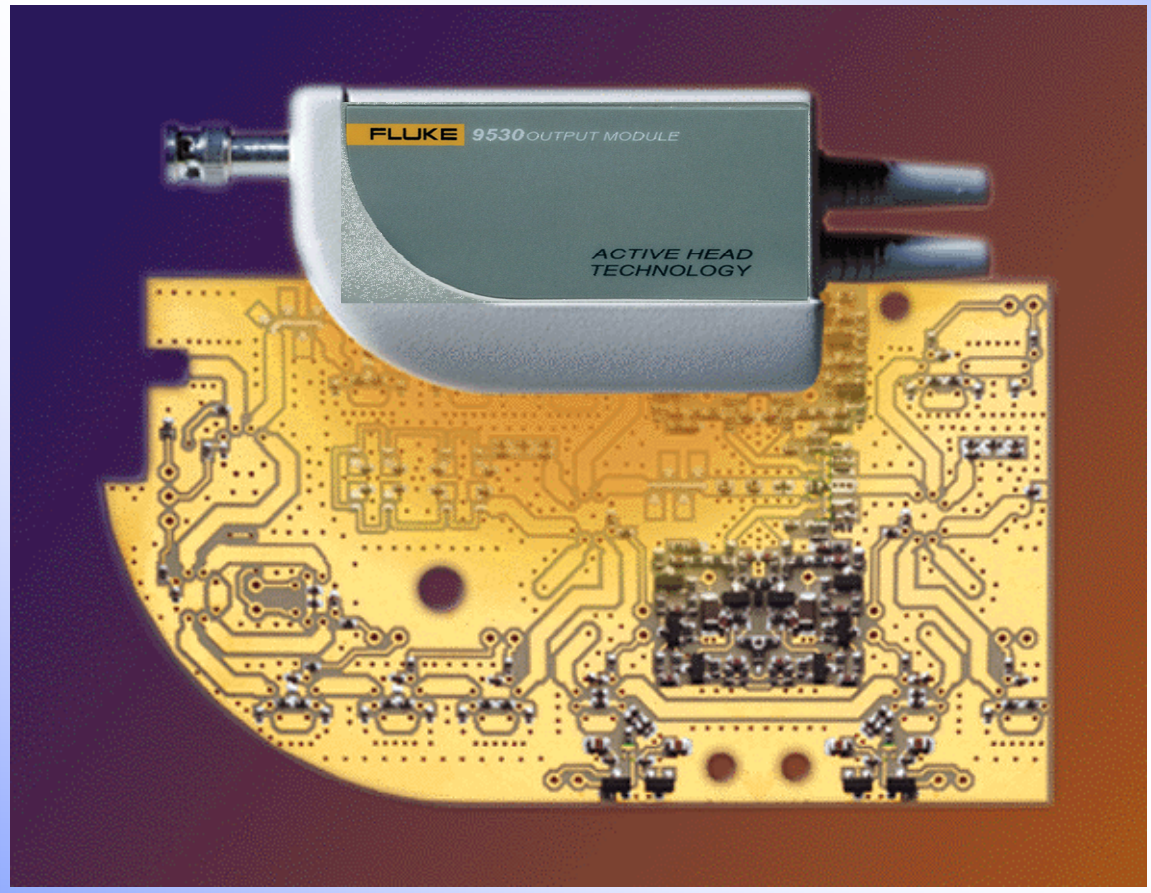



FLUKE
Dedicated Scope Calibrator Platforms
Alternatives for Maximum Capabilities

9500B Oscilloscope Calibrator

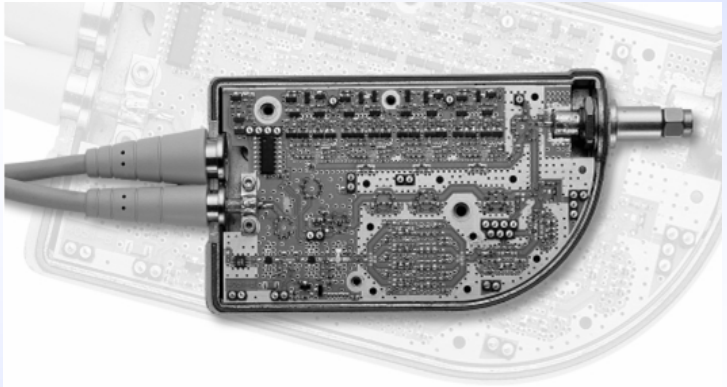
- Calibration of Analog and Digital scopes with bandwidths to 6.4 GHz (edge/pulse to 25ps, 14GHz)
- All signals routed through output module / head
- Multiple heads allow for full "hands free" automation
  - 5 heads from a single 9500B
- Wide range of test signals
- Single instrument solution to oscilloscope calibration and documentation

Active Head Technology™



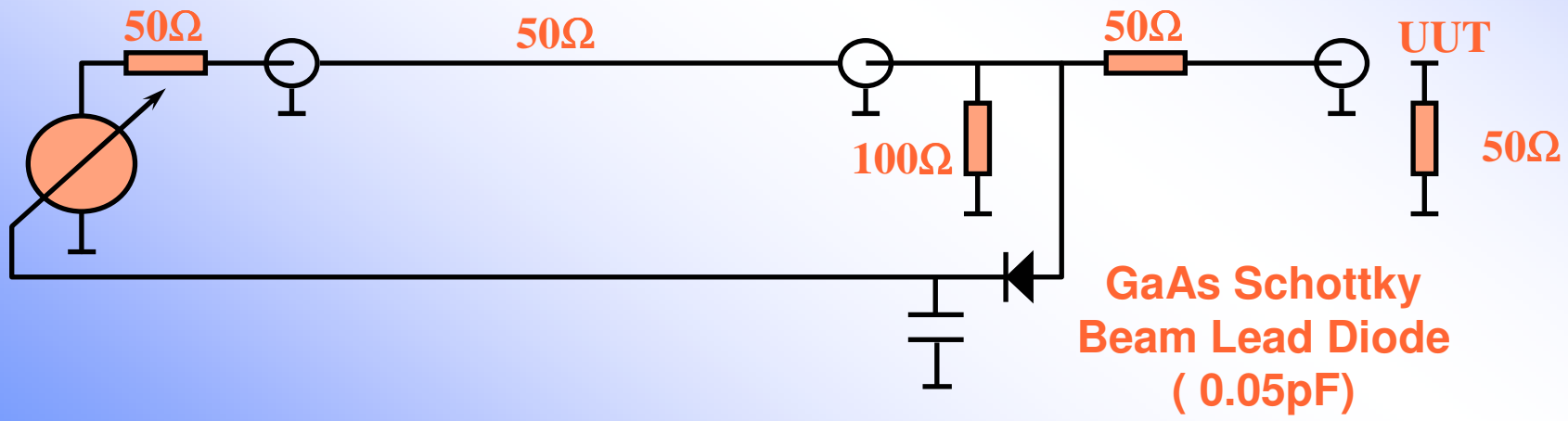
Active Head Technology™

- Integrates all functions into a single output
- A leveled sine wave frequencies
  - 600MHz
  - 1.1GHz
  - 3.2GHz
  - 6.4 GHz
- Generates and delivers 500ps, 150ps and 25ps wide dynamic range pulses
- Precision attenuation of HF signals
- Ensures specifications are at oscilloscope terminals
- Full automation, as up to 5 heads can connect simultaneously to UUT
- Rugged construction
  - Inclusive of 3 year Active Plus Careplan



Sine leveling at the load

- Peak Detect Leveling close to UUT
- Well defined VSWR at the signal frequency
- Traceability via RF Power Measurement
  - High Sine Purity (> -35dBc) necessary



Plus a repeatable, tightly specified edge -

- Two primary and distinct applications
  - Determine UUT Step Settling Characteristic
    - * Overshoot, undershoot, pre-shoot
  - Determine UUT Transition Time
    - * Rise and Fall (often different)
    - * Alternate assessment of UUT Band Width
- Requirements of the Edge are:
  - Edge of both polarities
  - Minimal source aberrations
    - * Return to Ground assures minimal long term aberrations
  - Speed to exercise the whole UUT Bandwidth
  - Accurately known (stable) Transition Time

Summary – The 9500B

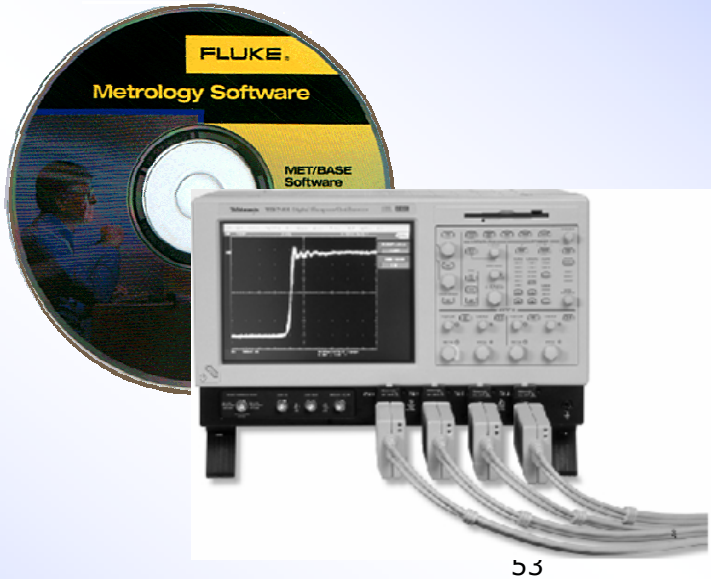
The worlds highest performance, fully automated upgradeable oscilloscope calibration workstation.

- A fully automated scope calibration system to 6.4 GHz (pulse to 25ps, 14GHz)
- Active Head Technology™
  - Elimination of cables and switches
  - Unrivalled performance
- High Accuracy - Up to ten times better accuracy than other scope calibrators on the market
- Upgradeable, modular architecture
- Fully supported procedures
- Dramatic increase in throughput
  - Achieves 5-10 fold reduction in cal times
- Simplified support philosophy

Automation

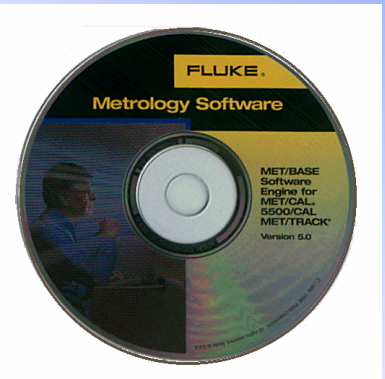
Benefits Of Automation

- Simplify oscilloscope calibration on all calibrator platforms (9100, 55XX, 9500B)
  - Allow for full automation
  - All signals should be through single connection
  - Hundreds of scope procedures available
  - Fluke Warranted procedures also available
- Significant reduction in calibration times
- Connect and Go approach - Full automation provides hands free oscilloscope calibration
- Reduce cost of ownership
  - Integrated into a single unit
  - Simplify calibrator traceability support
  - Allow for upgradeability as workload changes



Automated 9500B Scope Calibration Workstations

- A complete integrated solution to managed scope calibration
  - Model 9500B Oscilloscope calibrator
  - MET/CAL Plus Metrology Software
- The only fully automated system available
  - Multi channel & high bandwidth
- Configurations to suit all budgets and workloads
- Fully upgradeable workstations



Return On Your Investment

- Small to moderate sized scope calibration workloads can justify an investment in a dedicated scope calibration system
- An ROI analysis shows excellent payback, often in just 1 to 2 years compared to using third party calibration providers
- An Excel spreadsheet tool can simplify ROI calculations for individual situations
- This spreadsheet is available for download as a follow up to this seminar.

Date: 8/16/2007

RETURN ON INVESTMENT CALCULATOR

Oscilloscope Calibration

Enter your data into the [blue] cells to customize. Place your mouse icon over the [blue] cells for instructions

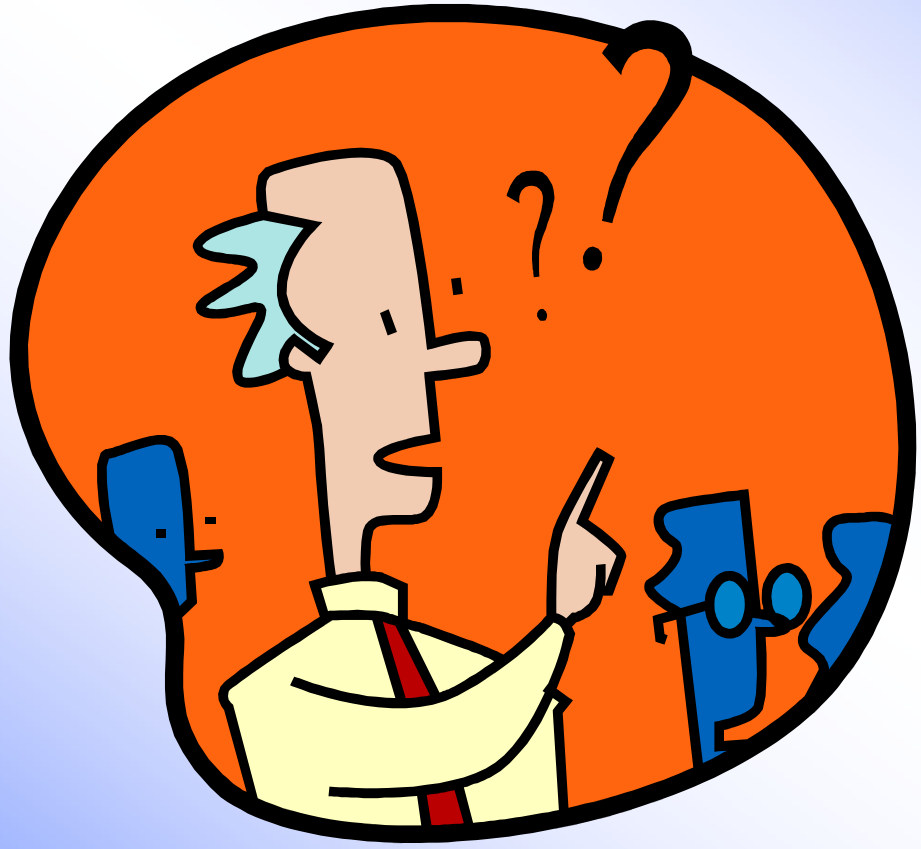
General Information									
Current Year	2007								
Currency	$								
Annual Co. Growth	5%								
Annual Inflation	3%								
Hours/Year	1980								
Internal Labor /Overhead Rates									
Labor Rate	$ 30								
Overhead Rate	$ 20								
Admin Rate	$ 20								
Third Party Costs	Cost	Admin Time	Total/Cal						
Simple	$ 100	1.00	$ 140						
Moderate	$ 250	1.00	$ 290						
Complex	$ 500	1.25	$ 550						
Calibrator				2007	2008	2009	2010	2011	
Cal Instrumentation	$ 32,000								
Annual Depreciation	20%			$ 6,400	$ 6,400	$ 6,400	$ 6,400	$ 6,400	
Calibrator Cals/Year	1								
Calibrator Cal Cost	$ 725			$ 725	$ 747	$ 769	$ 792	$ 816	
Annual Calibrator Cost				$ 7,125	$ 7,147	$ 7,169	$ 7,192	$ 7,216	
Cost/Cal Hour				$ 86	$ 83	$ 79	$ 75	$ 72	
Calibration Workload Inventory	Cals/Yr			2007	2008	2009	2010	2011	
Simple	1			25	26	28	29	30	
Moderate	1			60	63	66	69	73	
Complex	1			20	21	22	23	24	
Calibration Time	Cal	Admin		2007	2008	2009	2010	2011	
Simple	0.25	0.25		12.50	13.13	13.78	14.47	15.19	
Moderate	0.50	0.25		45.00	47.25	49.61	52.09	54.70	
Complex	1.00	0.25		25.00	26.25	27.56	28.94	30.39	
Total Hours/Year				82.50	86.63	90.96	95.50	100.28	
Third Party Cal Cost				2007	2008	2009	2010	2011	
Simple				$ 3,500	$ 3,785	$ 3,975	$ 4,173	$ 4,382	
Moderate				$ 17,400	$ 18,818	$ 19,759	$ 20,747	$ 21,784	
Complex				$ 11,000	$ 11,897	$ 12,491	$ 13,116	$ 13,772	
Total				$ 31,900	$ 34,500	$ 36,225	$ 38,036	$ 39,938	
Total In-House Cal Cost using Model 9500				2007	2008	2009	2010	2011	
Simple				$ 563	$ 595	$ 624	$ 656	$ 688	
Moderate				$ 2,100	$ 2,214	$ 2,325	$ 2,441	$ 2,564	
Complex				$ 1,200	$ 1,263	$ 1,326	$ 1,393	$ 1,462	
Total Operational Cost				$ 3,863	$ 4,072	$ 4,276	$ 4,490	$ 4,714	
Annual Calibrator Cost				$ 7,125	$ 7,147	$ 7,169	$ 7,192	$ 7,216	
Total In-house Calibration Cost				$ 10,988	$ 11,219	$ 11,445	$ 11,682	$ 11,930	
Savings(Deficit)				$ 20,913	$ 23,281	$ 24,780	$ 26,354	$ 28,008	
Equipment Utilization				4%	4%	5%	5%	5%	

The Resulting Payback Period is 1.3 Years

Conclusion & Review – What have we done?

- Topics
  - Reviewed basic scope calibration technical requirements
  - Provided technical references for scope calibration
  - Examined calibration instrumentation alternatives
  - Introduced the benefits of automation
  - Offered an ROI analysis tool to assist in analyzing and justifying a scope calibrator
- In Conclusion
  - Scope calibration is better understood
  - Instrumentation alternatives can be evaluated in a better manner

Questions about oscilloscope calibration?



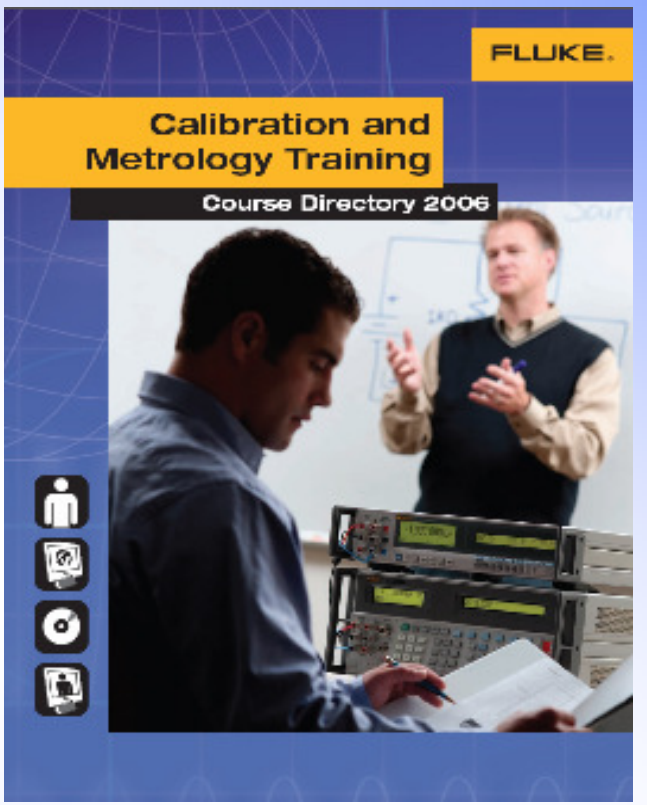
Calibration and metrology training from Fluke

- Fluke calibration and metrology training helps you get the most from your investment in calibration instruments and software
- Multiple ways to learn:
  - Instructor-led classroom sessions
  - Instructor-led web-based courses
  - Self-paced web-based training
  - Self-paced CD-ROM training
- Multiple locations
  - United States and Canada
  - Europe
  - Singapore

Members of the MET/SUPPORT Gold and Priority Gold CarePlan support programs receive a 20 % discount off any Fluke calibration training course

Calibration and metrology training

- **Instructor-Led Classroom Training**
  - MET-101 Basic Hands-on Metrology (new in 2007)
  - MET-301 Advanced Hands-on Metrology (new in 2007)
  - Cal Lab Management for the 21st Century
  - Metrology for Cal Lab Personnel (A CCT prep course)
  - MET/CAL Database and Reports
  - MET/CAL Procedure Writing
  - MET/CAL Advanced Programming Techniques
  - On-Site Training
  - Product Specific Training
- **Instructor-Led Web-Based Training**
  - MET/CAL Database Web-Based Training
  - MET/CAL Procedure Development Web-Based Training
- **Self-Paced Web-Based Training**
  - Introduction to Measurement and Calibration
  - Precision Electrical Measurement
  - Measurement Uncertainty
  - AC/DC Calibration and Metrology
  - Metrology for Cal Lab Personnel (A CCT prep course)
- **Self-Paced Training Tools**
  - MET/CAL-CBT7 Computer Based Training
  - MET/CAL-CBT/PW Computer-Based Training (new in 2007)
  - Cal-Book: Philosophy in Practice textbook



More information:
www.fluke.com/fluketraining

THANK YOU !

For material related to this session, visit our web site:

http://www.fluke.com

For any questions or copies of this presentation:

email inquiries to: fpmseminars@fluke.com