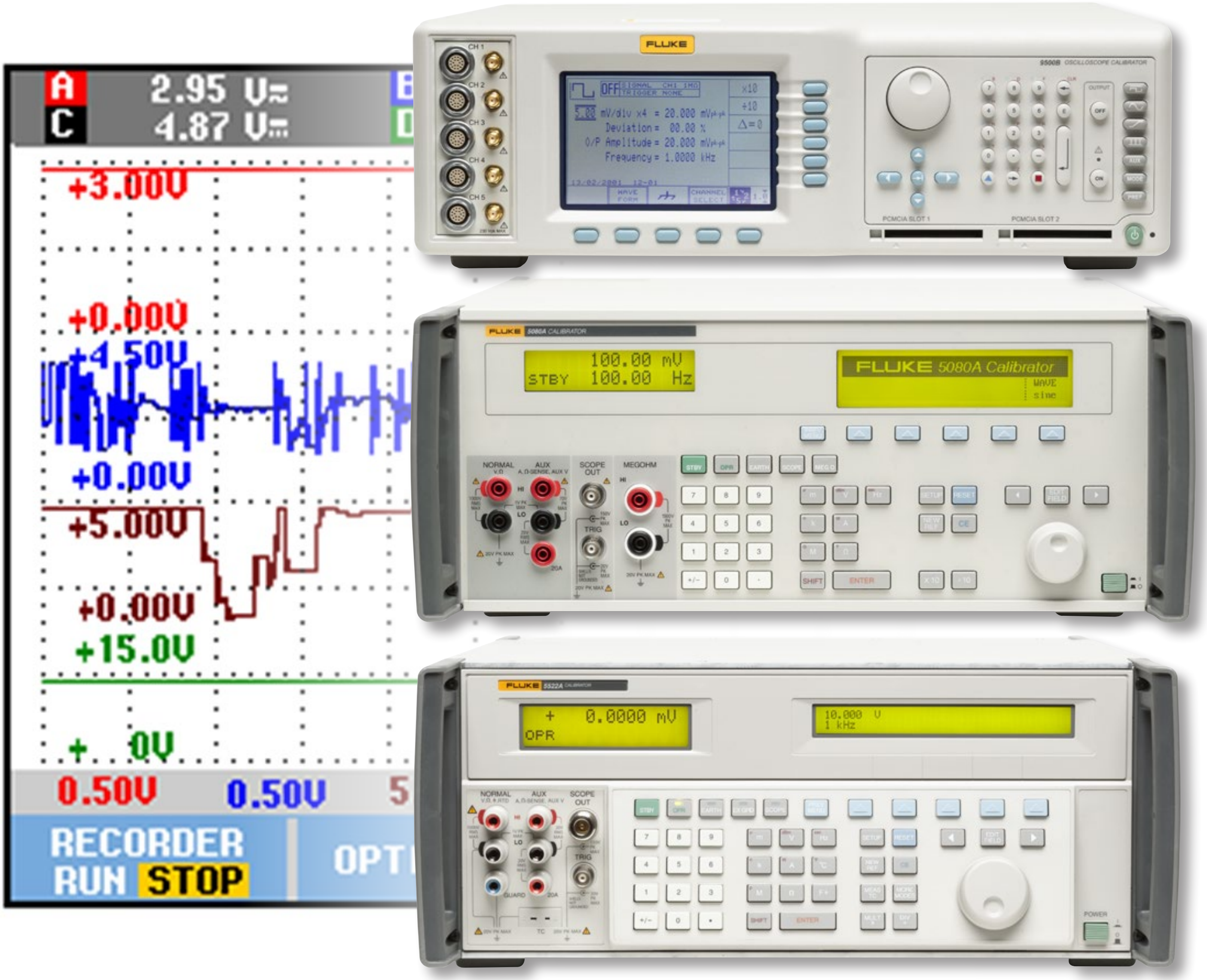
FLUKE®
Calibration

Oscilloscope calibration

Application Note

A guide to oscilloscope calibration using dedicated or multiproduct calibrators



User requirements
Oscilloscopes are very complex instruments, mainly because of attempts to provide easy and direct access to waveforms, then to permit both qualitative and quantitative analysis.

Users demand enough flexibility to deal with a wide range of functions, frequencies and voltages without having to buy an array of instruments.

Need for calibration

Older low-cost oscilloscopes
At the low-cost end of the range of oscilloscopes, we can remember older analog instruments, with deflection accuracy and bandwidth so limited as to present merely a rough picture of a signal. Power supplies were often unregulated and there was no external means of X/Y gain or bandwidth adjustment.

The accuracy of such an instrument was seriously degraded by fluctuations in the line supply, accompanied by component temperature and time drift. These types of instruments possessed poor performance repeatability, and calibration would have been largely a waste of time; nowadays, however, calibration will more often be required.

Modern developments in low-cost oscilloscopes
Modern low-cost instruments are vastly different from the older image presented above. Many newer low-cost oscilloscopes have resulted as a spin-off from the development of more expensive and sophisticated instruments, with significant improvements in component quality, performance repeatability, and expanded functionality.

The advent of more stringent quality standards (such as the ISO 9000 series), bringing insistence on traceability for qualifying measurement systems, now emphasizes the need to calibrate even low-cost oscilloscopes.

More sophisticated oscilloscopes
In many cases, these are more specialized instruments, concentrating on such features as multi-channel comparison, computation, data collection and dual-sourced Y-axis deflection. (e.g. presenting both time and frequency bases simultaneously on the same screen).

Oscilloscopes passed through a phase of using a mainframe, with plug-in modules carrying specialized hardware. Subsequently, with the introduction of microprocessors, the development of the Digital Storage Oscilloscope (DSO) permits functionality to be more-effectively controlled by suites of software, allowing specialist programs to dispose of much of the specialized hardware.

DSOs have many advantages when the signal is repetitive and can be retained for examination by inbuilt measurement programs and signal transfer to other systems (e.g. for pass/fail tests or hard-copy printing). They can also capture and display pre-trigger, single-event and short-lived waveforms which present difficulties with analog oscilloscopes. Some transients cannot be displayed on analog oscilloscopes with sufficient light output to be viewed conveniently, but capture in a DSO permits enhancement of the light output.

Because the DSO depends largely on sampling techniques, for some applications this cannot replace the purer 'real-time' nature of the signals. For example, when viewing amplitude modulated waveforms and jitter signals on a DSO, 'aliased information' can distort the presentation due to the need for incompatible sampling rates.

Calibration requirements
Despite the growing increase in oscilloscope functionality, the essential features of faithful and accurate representation remain few:

- Vertical deflection coefficients
- Horizontal time coefficients
- Frequency response
- Trigger response

Techniques and procedures for calibration must measure these features, while coping with the functional conditions which surround them. Good metrological practice must be used to ensure that an oscilloscope's performance at the time of use is comparable with that observed and measured during calibration. This will provide confidence in certificates of traceability and documentation which result from calibration.

Manual or automated calibration?
Manual calibration methods are well established, and for analog oscilloscopes there is possibly no cost-effective alternative, although techniques are being developed which employ oscilloscope calibrators together with memorized calibration procedures directed at individual oscilloscope models. These procedures use a form of prompted manual calibration.

For DSOs, which are based on programmable digital techniques, and may already be programmed to respond to remote signals (say via the IEEE-488 interface), automated calibration can be achieved, with great benefits to repeatability, productivity, documentation generation, and statistical control.

This guide is intended as an introduction to the basic techniques of oscilloscope calibration, and will concentrate on the types of tests and adjustments which are likely to be used by both manual and automated methods, and not differentiating between them.

Oscilloscope display geometry

Before it is possible to calibrate the main parameters it is necessary, for many oscilloscopes, to ensure that the essential geometry of the oscilloscope is set up correctly. This may, in fact, be regarded as part of the calibration process, as the parameter measurements are dependent on visual observations.

In real-time (analog) oscilloscopes, the graticule is a separate entity from the screen images. This means that if the graticule is to be used as a measurement tool, alignment to it must be included in the calibration process. The innovation of the Electronic Graticule in DSOs has largely removed the need to establish geometrical links between screen data and the graticule—this is done automatically, and tube rotation does not disturb relative alignments.

Where an electronic cursor is used, this links internally with trace data and channel sensitivities, tied to an internal dc voltage standard. In these cases the main requirement is to calibrate the voltage standard.

Parameters to be calibrated

At this point, it may be useful to provide a list of the parameters which need to be verified or calibrated in order to ensure traceability in the majority of oscilloscopes. This list breaks down the features listed earlier:

- Accuracy of vertical deflection
- Range of variable vertical controls
- Vertical channel switching
- Accuracy of horizontal deflection
- Accuracy of any int. calibrator
- Pulse edge response
- Vertical channels bandwidth
- Z-axis bandwidth
- X-axis bandwidth
- Horizontal timing
- Time base delay accuracy
- Time magnification
- Delay time jitter
- Standard trigger functions
- X-Y phase relationship

Parameter details

Geometry setup

Although setting up the display geometry may not be strictly regarded as a calibration parameter, the oscilloscope display is the window through which most of the (visual) measurements are made. The display geometry should be set up, or at least examined, before going ahead with calibration, if only to ease the measurement processes. Examples of geometry features are:

- CRT alignment
- Earth's field screening or compensation
- Range of focus and intensity controls
- Barrel distortion
- Pincushion distortion
- Range of Y- and X-axis positioning controls

Vertical deflection accuracy

Amplitude

The Y-axis is used, almost exclusively, for displaying the amplitude of incoming signals. These are processed through 'channel' amplifiers (mainly two channels, often four or more).Basic setup features include:

- Zero alignment to graticule (Offset)
- Vertical amplifier balance
- Vertical channel switching
- Operation of alternate/ chopped presentations

Multiple-traces are created using alternate-sweep switching or 'chopped' high-speed switching. In alternate-sweep switching, the trace completes before switching to the next. With 'chopped' high-speed switching, usually used for low frequency signals, inputs are sampled alternately at high speed and steered into separate channels. DSOs use different forms of switching to achieve similar effects. Whichever system is in use, there will be a series of alternative channel amplifiers and attenuators whose gain characteristics are the major influence on vertical accuracy.

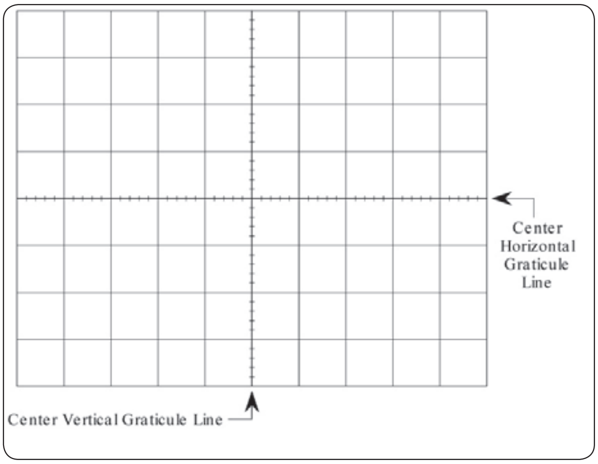


Fig. 1.1 Standard graticule.

There are five main parameters to be checked in calibrating each vertical amplifier system: offset, gain, linearity, bandwidth and pulse response.

These parameters are crucial to achieve accurate representation of the signal. For effective comparisons between signals applied through different channels, their channel parameters must be equalized.

Measurement of a channel amplifier's gain is usually performed by injection of a standard signal and measurement of its presentation against the display graticule. Because the amplifier coupling may be switched between ac/dc and often 50 Ω/1 MΩ, it will be necessary to inject signals which test the operation of each of these forms of coupling.

Two standard signals for measuring an amplifier's gain are usually employed:

i. With dc coupling, either a dc signal (Fig. 1.2 – includes offset) or a square wave (Fig. 1.3 – can be manipulated to remove the offset) is injected, and the channel's response is measured against graticule divisions or cursor readings.
   All Fluke scope calibrators provide dc voltage and 1 kHz square wave outputs for testing the gain and offset of dc coupled amplifiers.

ii. With ac coupling, a square wave signal is injected at 1 kHz, and again the channel's response is measured against graticule divisions or cursor readings.

Using a low frequency pulse can also provide a rough check of the gross LF and HF response (Fig 1.4). This is only a very rough test of gross distortion. A result which looks square must still be checked for pulse response and bandwidth.

All Fluke scope calibrators provide a 1 kHz square wave for testing the LF gain of ac-coupled amplifiers.

Channel amplifiers' linearity can be tested by injecting either a dc or a square wave signal, varying the amplitude and checking the changes against the graticule or cursor readings.

Pulse response

Viewing the rise time of pulse fast edges is one of two complementary methods of measuring the response of the vertical channel to pulsed inputs (the amplifier's bandwidth should also be measured—refer to the section Channel Bandwidth).

Response to fast edges depends on the input impedance of the oscilloscope to be tested. Two standard input impedances are generally in use: 50 Ω and 1 MΩ//(typically) 15 pF. 1 MΩ is the industry standard input generally used with passive probes. Where the 50 Ω input is provided it gives optimal matching to HF signals.

To measure the rise time, the pulse signal is injected into the channel to be tested; the trigger and time base are adjusted to present a measurable screen image, and the rise/fall time is measured against the graticule or cursor readings. The observed rise/fall time has two components: that for the applied signal and that for the channel under test. They are combined as the root of the sum of squares, so to calculate the time for the UUT channel, a formula must be used:

UUT rise/fall time =
Square root [(Observed time)^2 – (Applied signal time)^2]

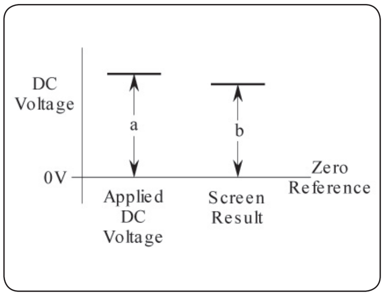


Fig. 1.2 DC voltage – gain.

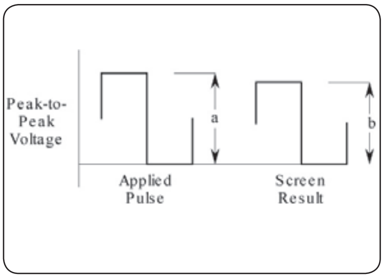


Fig. 1.3 LF square wave – gain. The peak-to-peak value shown on the screen (b) is compared with the known value (a): b ÷ a = Gain at 1 KHz.

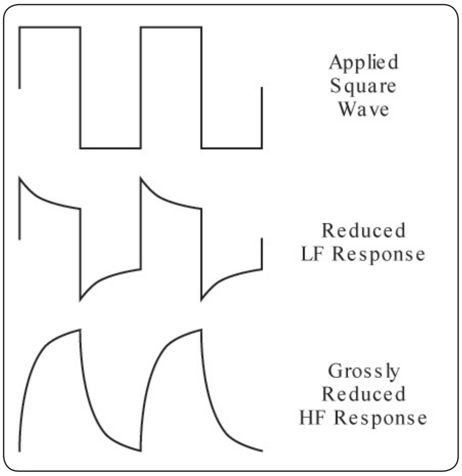


Fig. 1.4 LF square wave – distortions.

In some oscilloscopes the vertical graticule is specially marked with 0 %, 10 %, 90 % and 100 % to make it easy to line up the pulse amplitude against the 0 %/100 % marks, then measure the 10 %/90 % crossing points against marks on the center horizontal graticule line.

Measurement

In all Fluke models, two different sort of pulses are used:

- **Low Edge Function:** a low voltage amplitude pulse matched into 50 Ω with a rise/fall time less than or equal to 1 ns. When using the formula to calculate the UUT rise/fall time, the applied signal rise time must be that certified at the most-recent calibration of the calibrator, closest to the amplitude of the applied pulse.
- **High Edge Function:** a high voltage amplitude pulse matched into 1 MΩ with a rise time less than or equal to 100 ns. This function is used mainly to calibrate the response of the oscilloscope's channel attenuators.

Leading-edge aberration

In Fig. 1.5, some leading-edge aberrations (overshoot and undershoot) are shown at the top end of the edge, before the voltage settles at its final value (which is the value defined as 100 %).

Where scope specifications include aberrations, the specification limits can be expressed as shown in the shaded area of the magnified Fig. 1.6 (typical limits shown).

When aberrations are displayed for measurement, they should be within the specification limits, although where the oscilloscope's aberration specification approaches that of the calibrator, other methods must be used.

Channel bandwidth

As well as determining the pulse response by viewing a specimen pulse on the screen, this should be supported by measuring the amplifier's bandwidth using a 'leveled sine wave'. This is done at an input impedance of 50 Ω, to maintain the integrity of the 50 Ω source and transmission system. For high input impedance oscilloscopes, an in-line 50 Ω terminator is used to match the line at the oscilloscope input. The in-line 50 Ω could take the form of a separate 50 Ω terminator or be incorporated within an 'Active' head—the latter gives the benefit of full automation and requires no additional calibration.

First the displayed amplitude of the input sinusoidal wave is measured at a reference frequency (usually 50 kHz), then the frequency is increased, at the same amplitude, to the specified 3 dB frequency of the channel. The displayed amplitude is measured again.

The bandwidth is correct if the observed 3 dB point amplitude is equal to or greater than 70 % of the value at the reference frequency.

If it is needed to establish the actual 3 dB point, the frequency should be increased until the peak-to-peak amplitude is 70 % of the value at the reference frequency, then this frequency is close to the 3 dB point.

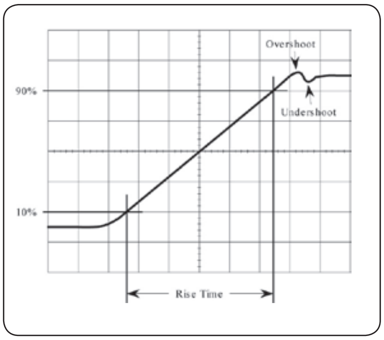


Fig. 1.5 Measurement of rise time.

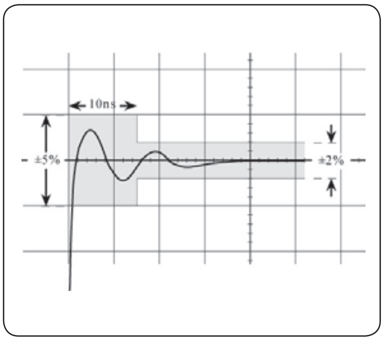


Fig. 1.6 Leading edge aberration.

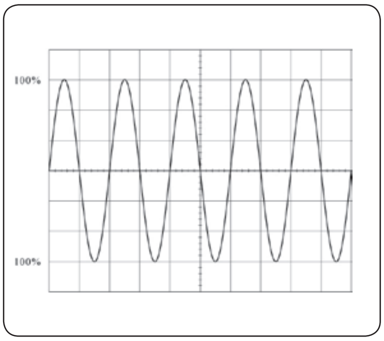


Fig. 1.7 Setting the amplitude at the reference frequency.

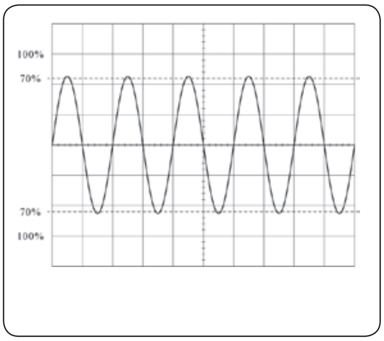


Fig 1.8 Measuring the amplitude at the 3 dB point frequency.

Horizontal deflection accuracy

Introduction

The X-axis is dedicated almost exclusively to use as the vehicle for the time base(s). As well as two vertical channels, there will often be two time bases: Main and Delayed. These may be achieved in DSOs by two independent sampling rates, or via a positioned ‘zoom’ window on a single, but long, store.

When determining the accuracy of horizontal deflection, where applicable, the geometry of the display must have first been set up. It is assumed that this will be included as part of the initial geometry setup.

Once this has been done, the following adjustments or checks can be attempted:

- X-axis bandwidth
- Horizontal timing
- Timebase delay accuracy
- Time magnification
- Delay time jitter
- Trigger functions
- X-Y phase relationship

X-axis bandwidth

For real-time oscilloscopes, the horizontal amplifier’s bandwidth will be checked using a ‘leveled sine wave’, similar to the checks of vertical channels, but with the time base turned off. This consists first of measuring the displayed length of the horizontal trace (Fig. 1.9), for a sinusoidal wave provided as X input at a reference frequency (usually 50 kHz).

The frequency is then changed, at the same amplitude, to the specified 3 dB point of the horizontal amplifier and the displayed trace length is measured again (Fig. 1.10). The bandwidth is correct if the observed 3 dB point trace length is equal to or greater than 70 % of the length at the reference frequency.

DSOs generally employ a vertical channel amplifier as the horizontal amplifier, so having measured the vertical deflection bandwidth, there is generally no need to measure horizontal deflection bandwidth.

Horizontal timing accuracy

Test setup

In this test the time base is switched to the sweep speed (or time/div) to be checked, and the output from a timing marker generator is input via the required vertical channel. On oscilloscope calibrators these are square waves, changing to sine waves at a specific frequency.

Timing calibration accuracy

A timing accuracy of 25 ppm will be sufficient to calibrate most real-time oscilloscopes and many DSOs, although a timing accuracy better than 0.3 ppm is required for some higher-performance DSOs.

Why use square waves?

In the past, timing markers have taken the form of a ‘comb’ waveform, consisting of a series of differentiated edges in one direction, with the return edges suppressed. This leads to difficulties in DSOs due to sampling, in which the comb peak can fall between samples, leading to amplitude variations and difficulty in judging the precise edge position. The use of timing markers in the form of square or sine waves significantly reduces the inaccuracies due to 1-dot jitter.

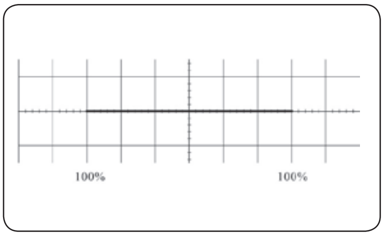


Fig. 1.9 Setting the trace length at the reference frequency.

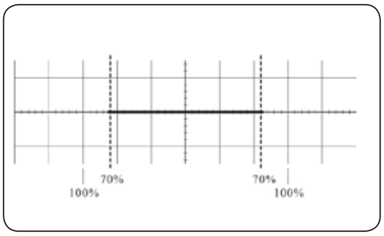
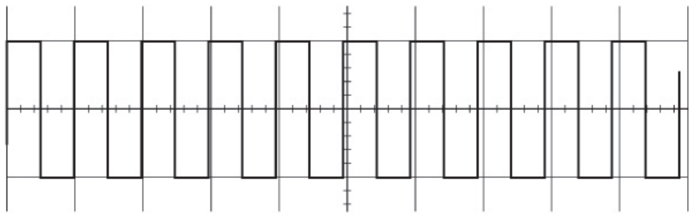
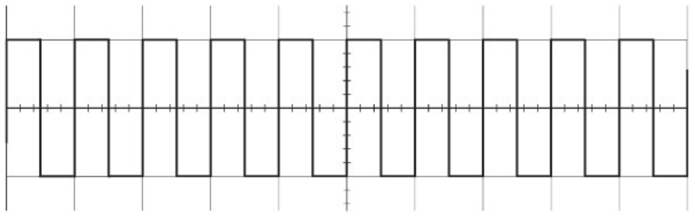


Fig. 1.10 Measuring the trace length at the 3 dB point frequency.



a. Initial state before deviation adjustment



b. Aligned state after deviation adjustment

Fig. 1.11 Adjusting the marker generator’s deviation for correct alignment.

Measurement
The marker timing is set to provide one cycle per division if the horizontal timing is correct.

By observation, the marker generator's deviation control is adjusted to align the markers on the screen behind their corresponding vertical graticule lines, and the applied deviation is noted. The applied deviation should not exceed the oscilloscope's timing specification.

The operation is repeated for all the sweeps and time base time/division settings designated for calibration by the oscilloscope manufacturer.

Time base delay accuracy
For this test it is assumed that the delayed time base is indicated as an intensification of the main time base, and can be switched to show the delayed time base alone. For all oscilloscopes, ensure that the retrigger mode is switched off.

The output from a timing marker generator is input via the required vertical channel, and the oscilloscope is adjusted to display one cycle per division as illustrated in Fig 1.12 {a}. The oscilloscope mode switch is set to intensify the delayed portion of the main time base over a selected marker edge as shown (this may require some adjustment of the oscilloscope's Delay control).

The oscilloscope delay mode switch is set to display the delayed sweep alone, and the delay control is adjusted to align the time marker edge to a chosen vertical datum line (e.g. center graticule line as shown at Fig 1.12 {b}). The setting of the oscilloscope's delay is noted.

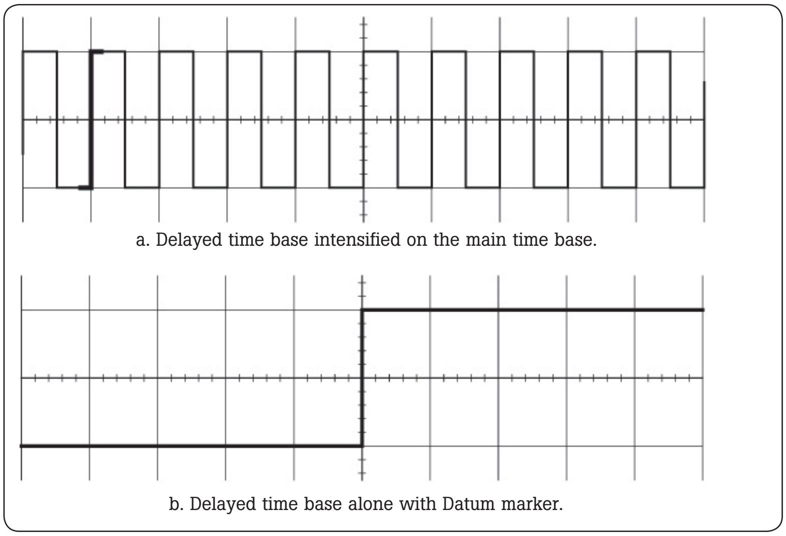
The oscilloscope mode switch is set to intensify the delayed portion of the main time base over a different selected marker edge—(Fig. 1.13 {a}).

The oscilloscope delay mode switch is again set to display the delayed sweep alone, and the delay control is adjusted to align the time marker edge to the same vertical datum line (Fig. 1.13 {b}). The setting of the oscilloscope's delay is again noted.

Finally, the two settings of the oscilloscope delay are compared, to check that their difference is the same as the time between the two selected markers, within the specified limits for the oscilloscope.

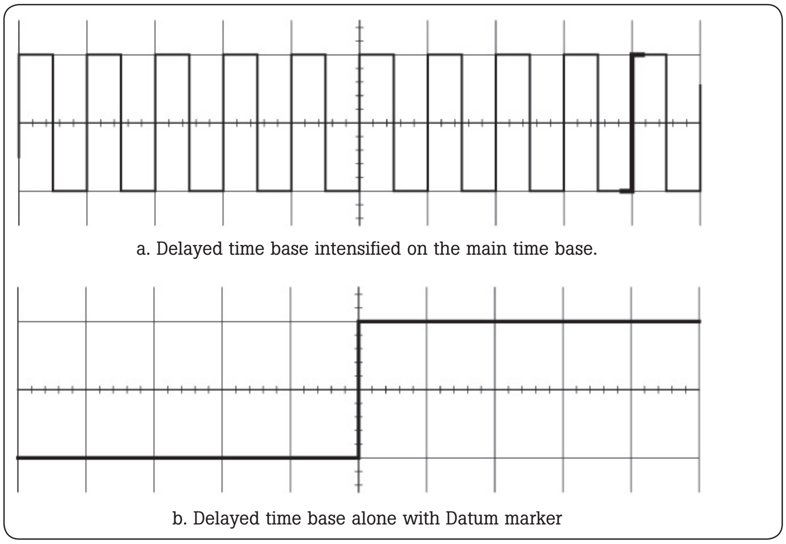
Horizontal x10 magnification accuracy
The output from a timing marker generator is input via the required vertical channel, and the oscilloscope is switched to display 10 cycles per division as illustrated in Fig 1.14 {a}. The timing marker generator frequency/period is adjusted to give exactly 10 cycles per division.

The errors are likely to be greatest on the right of the trace (the longest time after the trigger), so the oscilloscope's horizontal position control is adjusted to place the marker edge at 'A' at the center of the screen.


a. Delayed time base intensified on the main time base.

b. Delayed time base alone with Datum marker.

Fig. 1.12 Adjusting the delayed time base to the first Datum marker.


a. Delayed time base intensified on the main time base.

b. Delayed time base alone with Datum marker

Fig. 1.13 Adjusting the delayed time base to the second Datum marker.

The oscilloscope is set to display the X10 sweep, and the horizontal position control is adjusted to align the marker edge 'A' exactly to the center graticule line.

The marker generator Frequency/Period deviation control is adjusted to align the marker edges exactly to the graticule lines as shown at Fig 1.14 {b}.

The marker generator Frequency/Period deviation setting is noted. This setting should be within the specified limits for the oscilloscope.

Similarly, for a DSO, the range of available 'Zoom' or X-magnification' factors are calibrated as designated by the manufacturer.

Delay time jitter

The delay jitter on oscilloscopes is often measured under time magnifications of the order of 20,000:1. This means that the delayed time base must run 20,000 times faster than the main time base (for a main time base running at 20 ms/div, the delayed time base must run at 1µs/div).

For this test the intensification of the main time base is adjusted onto the edge at the center graticule line (with such a difference between the speeds of the main and delayed time bases, a very small part of the main time base is intensified, and adjustment may be difficult).

The 20 ms period output from a timing marker generator is input to the required vertical channel, and the oscilloscope is adjusted to display one cycle per division (20 ms/div) as illustrated in Fig 1.15a.

The delayed time base is set to run at 1 µs/div, and the oscilloscope mode switch is set to intensify the delayed portion of the main time base over the center marker edge as shown using the oscilloscope's delay time control.

The oscilloscope delay mode switch is set to display the delayed sweep alone, and the delay control is adjusted to align the time marker edge to a chosen vertical datum line (e.g. center graticule line as shown at Fig 1.15b).

The width of the vertical edge (which displays the jitter) of the displayed portion of the waveform, measured along a horizontal axis, should not exceed the oscilloscope's specified jitter limits (i.e. in this example, for 20,000:1 specification, the oscilloscope's contribution to the width should be less than 1 division).

Trigger operation

Standard functions—introduction

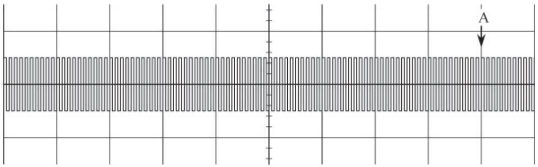
For most oscilloscopes, a wide variety of trigger modes exist, being sourced either via a nominated Y-input channel, or from a separate external trigger input.

The functionality of the trigger modes allow for ac or dc coupling, repetitive or single-sweep, and trigger-level control operations.

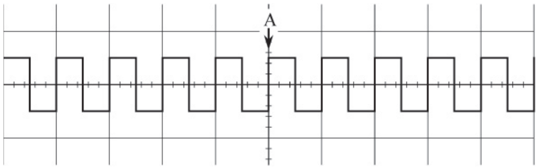
These tests check the operation of:

- Internal trigger sensitivity in both polarities, from each of the available Y-input channels
- Operation of the trigger level control for a sinewave external trigger input
- Effect of vertical position on trigger sensitivity.
- Minimum trigger levels for normal and 'trigger view' modes
- Bandwidth of trigger circuits, and effect of HF rejection filters
- LF and dc performance of the trigger circuits
- Single-sweep performance and response to position controls

Note: Tests which are performed using a Y-channel input are also carried out on all the other available Y-channels.

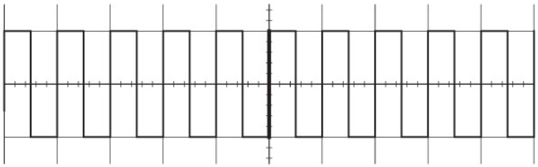


a. Markers set at 10/div at x1 magnification.

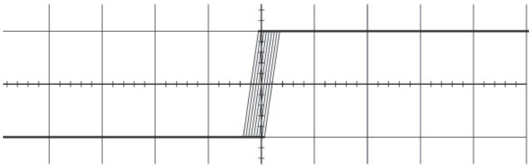


b. Markers set at 10/div at x10 magnification.

Fig. 1.14 Checking the effect of x10 magnification.



a. Delayed time base intensified on main time base.



b. Edge showing jitter on delayed time base.

Fig. 1.15 Measuring the delay time jitter.

Internal triggers—trigger level operation

a. Initial setup
A standard 4 Vp-p (50 Ω) reference sinusoidal signal is input via ac coupling into the Y-input channels in turn. Using internal triggers and dc trigger coupling (not 'AUTO'), the +ve and -ve slopes are selected in turn. The sweep speed setting is 10 µs/division; the Y-channel sensitivity is 0.5 V/division so that the input signal occupies 8 divisions.

b. Trigger level adjustment
Over almost all of its range of adjustment, the trigger level control must be shown to produce a stable trace, moving the starting point over a range of levels up and down the selected slope of the displayed sine wave.

c. Trigger sensitivity
With the input signal reduced to 10 % of its amplitude, adjustment of the trigger level control must be shown to reacquire stable triggering. With trigger coupling switched to ac, and using vertical positioning to place the trace at extreme upper and lower limits of the CRT screen in turn, stable triggering must be maintained.

d. 'Display triggers' feature
If the oscilloscope has a 'Display Triggers' or 'Trigger View' feature, this is selected to display the trigger region of the waveform. Using a 200 mV sinusoidal signal input to the channel, the trigger region is checked for correct amplitude on the display.

N.B. In the following trigger operations, during tests on a DSO, the trace will not disappear as a result of the interruption of the trigger (or reduction of its amplitude below the threshold). Instead, the trace will remain but not be refreshed, and this is the condition to be detected.

External triggers

a. Initial setup
These tests start with the 200 mV signal, described in the previous paragraph 'Display Triggers' feature, applied to the external trigger input of the oscilloscope.

b. Presence of a trace
Adjustment of the oscilloscope's trigger level control should be able to produce a trace. The Ext Trig input is disconnected and reconnected again, while checking that the trace disappears and is then reinstated.

c. Trigger sensitivity
With the input signal reduced to the minimum amplitude specified by the manufacturer, adjustment of the Trigger Level control must be shown to regain stable triggering.

d. Trigger bandwidth
With the input signal set to the minimum amplitude and maximum frequency specified by the manufacturer, adjustment of the trigger level control must be shown to acquire stable triggering. The Ext Trig input is disconnected and reconnected again, while checking that the trace disappears and is then reinstated.

e. ACHF rejection trigger mode
With the input signal set as for the trigger bandwidth check, the ACHF Reject feature is activated then deactivated again, while checking that the trace disappears and is then reinstated.

Internal triggers—dc-coupled operation

a. Initial setup
With the Ext Trig input disconnected, and the Y-channel input externally grounded, the oscilloscope Y-channel is set to 'DC-coupling' and trigger mode for 'internal triggers' from the Y-channel. There should be no trace on the CRT.

b. DC triggering
By adjusting the Vertical Positioning control to pass through a point in its range corresponding to the Trigger Level setting and selected slope direction, a single trace should appear then disappear.

c. ACLF rejection trigger mode
With the input signal set as for the Trigger Bandwidth check, the ACLF Reject feature (if available) is activated and paragraph (b) is repeated. The single trace action should not occur.

External triggers—Single-sweep operation

a. Initial setup
(Applies only to those scopes with single sweep capability). With the Ext Trig input connected, the oscilloscope is set to 'Single Sweep', and trigger mode for 'Internal Triggers' from the Y-channel. There should be no trace on the CRT.

b. Single sweep triggering
Pressing the 'Reset' or 'Rearm' switch should produce a single trace. This action should not produce a trace when the Ext Trig input is disconnected.

Low frequency triggers

a. Initial setup
A 30 mV, 30 Hz sinewave signal is input simultaneously to Channel 1, Channel 2, Ext Trig Sweep A (main time base) and Ext Trig Sweep B (delayed time base). The oscilloscope is set for: trigger mode to 'Internal Triggers', Channels 1and 2 sensitivity to 10 mV/div, and sweep speed to 5 ms/div. Both main and delayed time bases should be displayed when selected, for both channels.

b. Channel 2 grounded
With Channel 2 input grounded, and Channel 1 set for 0.1V/div with the trigger selector set to Channel 1, stable displays should appear as expected.

c. Channel 1 grounded
With Channel 1 input grounded, and Channel 2 set for 0.1V/div with the trigger selector set to Channel 2, stable displays should appear as expected.

d. ACHF reject
With Channel 2 input grounded, and Channel 1 set for 50 mV/div with the trigger selector set to Channel 1, the ACHF Reject feature is activated for both Sweeps A and B. Adjusting the trigger level control should acquire a stable display.

e. Positive and negative slope operation
With Channel 2 input grounded, and Channel 1 set for 10 mV/div with the trigger selector set to Channel 1, adjusting the trigger level control should acquire a stable display for both + and -slope selections.

f. ACLF reject
With Channels 1 and 2 set for 10 mV/div with the trigger selector set to either channel, the ACLF Reject feature is activated for both Sweeps A and B. Adjusting the Trigger Level control should not be able to acquire a stable display for either + or – slope selection.

Z-axis

Z-axis input
If provided, the Z-axis input is usually positioned on the rear panel, but sometimes can be found near the CRT controls on the front panel. DSOs generally do not have a Z-input.

Z-axis bandwidth

a. Initial setup
A 3.5 Vp-p, 50 kHz sinewave is applied to both Channel 1 and Ext Trig inputs. The sweep speed, trigger slope and trigger level controls are set to provide a stable display of 1 cycle per division.

b. Signal transfer to Z input
The signal input to Channel 1 is disconnected and transferred to the Z-axis input. the trace should collapse to a series of bright and dim sections. Using the oscilloscope brightness control, the trace is dimmed so that the brightened portions just disappear.

c. Bandwidth check
The frequency of the input sinewave is increased to the exact specified Z-axis bandwidth point. The amplitude of the sinewave is increased to 5 Vp-p. Adjustment of the sweep speed and trigger level controls should acquire a dotted, or intermittently brightened trace.

X-Y Phasing

X input
Depending on the type of oscilloscope, the X input will be applied either via the External Trigger connector, or via Channel 1, with suitable switching. In either case, the same signal of 50 mV, 50 kHz will be applied to both X and Y inputs.

Phasing test

a. Initial setup
The oscilloscope controls are set as follows:

Vertical mode:	X-Y;
Sensitivity:	5 mV/div, both channels
Ch 1 or X:	AC coupled
Ch 2 or Y:	Grounded
Vertical mode:	X-Y
Vertical position:	Central
Horizontal position:	Central

N.B. During X-Y phasing tests on a DSO, maximum sampling rate would be used. Even so, the visible extent of any captured lissajou is limited to interrupted segments by the store length, until the test frequency is high enough for an entire cycle to be captured.

b. Trace acquisition
The display intensity is adjusted until a horizontal trace is just visible (should be 10 divisions long). After the X and Y position controls have been used to center the trace, the intensity and focus controls are adjusted for best display.

c. Phasing check
The common input signal is reduced until the trace is 8 divisions long. Channel 2 (or Y) input mode is switched to dc, and the X and Y position controls are used to center the (now sloping) trace. If the X and Y channels do not introduce any phase error, then the center of the trace will pass through the origin. Phase error between X and Y channels will cause the sloping trace to split into an ellipse, which for small phase errors will be apparent only close to the origin. The trace separation at the origin, along the center horizontal graticule line, should be not greater than 0.4 division for a commonly-specified phase-shift of 3 degrees.

Other useful reference material:

Fluke publications:

1612935 A ENG-N 02/2001 “Fully Automated True Bandwidth Testing of High Performance Oscilloscopes”

B0252EEN Rev B 02/97 “How many Calibrators do you need to meet ISO9000”

1282496 A-ENG-N 09/99 “In-House Calibration - Is it best for you”

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