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PROPOSED STANDARD ON

SPECIFICATION OF

GENERAL-PURPOSE LABORATORY CATHODE-RAY OSCILLOSCOPES

SUBCOMMITTEE ON OSCILLOSCOPES

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GENERAL-PURPOSE LABORATORY CATHODE-RAY OSCILLOSCOPES

by the

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

PURPOSE: The purposes of this standard are (1) to document the minimum information that users of general-purpose laboratory cathode-ray oscilloscopes typically need, (2) to provide potential purchasers and others with a common means for making comparisons between instruments, and (3) to provide uniformity of information from manufacturers.

SCOPE: This standard applies primarily to general-purpose laboratory cathode-ray oscilloscopes; it does not necessarily apply to specific kinds of oscilloscopes such as those employing sampling techniques, nor to storage oscilloscopes, spectrum analyzers, television monitors, or other instruments using cathode-ray tube displays. Information for cathode-ray oscilloscopes designed or modified for specific applications and (or) environments may require modification of certain listed information or the addition of more information.

SECTION I

INFORMATION TO BE PROVIDED IN A SPECIFICATION

1.1 IDENTIFICATION OF OSCILLOSCOPE

1.1.1 Name and (or) type, model number, and manufacturer, where applicable

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SECTION II

DEFINITIONS OF TERMS

accelerating voltage - The cathode-to-viewing-area voltage applied to a cathode-ray tube for the purpose of accelerating the electron beam.

alternate display - A means of displaying output signals of two or more channels by switching the channels in sequence.

amplifier, difference - See differential amplifier.

amplifier, differential - See differential amplifier.

amplifier, horizontal - See horizontal amplifier.

amplifier, intensity - See intensity amplifier.

amplifier, vertical - See vertical amplifier.

amplifier, X-axis - See horizontal amplifier.

amplifier, Y-axis - See vertical amplifier

amplifier, Z-axis - See Z-axis amplifier and intensity amplifier.

armed sweep - See single sweep mode

astigmatism - In the viewing plane of the cathode-ray tube, any deviation of the indicating spot from a circular shape. (See also IEEE 160.)

attenuator - A device for reducing the amplitude of a signal without deliberately introducing distortion. (See also IEEE 151 and 165.)

automatic triggering - A mode of triggering in which one or more of the triggering circuit controls are preset to conditions suitable for automatically displaying repetitive waveforms. The automatic mode may also provide a recurrent trigger or recurrent sweep in the absence of triggering signals.

axis, deflection - See deflection axis.

balanced circuit - A circuit in which two branches are electrically alike and symmetrical with respect to a common reference point, usually ground. For an applied signal difference at the input, the signal relative to the reference at equivalent points in the two branches must be opposite in polarity and equal in amplitude.

bandwidth -"1. The difference between the limiting frequencies of a continuous frequency band. 2. Of a device, the difference between the limiting frequencies within which performance with respect to some characteristic falls within specified limits." (IEEE 270) 3. Of an oscilloscope, the difference between the upper and lower frequency at which the voltage or current response is 0.707(-3dB) of the response at the reference frequency. Usually both upper and lower limit frequencies are specified rather than the difference between them. When only one number appears, it is taken as the upper limit.

Note 1: The reference frequency shall be 20 times the limit frequency for the lower bandwidth limit, and 1/20 the limit frequency for the upper bandwidth limit. The upper and lower reference frequencies are not required to be the same. In cases where exceptions must be made, they shall be noted.

Note 2: This definition assumes the amplitude response to be essentially free of departures from a smooth roll-off characteristic.

Note 3: If the lower bandwidth limit extends to DC, the response at DC shall be equal to the response at the reference frequency, not -3dB from it.
(See also IEEE 165, 188 and ANSI C42.65)

beam finder - A provision for locating the spot when it is not visible.

beam locator - See beam finder.

bezel - The flange or cover used for holding an external graticule or cathode-ray tube cover in front of the cathode-ray tube. May also be used for mounting a trace recording camera or other accessory item.

blanking - Extinguishing of the spot. Retrace blanking is the extinction of the spot during the retrace portion of the sweep waveform. The term does not necessarily imply blanking during the sweep holdoff interval or while waiting for a trigger in a triggered sweep system.

blanking, chopped - See chopping transient blanking.

blanking, transient - See chopping transient blanking.

brightness - "The attribute of visual preception in accordance with which an area appears to emit more or less light." (IEEE 201. For a more complete definition see ANSI Z7.1)

Note: See luminance.

calibrator - A signal generator whose output is used for purposes of calibration; normally either amplitude or time or both.

cathode-ray oscilloscope - An oscilloscope employing a cathode-ray tube.

cathode-ray tube display area - See graticule area.

channel - A single path for transmitting electric signals, usually in distinction from other parallel paths. (See also ANSI C42.65 and IEEE 162, 171, and 270)

chopped blanking - See chopping transient blanking.

chopped display - A time-sharing method of displaying output signals of two or more channels with a single cathode-ray tube gun, at a rate which is higher than, and not referenced to, the sweep time/division.

chopped frequency - See chopping rate.

chopping rate - The rate at which channel switching occurs in chopped display operation.

chopping transient blanking - The process of blanking the indicating spot during the switching periods in chopped display operation.

circuit, balanced - See balanced circuit.

circuit, push-pull - See balanced circuit.

common-mode rejection ratio (CMRR) - The ratio of the deflection factor for a common-mode signal to the deflection factor for a differential signal applied to a balanced circuit input.

common-mode signal - The instantaneous algebraic average of two signals applied to a balanced circuit, both signals referred to a common reference.

common-mode signal maximum - The largest common-mode signal at which the specified common-mode rejection ratio is valid.

compression - An increase in the deflection factor, usually as the limits of the quality area are exceeded. (See also IEEE 170.)

DC balance - An adjustment to avoid a change in DC level when changing gain.

DC drift - See stability.

DC offset - A DC level which may be added to the input signal, referred to the input terminals.

DC shift - A deviation of the displayed response to an input step, occurring over a period of several seconds after the input has reached its final value.

deflection axes (Vertical deflection axis, horizontal deflection axis) - The vertical trace obtained when there is a vertical deflection signal and no horizontal deflection signal, and the horizontal trace obtained when there is a horizontal deflection signal but no vertical deflection signal.

deflection blanking - Blanking by means of a deflection structure, in the cathode-ray tube electron gun which traps the electron beam inside the gun, to extinguish the spot, permitting blanking during retrace and between sweeps regardless of intensity setting.

deflection coefficient - See deflection factor.

deflection factor - The ratio of the input signal amplitude to the resultant displacement of the indicating spot (for example, volts/division). (See also IEEE 160.)

deflection polarity - The relation between the polarity of the applied signal and the direction of the resultant displacement of the indicating spot (conventionally a positive going voltage causes upward deflection or deflection from left to right).

deflection sensibility - The number of trace widths per volt of input signal that can be simultaneously resolved anywhere within the quality area.

deflection sensitivity - The reciprocal of the deflection factor (for example, divisions/volt). (See also IEEE 160 and IEC 50 (07))

delay line - A passive transmission system intended to introduce a time delay. (See also IEEE 162, 270 and IEC 50 (20))

delay pickoff - A means of providing an output signal when a ramp has reached an amplitude corresponding to a certain length of time (delay interval) since the start of the ramp. The output signal may be in the form of a pulse, a gate, or simply amplification of that part of the ramp following the pickoff time.

delay, signal - See signal delay.

delayed sweep - 1. A sweep which is started after a defined interval of delay following a triggering pulse
2. A mode of operation sweep, as defined above.

delaying sweep - A sweep used to delay another sweep. See delayed sweep.

difference amplifier - See differential amplifier.

differential amplifier - An amplifier whose output signal is proportional to the algebraic difference between two input signals. (See also ANSI C42.65)

difference signal - See differential signal.

differential signal - The instantaneous algebraic difference between two signals.

display - The visual presentation on the indicating device of an oscilloscope. (See also IEEE 172.)

drift - See stability.

dual-beam oscilloscope - An oscilloscope in which the cathode-ray tube produces two separate electron beams that may be individually or jointly controlled.
See multi-beam oscilloscope.

dual trace - A multi-trace operation in which a single beam in a cathode-ray tube is shared by two signal channels.
See alternate display, chopped display and multi-trace.

expanded sweep - See magnified sweep.

expansion - A decrease in the deflection factor, usually as the limits of the quality area are exceeded. (See also IEEE 170.)

external sweep - A sweep generated external to the instrument.

external trigger - A triggering signal introduced into the trigger circuit from an external source.

floating input - Circuits at the input of a differential deflection amplifier which provide rejection, with minimum distortion, of common-mode signals. Such signals must be defined for limits of amplitude, frequency content, and impedance balance to ground.

fluorescence - Emission of light from a substance (a phosphor) during excitation by radiant energy.

focus - Maximum convergence of the electron beam manifested by minimum spot size on the phosphor screen. (Note definition for astigmatism.)

free-running sweep - A sweep that recycles without being triggered and is not synchronized by any applied signal.

gated sweep - A sweep controlled by a gate waveform. Also, a sweep which will operate recurrently (free-running, synchronized, or triggered) during the application of a gating signal.

Gaussian response - A particular frequency response characteristic following the curve $y(f) = e^{-af^2}$ Typically, the frequency response approached by an amplifier having good transient response characteristics.

geometry - See pattern distortion.

graticule - A scale for measurement of quantities displayed on the cathode-ray tube of an oscilloscope.

graticule area - The area enclosed by the continuous outer graticule lines. Unless otherwise stated the graticule area shall be equal to or less than the viewing area. See also quality area and viewing area.

guarded input - A shielded input where the shield is driven by a signal in phase with and equal in amplitude to, the input signal.

holdoff - See sweep holdoff interval.

horizontal amplifier - An amplifier for signals intended to produce horizontal deflection.

incremental sweep - A sweep which is not a continuous function, but which represents the independent variable in discrete steps. (See also, stairstep sweep.)

information writing speed - The oscilloscope-recorder characteristic that is a measure of the maximum number of spots of information per second that can be recorded and identified on a single trace. Test conditions must be specified.

input leakage current - A direct current (of either polarity) that would flow in a short circuit connecting the input terminals of an amplifier.

input RC characteristics - The DC resistance and parallel capacitance to ground present at the input of an oscilloscope.

intensity - A term used to designate brightness or luminance of the spot. (For a more complete definition see ANSI Z7.1 - 1967)

intensity amplifier - An amplifier for signals controlling the intensity of the spot.

intensity modulation - The process and (or) effect of varying the electron beam current in a cathode-ray tube resulting in varying brightness or luminance of the trace. (See also IEEE 172.)

internal graticule - A graticule whose rulings are a permanent part of the inner surface of the cathode-ray tube faceplate.

internal triggering - The use of a portion of a deflection signal (usually the vertical deflection signal) as a triggering signal source.

inverted input - An input such that the applied polarity causes a deflection polarity opposite from conventional deflection polarity.

jitter - An aberration of a repetitive display indicating instability of the signal or of the oscilloscope. May be random or periodic, and is usually associated with the time axis. (See stability.) (See also IEEE 172, 204 and ANSI C42.65)

leakage current - See input leakage current.

line triggering - Triggering from the power-line frequency.

Lissajous figure - A special case of an X-Y plot in which the signals applied to both axes are sinusoidal functions. For a stable display the signals must be harmonics. Lissajous figures are useful for determining phase and harmonic relationships.

lockout - See sweep lockout.

luminance - "The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction." (IEEE 201. For a more complete definition see ANSI Z7.1 - 1967.)

Note: The term luminance is recommended for the photometric quantity which has been called brightness. Use of this term permits brightness to be used entirely with reference to sensory response. The photometric quantity has been confused often with the sensation merely because of the use of one name for two distinct ideas. Brightness will continue to be used properly in nonquantitative statements, especially with reference to sensations and perceptions of light.

magnified sweep - A sweep whose time per division has been decreased by amplification of the sweep waveform rather than by changing the time constants used to generate it.

marker signal - A signal introduced into the presentation for the purpose of identification, measurement, calibration, or comparison.

maximum common mode signal - See common mode signal maximum.

minus input - See inverted input.

mixed sweep - In a system having both a delaying sweep and a delayed sweep, a means of displaying the delaying sweep to the point of delay pickoff and displaying the delayed sweep beyond that point.

modulation, intensity - See intensity modulation.

multi-beam oscilloscope - An oscilloscope in which the cathode-ray tube produces two or more separate electron beams that may be individually, or jointly controlled. See dual-beam oscilloscope.

multi-trace - A mode of operation in which a single beam in a cathode-ray tube is shared by two or more signal channels. See dual trace, alternate display and chopped display.

noise - Any extraneous electrical disturbance tending to interfere with the normal display. (See also IEEE 168 and ANSI C42.65)

orthogonality - The deviation from 90° of the angle between the horizontal deflection axis and the vertical deflection axis.

oscillogram - A record of the display presented by an oscillograph (oscilloscope or mechanical recorder).

oscillograph - An instrument which graphically plots one or more quantities as a function of another quantity, usually time. (See also IEC 50 (20))

Note: Includes oscilloscopes and mechanical recorders.

oscillography - The art and practice of utilizing the oscillograph (oscilloscope or mechanical recorder).

oscilloscope - An oscillograph primarily intended for the immediate viewing of the graphic plot; most commonly used to denote a cathode-ray oscilloscope. (See also IEC 50 (20))

oscilloscope, cathode-ray - See cathode-ray oscilloscope.

overshoot - In the display of a step function (usually of time), that portion of the waveform which, immediately following the step, exceeds its nominal or final amplitude. (See also IEEE 204.)

pattern distortion -"Any deformation of the pattern from its intended form."(IEC 151-14). In an oscilloscope the intended form is rectilinear and rectangular. An oscilloscope control which affects pattern distortion may be labled "pattern" or "geometry".

persistence -"The decaying luminosity of the luminescent screen [phosphor screen] after the stimulus has been reduced or removed." (IEC 50 (07))

phase shift -"The absolute magnitude of the difference between two phase angles. Note 1: The phase shift between two planes of a 2-port network is the absolute magnitude of the difference between the phase angles at those planes. The total phase shift (or absolute phase shift) is expressed as the total number of cycles, including any fractional number, between the two planes where one complete cycle is 2π radians (or 360 degrees). The unit of phase shift is, therefore, the radian or the electrical degree. (The term "2-port network" is used in its most general sense to include structures of passive or active elements. This includes the case of a given length of waveguide but may also refer to any two ports of a multi-port device, where it is understood that a signal is incident only at one port.) Note 2: A phase shift can be either a phase lead (advance) or a phase lag (delay)." (IEEE 285)

phosphor screen - All the visible area of the phosphor on the cathode-ray tube faceplate. (See also "screen" in IEEE 160 and IEC 50 (07))

phosphorescence - Emission of light from a substance after excitation has been removed. (See also IEC 50 (07))

plus input - An input such that the applied polarity causes a deflection polarity in agreement with conventional deflection polarity.

preshoot - In the display of a step function (usually of time), that portion of the waveform which immediately precedes the step. Polarity of the excursion is usually but not necessarily opposite to that of the step which follows.

push-pull circuit - See balanced circuit.

quality area - The area of the cathode-ray-tube phosphor screen that is limited by the cathode-ray tube and instrument specifications. (See graticule area and viewing area.)

Note: If the quality area and the graticule area are not equal, this must be specified.

ramp - A voltage or current that varies at a constant rate; for example, that portion of the output waveform of a time-linear sweep generator used as a time base for an oscilloscope display.

raster - A predetermined pattern of scanning lines which provides substantially uniform coverage of an area (IEEE 160 and 204 and IEC 151-14)

recurrent sweep - A sweep which repeats or recurs regularly; it may be free running or synchronized.

reference frequency, upper and lower - See bandwidth.

resolution - A measure of the total number of trace lines discernible along the coordinate axes, bounded by the extremities of the graticule or other specific limits. (See also IEEE 160.)

response, Gaussian - See Gaussian response.

response, transient - See transient response.

retrace - Return of the spot on the cathode-ray tube to its starting point after a sweep; also that portion of the sweep waveform which returns the spot to its starting point.

retrace blanking - See blanking.

return trace - The path of the scanning spot during the retrace.

ringing - A damped oscillatory transient occurring in the output of the system as a result of a sudden change in input. (IEEE 168 and 188.)

risetime - In the display of a step function, the interval between the time at which the amplitude first reaches specified lower and upper limits. These limits shall be 10% and 90% of the nominal or final amplitude of the step, unless otherwise stated.

roll-off - "A gradually increasing loss or attenuation with increase or decrease of frequency beyond the substantially flat portion of the amplitude-frequency response characteristic of a system or transducer." (IEEE 151.)

rounding - In the display of a step function, the decrease in sharpness of the corner following the step.

sawtooth - See sawtooth waveform.

sawtooth sweep - A sweep generated by the ramp portion of a sawtooth waveform.

sawtooth waveform - A waveform containing a ramp and a return to initial value, the two portions usually of unequal duration.

scan - The process of deflecting the electron beam. (See graticule area, uniform luminance area, and phosphor screen.)

screen, viewing - See viewing area.

signal delay - In an oscilloscope, the time required for a signal to be transmitted through a channel or portion of a channel. The time is always finite, may be undesired, or may be purposely introduced as in a delay line. (See channel.)

sine-wave sweep - A sweep generated by a sinusoidal function.

single-sweep mode - Operating mode for a triggered-sweep oscilloscope in which the sweep must be reset for each operation, thus preventing unwanted multiple displays. This mode is useful for trace photography. In the interval after the sweep is reset and before it is triggered, it is said to be an armed sweep.

slave-sweep switching - A combination of sweep switching and multiple trace operation in which a specific channel is displayed with a specific sweep.

spot - The illuminated area that appears where the primary electron beam strikes the phosphor screen of a cathode-ray tube. (See also IEC 50 (07))

spot size - See trace width.

stability - Property of retaining defined electrical characteristics for a prescribed time and environment. Deviations from a stable state may be called drift if it is slow, or jitter or noise if it is fast. In triggered sweep systems, triggering stability may refer to the ability of the trigger and sweep systems to maintain jitter-free displays of high-frequency waveforms for long (seconds to hours) periods of time. Also, the name of the control used on some oscilloscopes to adjust the sweep for triggered, free-running, or synchronized operation. (See sweep mode.)

stairstep sweep - An incremental sweep in which each step is equal. The electrical deflection waveform producing a stairstep sweep is usually called a staircase or stairstep waveform. (See incremental sweep.)

step response - The characteristic reaction to a step input. The display of this reaction.

sweep - An independent variable of a display; unless otherwise specified, it is time linear, but may also vary in some other controlled and definable manner. (See also ANSI C42.65)

sweep accuracy - Accuracy of the horizontal (vertical) displacement of the trace compared with the reference independent variable, usually expressed in terms of average rate error as a percent of full scale. (See sweep linearity.)

sweep-delay accuracy - Accuracy of indicated sweep delay, usually specified in error terms.

sweep, delayed - See delayed sweep.

sweep duration - In a sawtooth sweep, the time required for the sweep ramp.

sweep duty factor - For repetitive sweeps, the ratio of the sweep duration to the interval between the start of one sweep and the start of the next.

sweep, expanded - See magnified sweep.

sweep, external - See external sweep.

sweep, free-running - See free-running sweep.

sweep frequency - The sweep repetition rate.

sweep gate - A rectangular waveform used to control the duration of the sweep; usually also used to unblank the cathode-ray tube for the duration of the sweep.

sweep, gated - See gated sweep.

sweep generator - A circuit that generates a signal used as an independent variable; the signal is usually a ramp, changing value at a constant rate.

sweep holdoff interval - The interval between sweeps during which the sweep and (or) trigger circuits are inhibited.

sweep, incremental - See incremental sweep.

sweep linearity - Maximum displacement error of the independent variable between specified points on the display area.

sweep lockout - Means for preventing multiple sweeps when operating in a single-sweep mode.

sweep magnifier - Circuit or control for expanding part of the sweep display. Sometimes known as sweep expander.

sweep mode control - The control used on some oscilloscopes to set the sweep for triggered, free-running, or synchronized operation.

sweep range - The set of sweep time/division positions provided.

sweep rate - See sweep time/division.

sweep recovery time - The minimum possible time between the completion of one sweep and the initiation of the next, usually the sweep holdoff interval.

sweep, recurrent - See recurrent sweep.

sweep reset - In oscilloscopes with single-sweep operation, the arming of the sweep generator to allow it to cycle once.

sweep switching (automatic) - Alternate display of two or more time bases or other sweeps using a single-beam cathode-ray tube; comparable to dual- or multiple-trace operation of the deflection amplifier.

sweep time - See sweep time/division.

sweep time/division - The nominal time required for the spot in the reference coordinate to move from one graticule division to the next. Also the name of the control used to select this time.

synchronized sweep - A sweep that free runs in the absence of an applied trigger signal but is synchronized by the signal when it is present.

synchronizing signal - A signal used to synchronize repetitive functions. (See also IEEE 168.)

time base - The sweep generator in an oscilloscope.

trace - The cathode-ray tube display produced by a moving spot. See spot. (See also IEC 50 (07) and 151-14)

trace finder - See beam finder.

trace width - The distance between two points on opposite sides of a trace (perpendicular to the direction of motion of the spot) at which luminance is 50% of maximum. If vertically and horizontally going trace widths differ (beam controls constant), worst case is stated.

transient blanking - See chopping transient blanking.

transient response - Time-domain reactions to abruptly varying inputs.

trigger - A pulse used to initiate some function (for example, a triggered sweep or delay ramp). Trigger may loosely refer to a waveform of any shape used as a signal from which a trigger pulse is derived as in "trigger source", "trigger input", etc. See triggering signal.

trigger countdown - A process that reduces the repetition rate of a triggering signal.

trigger lockout - See sweep lockout.

trigger pickoff - A process or a circuit for extracting a triggering signal.

triggered sweep - A sweep that can be initiated only by a trigger (not free-running).

triggering level - The instantaneous level of a triggering signal at which a trigger is to be generated. Also, the name of the control which selects the level.

triggering signal - The signal from which a trigger is derived.

triggering slope - The positive going (+ slope) or negative going (- slope) portion of a triggering signal from which a trigger is to be derived. Also, the control that selects the slope to be employed.

Note: + slope and - slope apply to the slope of the waveform only, and not to the absolute polarity.

unblanking - Turning on of the cathode-ray-tube beam.

undershoot - In the display of a step function (usually of time), that portion of the waveform which, following any overshoot or rounding that may be present, falls below its nominal or final value.

uniform luminance area - The area in which a display on a cathode-ray tube retains 70% or more of its luminance at the center of the viewing area.

vertical amplifier - An amplifier for signals intended to produce vertical deflection.

vertical linearity - The change in deflection factor of an oscilloscope as the display is positioned vertically within the graticule area. (See compression and expansion.)

viewing area - The area on the phosphor screen of a cathode-ray tube which can be excited by the electron beam to emit light.

viewing screen - See viewing area.

waveform distortion - A displayed deviation from the correct representation of the input reference signal.

writing rate - See writing time/division.

writing speed - See information writing speed

writing time - See writing time/division.

writing time/division - The minimum time per unit distance required to record a trace. The method of recording must be specified.

X-axis amplifier - See horizontal amplifier.

X-Y display - A rectilinear coordinate plot of two variables.

Y-amplifier - See vertical amplifier.

Y-axis amplifier. See vertical amplifier.

Y-T display - An oscilloscope display in which a time dependent variable is displayed against time.

Z-axis amplifier - An amplifier for signals controlling a display perpendicular to the X-Y plane (commonly intensity of the spot). (See intensity amplifier.)

SECTION III

TEST METHODS FOR GENERAL-PURPOSE LABORATORY CATHODE-RAY OSCILLOSCOPES

3.1 Bandwidth

Purpose: To measure the upper and lower limits of the band of frequencies an oscilloscope will display with its amplitude response within specified limits. Bandwidth is measured with a sinusoidal waveform to the first -3dB point from the amplitude of a reference frequency, unless otherwise stated. (In practice the 70% amplitude point rather than the -3dB point is used, because 70% can be more accurately and repeatably read on a conventional graticule.)

Accuracy of Measurement Method: Within ±5%

3.1.1 Upper Bandwidth Limit

Equipment: Sine-wave generator with peak-to-peak amplitude constant (within 3%) and a frequency range of 1/20 of the frequency specified or less to higher than the frequency specified. Harmonic distortion, less than 2% throughout the frequency range. Output impedance as specified. If a constant amplitude sine-wave generator is not available, the output of the generator used can be monitored,(at the generator) by a device with a bandwidth flat to greater than that in question,and kept constant manually.

Method: Apply a sine-wave at the upper reference frequency (1/20 the upper bandwidth limit or less). Adjust controls for the specified amplitude of display, or if unspecified, for a convenient amplitude at least 80% of the graticule height. Increase the frequency of the generator until the displayed amplitude is 70% of its original value. This frequency is the upper bandwidth limit. (The source impedance at the oscilloscope input must be specified for the test, since any terminations or attenuators can affect the source impedance.)

3.1.2 Lower Bandwidth Limit

When the lower bandwidth limit is DC, the gain at DC should be equal to the gain at the reference frequency; not -3dB from it.

Equipment: Constant peak-to-peak amplitude sine-wave generator with a frequency range of 20 times the frequency specified or more to lower than the frequency specified; harmonic distortion less than 2% and output impedance as specified.

Method: Apply a sine-wave at the lower reference frequency (20 times the frequency specified or more) to the oscilloscope to be tested. Adjust controls for a specified amplitude of display, or if unspecified, to a convenient amplitude at least 80% of the graticule height. Decrease frequency of the constant amplitude sine-wave generator until the displayed amplitued is 70% of its original value. This frequency is the lower frequency limit. The source impedance at the oscilloscope input must be as specified for the test.

3.2 Calibrator

3.2.1 Amplitude Accuracy

Purpose: To measure the voltage amplitude accuracy of an amplitude calibrator. A 100 volt calibrator having an output of 98 volts can be described as: (a) being within 2% of the stated value, or (b) having a 2% inaccuracy.

Accuracy of Measurement Method: Within ±1/2% for test #1 and #2, within ±1% for test #3.

3.2.1.1 Test Method #1

(To use this method, it must be possible to disable the calibrator waveform producing circuit without affecting the peak output voltage.)

Equipment: A DC differential voltmeter with an inaccuracy, at most, ¼ of the inaccuracy requirement for the calibrator under test; or a standard voltage source with an inaccuracy, at most, ¼ of the inaccuracy requirement for the calibrator under test, a means of switching between the standard voltage and the calibrator (chopper), and an AC coupled oscilloscope to read out the difference voltage.

Method: Disable the circuit producing the calibrator waveform so the calibrator output is a DC level. Attach a resistor which loads the calibrator output as recommended by its manufacturer. Measure the calibrator output voltage with the differential voltmeter or compare it to the standard voltage and measure the difference voltage (error) with a chopper and an AC-coupled oscilloscope. In like manner, measure each calibrator output voltage.

3.2.1.2 Test Method #2

(To be used if it is not possible to disable the calibrator waveform producing circuitry to obtain a DC output.)

Equipment: An oscilloscope with a slide-back voltmeter preamplifier. The inaccuracy of the comparison voltage in the preamplifier should be, at most, ¼ of the inaccuracy requirement for the calibrator to be tested.

Method: Load the output of the calibrator as recommended by its manufacturer and measure its output with the slide-back voltmeter oscilloscope. Measure each calibrator voltage output.

3.2.1.3 Test Method #3

The accuracy of this test is somewhat less than that of Methods #1 and #2 (within 1%) but it is more convenient.

Equipment: 1. A source of voltage with an amplitude equal to the nominal amplitude of the calibrator to be tested. This voltage source shall be no more inaccurate than ¼ the percentage inaccuracy specified for the calibrator being measured. 2. An oscilloscope.

Method: Calibrate the vertical-amplifier deflection factor with the known voltage source. Use the calibrated vertical amplifier to measure the calibrator voltage.

3.2.2 Time Accuracy (when applicable)

Purpose: To measure the accuracy of a signal provided for time calibration.

Test Equipment: A counter capable of making measurements to the specified accuracy.

Method: Measure the repetition rate or frequency of the calibrator output signal.

3.3 Common-Mode Rejection Ratio (CMRR)

Purpose: To measure a differential amplifier's ability to reject identical signals applied in phase to each input from equal source impedances. Unless otherwise stated, CMRR will always be assumed to be as good as that stated for the upper bandwidth limit at frequencies between the upper bandwidth limit and the upper reference frequency. For a DC-coupled circuit, CMRR will always be as good as that specified for the upper reference frequency at the upper reference frequency and below it. If signal amplitude is not specified, the maximum common-mode signal should be used.

Test Equipment: Source of signal at the amplitude and highest frequency specified for common-mode-rejection ratio test (if not specified, the test should be made at the upper reference frequency used to measure bandwidth and at the upper bandwidth frequency limit).

Method: Apply the specified signal to both inputs of the differential amplifier to be tested. Insure that signal connection method does not cause an unequal phase shift in the two signal paths. Determine the amplitude of deflection observed on the cathode-ray tube. CMRR is calculated by multiplying the amplitude of deflection by the deflection factor of the amplifier and dividing the input signal voltage by this voltage to determine a ratio.

This test does not indicate any differences in CMRR caused by unequal source impedances at the inputs.

3.4 Channel Isolation (crosstalk)

Purpose: To measure unwanted signals appearing on channels of a multi-channel device, other than the channel to which signal is applied. If channel isolation is to be specified at one frequency only, it should be at the upper bandwidth limit and should be checked to see that it is not greater anywhere within the bandwidth limits. This measurement can also be specified using pulses of given amplitude, duration, and risetime applied to the inputs of the amplifiers.

Test Equipment: A source of signals at the frequency and amplitude specified for the measurement.

Method: Apply a signal of the specified frequency and amplitude to one channel of a multichannel device, and shield the open-circuit inputs of the other channels. Unless specified otherwise, all channels should be set for minimum attenuation or maximum gain. Measure the amount of signal appearing on the other channels, displayed one at a time. Express crosstalk as a ratio by comparing the amplitude of the input signal to that measured on the other channels.

3.5 DC Shift

Purpose: To measure deviations in displayed step response which occur over several seconds after the input step has reached its final value.

Test Equipment: A DC voltage source.

Method: Apply a DC voltage to the DC-coupled oscilloscope. The amplitude of this voltage should be sufficient to cause the specified amount of deflection on the cathode-ray tube, (usually 80% to 100% of graticule height). Observe amount of any movement of trace for a one minute duration after initial deflection. DC shift is expressed in terms of graticule units of this trace movement. This test is valid only if there would have been no trace movement during this minute under no-signal conditions.

3.6 Deflection-Factor

Purpose: To measure the ratio of the input signal amplitude to the resultant displacement of the indicating spot. Deflection sensitivity is the reciprocal of deflection factor (deflection factor = volts/division, sensitivity = divisions/volt). Deflection factor is frequency dependent and should be measured at or between the reference frequencies described under bandwidth.

Accuracy: Measurements are typically within ±1% added to the test signal inaccuracy.

Test Equipment: Signal generator producing signals of known amplitude accuracy and at levels corresponding to the deflection factors to be measured.

Method: Set oscilloscope controls to specified settings and apply a signal of known amplitude not to exceed 80% of full scale as indicated by the graticule area. Measure divisions of deflection on the cathode-ray tube. Divide the amplitude of the signal by the divisions of deflection on the cathode-ray tube. Divide the amplitude of the signal by the divisions of deflection to obtain deflection factor or divide the number of divisions by the amplitude to find sensitivity.

Note: In some oscilloscopes a control labeled "sensitivity" may actually be calibrated in deflection factors.

3.7 Drift

Purpose: To measure an unwanted, usually slow, deflection of the trace (in any of the 3 axes) on a cathode-ray tube. This occurs as a function of a change in the oscilloscope's power-supply input, as a function of a change in operating characteristics of internal circuitry, and (or) as a function of a change in environment. It is sometimes classified as long-term drift or short-term drift.

Test Equipment: Means of varying the power input to the oscilloscope or of varying any other factor that is expected to cause drift. A recorder to measure variations in trace position over a period of time.

Method: Set up the oscilloscope so that the drift-causing factor can be varied. Keep all other factors constant. Record position of the display, vary the drift-causing factor, again record the position of the display. Express drift either in terms of graticule units per unit of time or in terms of a specified environmental change.

e.g.: A. Measurement of drift with line-voltage change
- (1) ground input
- (2) position trace to a reference line
- (3) vary line voltage within specified limits
- (4) measure peak-to-peak trace drift from original position

B. Measurement of drift with time
- (1) ground input
- (2) supply power to instrument from a constant source
- (3) record trace position
- (4) record peak-to-peak trace excursion during the specified period of time.

3.8 Pattern Distortion

Purpose: To measure the degree to which a cathode-ray tube display reproduces a rectangular pattern.

Test Equipment: Sine-wave generator

Method: 1. Vertical distortion - Apply a signal which will cause the cathode-ray tube to display a single vertical trace. Position the trace horizontally over the graticule area at several locations. Measure any bending or tilt of the lines. Deviations from straight vertical lines are expressed in degrees or as "no more than Xmm deviation in Ycm of deflection."

2. Horizontal distortion - Apply a signal which will cause the cathode-ray tube to display a single horizontal trace. Position the trace vertically over the graticule area at several locations. Measure any bending or slope of the lines. Deviation from straight horizontal lines are expressed in degrees or as "no more than Xmm deviation in Ycm of deflection."

3.8 Pattern Distortion (cont)

3. Orthogonality: Apply a signal which will cause the cathode-ray tube to display a single horizontal trace. Position the trace to the center horizontal graticule line and align the trace with the center line. Remove signal and apply a signal which will cause the cathode-ray tube to display a single vertical trace. Center this vertical trace and measure any deviation of the trace from a 90-degree angle with the horizontal graticule line.

3.9 Input Characteristics

3.9.1 Input leakage current

Purpose: To measure current which may be available at the input terminals of an oscilloscope or the effect of this current through the input resistance of a DC-coupled oscilloscope amplifier.

Test Equipment: A means of shorting and opening the input terminals of the amplifier being tested.

Accuracy: The accuracy of this measurement depends on the deflection-factor accuracy and the accuracy with which the input resistance can be measured.

Method: Set the amplifier to the specified deflection factor (usually minimum). Short circuit the input externally and position the trace to the graticule center. Remove the short from the input and measure distance from graticule center to new trace location. The effect of input current can be expressed as the measured number of graticule units or the input current itself can be expressed by converting the measured deflection to volts (using the deflection factor) and calculating the current producing this voltage across the resistance from input to ground.

3.9.2 Input RC Characteristics (Oscilloscopes with DC coupled input circuits)

Related parameters are: input capacity, input resistance, input time constant (RC products), and input admittance.

Purpose: To determine the DC resistance and RC product present to ground at the input of an oscilloscope.

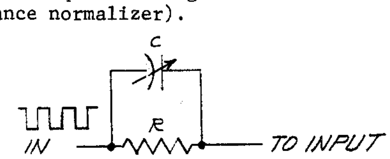
3.9.2.1 Test #1, Input Resistance

Equipment: A resistance bridge with accuracy at least 4 times greater than the accuracy specified.

Method: Using the bridge, measure the input resistance at each attenuator setting with the oscilloscope turned off.

3.9.2.2 Test #2a, RC Product

Equipment: Square-wave generator and time-constant normalizer (also called capacitance normalizer).



TIME-CONSTANT NORMALIZER

R = resistance approximately equal to that measured in 3.9.2.1

C = A capacitance adjusted so that RC is equal to the input time constant of the oscilloscope.

Method: Apply a square-wave with the specified characteristics through a time-constant normalizer to the oscilloscope's input. Check cathode-ray tube display for specified square-wave response. This procedure should be repeated at each attenuator setting.

3.9.2.3 Test #2b, (Alternate to #2a)

Equipment: Capacitance meter or bridge with an accuracy at least 4 times greater than accuracy specified for the capacitance to be measured. This instrument must be capable of measuring capacitance which is shunted by the resistance measured in 3.9.2.1.

Method: With the oscilloscope operating, measure the capacitance at the input of the oscilloscope. This value may be multiplied by the resistance determined in Test #1 to find the RC Product.

3.10 Jitter, Delay Time

Purpose: To measure jitter of non-triggered, delayed sweep, in an oscilloscope with two sweeps, one of which can be used to delay the other.

Accuracy: The accuracy of this measurement is affected by any jitter in the time mark generator.

Test Equipment: Time mark generator with known jitter characteristics.

Method: Using the delaying sweep, obtain a stable display of time marks, one per division. Use the two sweeps to obtain a display with an intensified time mark on the portion of the trace to be investigated. Change oscilloscope controls to display over the full graticule the portion that was intensified. Measure the horizontal jitter of the displayed time mark.

This jitter can be expressed as a portion of the delaying sweep time/division by the following expression:

$$\frac{\text{Delaying time/division}}{\text{Delayed time/division}} \times \frac{1}{\text{Divisions of measured jitter}}$$

Example:
Delaying sweep time per division: 1 ms
Delayed sweep time per division: 1 μs
Jitter measured: 0.5 division.

$$\frac{10^{-3}\text{ seconds/div}}{10^{-6}\text{ seconds/div}} \times \frac{1}{0.5\text{ divisions}} = 2{,}000$$

Therefore, jitter is one part in 2,000 of the delaying sweep time/division setting.

3.11 Jitter, Trigger

Purpose: To measure horizontal display stability of a triggered sweep oscilloscope using a specified triggering signal (usually minimum amplitude triggering requirements at several frequencies and using specified triggering modes).

Test Equipment: A sine-wave generator capable of supplying specified frequency(ies) and amplitude(s).

Method: Apply the specified triggering signal and adjust triggering controls for the most stable display. Adjust focusing controls for a sharply defined trace. Set sweep time control as specified and measure horizontal trace width on the portion of steepest ascent on the sine wave, near the sweep start, before the first peak. This measurement should be made at several specified frequencies and in all triggering modes.

Jitter is expressed in terms of time by multiplying sweep rate and jitter width.

Any FM or jitter in the generator signal must be taken into account.

3.12 Linearity, Vertical (compression and (or) expansion)

Purpose: To measure the change in deflection factor of an oscilloscope as the display is positioned vertically within the graticule area.

3.12.1 Low Frequency

Equipment: A variable amplitude square-wave or sine-wave source at the frequency used as the upper bandwidth reference frequency (see bandwidth).

Method: Obtain a two graticule-division display of the specified amplitude accurately centered on the graticule. Position the display upward one graticule division at a time until the top of the display is at the top of the graticule. Measure any changes in display amplitude.

Position the display downward one graticule division at a time until the bottom of the display is the bottom of the graticule. Measure any changes in the display amplitude from the centered value.

Less amplitude at a noncentered position than at the center indicates compression; more indicates expansion. The linearity can be expressed in terms of graticule divisions of compression and(or) expansion or as a percentage change of the centered amplitude.

3.12.2 High Frequency

Repeat 3.12.1 using a sine-wave at the upper bandwidth limit frequency.

3.13 Displayed Noise

Purpose: To measure unwanted trace deflection electrically or mechanically induced from inside the instrument.

Test Equipment: Square-wave generator with continuously variable amplitude and an accurate 100:1 attenuator.

Method: Apply a continuously variable square-wave, through the 100:1 attenuator, to the input of the oscilloscope being tested. Free run the sweep, set volts per division to minimum or as specified, adjust focus and astigmatism for a well defined trace. Adjust intensity as specified or for a normally bright level. Adjust the square-wave amplitude so the display is of two bands across the cathode-ray tube face. Reduce the output of the square-wave generator till the two bands just merge. Remove the 100:1 attenuator and increase the deflection factor by a factor of 10. Measure the square-wave amplitude. 1/10 of the square-wave amplitude is the displayed noise. This can be expressed as divisions of deflection or as a voltage referred to the the input by multiplying the divisions by the deflection factor.

Note #1: If trace width represents a major portion of the measured deflection it should be subtracted from the measured amount.

Note #2: This is a quasi peak-to-peak noise measurement, and assumes random noise. If the noise is random, the RMS noise value is smaller by a figure of approximately 3. If the noise is non-random (e.g., power line-related) the nature of the noise must be more fully described.

3.14 Phase Difference

Purpose: To measure the phase relationship between the horizontal and vertical display systems of an oscilloscope.

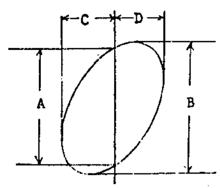
Test Equipment: Sine-wave generator capable of specified frequency(ies) and amplitude(s). A standard graticule or special phase measuring graticule.

Method: Apply identical sine-waves (of the amplitude and frequency specified) to the horizontal and vertical inputs. Measure phase difference (Θ) from the Lissajous pattern displayed.

$C = D$

$\sin \Theta = \frac{A}{B}$

Θ = Phase difference



Express phase difference in degrees. If a special phase measurement graticule is used, follow the manufacturer's instructions for determining Θ from the graticule.

Phase difference should be recorded over the instrument's frequency and deflection factor range and if only one case is quoted, it should be the worst.

3.15 Resolution

Purpose: To confirm that a given number of lines can be resolved in the graticule area or a specified portion of it.

3.15.1 Test: Horizontal Resolution

Equipment: Sine-wave generator.

Method: Apply the output from the sine-wave generator to the vertical input. Display several cycles of sine-wave of amplitude to fill the graticule height. Adjust focus and astigmatism controls for optimum trace definition. Set trace intensity to minimum usable level or as specified. Set the sweep time-sine-wave frequency relationship so that the specified number of lines appear across the graticule. Check through the center of the sine-wave to see that the lines appear as separated. Position the center of the sine-wave to the top and bottom graticule lines and check that the lines appear as separated.

3.15.2 Test: Vertical Resolution

Method: Repeat the method for horizontal resolution but apply the sine-wave to the horizontal input and the sweep to the vertical input.

Note: If it is desired to determine the maximum number of lines that can be discerned, vary the frequency of the sine-wave until the lines just appear to merge. Resolution can now be calculated from the following:

2 X frequency (Hz) X Sweeptime (s/division) = resolution (lines/division)

3.16 Sweep Time/Division Accuracy

Purpose: To Measure the accuracy of the sweep time/division.

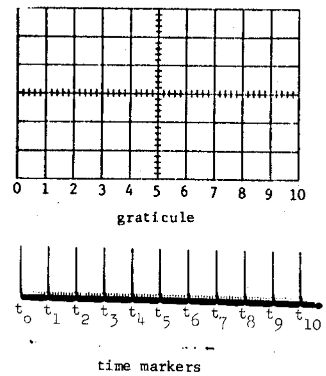
Accuracy: Within ±½% plus the error of the time mark generator.

Test Equipment: Time mark generator of known accuracy.

Method: Apply time marks corresponding to the sweep rate to be measured. Position the marks to their respective graticule lines in the area of the graticule over which timing is to be measured. Determine the amount of error between graticule lines and the time marks.

Sweep time/division is usually expressed as accurate within a percentage (i.e., ±1%) of the interval which is being measured.

Example:



If the timing is to be measured over 10 divisions of the graticule align t_0 with graticule line 0 and note the position of t_{10} in relation to graticule line 10. If t_{10} is on line 10 the timing has no error; if it misses by 0.1 division, the timing is in error by $\frac{0.1}{10}$ = 0.01 or 1%.

If the timing is to be measured over 8 divisions of the graticule, aligh t_1 with graticule line 1 and note the position of t_9 in relation to line 9. If t_9 is on line 9, there is no error; if it misses by 0.1 division, the timing is in error by $\frac{0.1}{8}$ = 0.0125 or 1.25%.

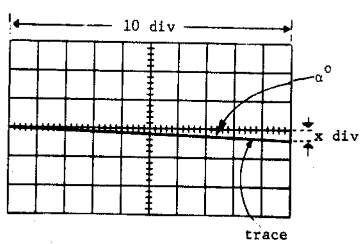
3.17 Trace Alignment

Purpose: To measure the alignment of the trace in relation to a horizontal graticule line.

Test Equipment: None

Method: Free run the sweep. Position the left end of the trace to the intersection of the left vertical graticule line and a horizontal graticule line (reference). Determine the distance along the right graticule line from the trace to the reference horizontal graticule line. The trace mis-alignment is expressed in degrees using trigonometry.

Example:



$\tan \alpha = \frac{X}{10} = Y$

$\arctan Y = \alpha$

Therefore, trace is not aligned by α degrees.

In multi-gun cathode ray tubes, the alignment of traces in relation to each other should be measured as well as alignment with respect to the graticule.

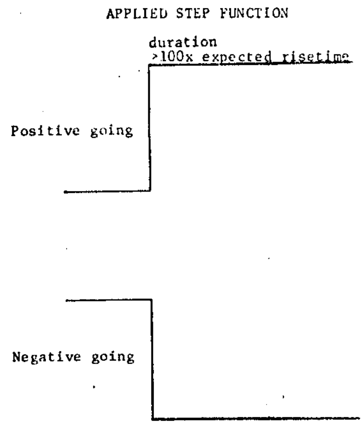
3.18 Step Response

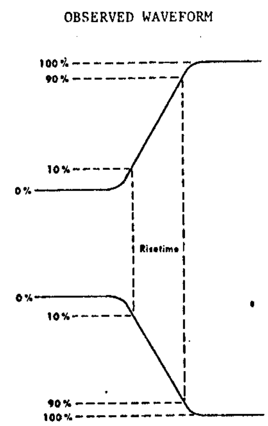
Purpose: To measure the ability of an oscilloscope to accurately display a step function waveform. Step response includes risetime, overshoot, rounding, preshoot, and ringing.

Test Equipment: A generator of step functions with known characteristics.

METHODS:

3.18.1 Risetime (t_r). A measurement of the interval between the instants at which the instantaneous amplitude first reaches specified lower and upper limits. These limits are 10% and 90% of the step reference amplitude unless otherwise stated.



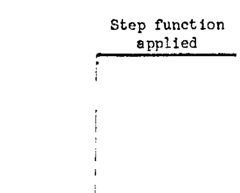


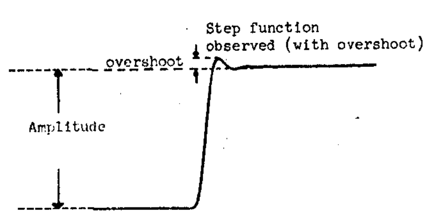
Obtain a display of the step and measure the time required for the leading edge to go from 10% to 90% of its amplitude (or other limits if specificed). The risetime of the applied step should be four times or more faster than the risetime to be measured. In "state of the art" measurements, where the risetime of the applied step may approach the risetime of the system under test, risetime may be determined more accurately by the following root-mean-square correction:

$$t_r \text{ measured} = \sqrt{(t_r \text{ step})^2 + (t_r \text{ system})^2}$$

Sweep-rate accuracies, resolution and geometry must be taken into consideration in risetime measurements. It is presumed a general-purpose laboratory oscilloscope and the step generator have a response near gaussian; if not, the root-mean-square correction shown above will not apply.

3.18.2 Overshoot: A measurement of a step response which immediately follows the display of the step rise and exceeds its nominal or final amplitude.

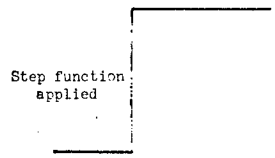


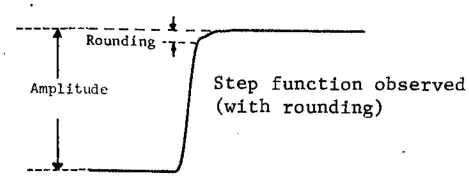


3.18.2 Overshoot (cont)

Apply a step function of known characteristics, and of the specified amplitude, to the oscilloscope vertical input. Obtain a stable display. Measure the amount of peak overshoot and determine this as a percentage of the amplitude applied. Any overshoot or rounding of the applied step function and their time constant must be taken into account (since this is difficult, a step function with good transient response should be used).

3.18.3 Rounding: A measurement of the loss of a sharp corner of a step function.

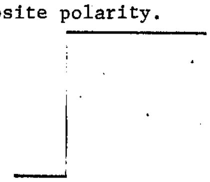




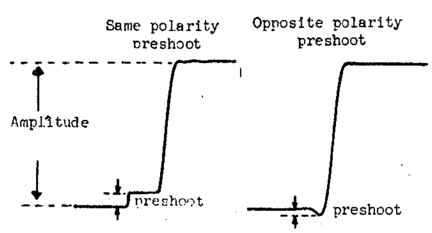
Apply a step function of known characteristics, and of the specified amplitude, to the oscilloscope vertical input. Obtain a stable display. Measure the amount of rounding and determine this as a percentage of the amplitude applied. Any overshoot or rounding of the applied step function and their time constants must be taken into account (since this is difficult, a step function with good transient response should be used).

3.18.4 Preshoot: A measurement of a step response which precedes the step display and may be of same, or opposite polarity.

Step function applied:

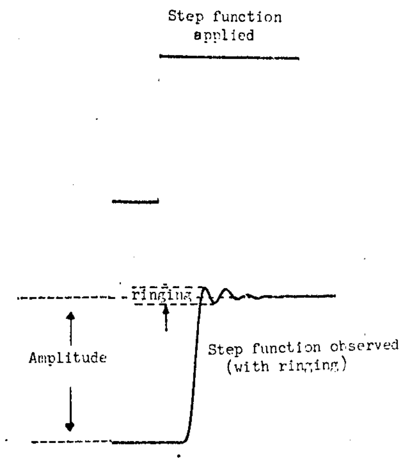


Step function observed:



Apply a step function of known characteristics, and of the specified amplitude, to the oscilloscope vertical input. Obtain a stable display. Measure the amount of peak preshoot and determine this as a percentage of the amplitude applied. Any preshoot on the applied step function and its time constant must be taken into account (since this is difficult, a step function free from preshoot should be used).

3.18.5 Ringing: A measurement of an oscillatory transient, damped in time, occurring on the display of a step function.



Apply a step function of known characteristics, and of the specified amplitude and risetime, to the oscilloscope vertical input. Obtain a stable display. Measure the amount of peak to peak ringing and express this as a percentage of the applied amplitude. Since it is difficult to take into account the effect ringing on the step function has on the observed ringing, a relatively ring-free source should be used.

3.19 Writing Speed - Photographic

Purpose: To measure the maximum spot speed which produces a trace that can be photographed using a specified system and without using film "fogging" techniques.

Repeatability: Within ±50%.

Test Equipment:

1. Oscilloscope camera without beam splitting mirror.*
2. Film in five camera backs.*
3. Pulser and ring boxes capable of producing single shot and repetitive damped sine-waves of known frequency.
4. Watch or clock with second hand.
5. Light source for back-lighting prints.
6. Measuring scale (see method).

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* While this measurement method will produce valid results for any system (lens, camera, and film) the results will not be directly comparable between different systems. Two systems seem to represent current practice:

Common System

1. Camera with 1:0.85 or 1:0.9 object-to-image ratio f/1.9 lens.
2. Polaroid ® Type 47 (ASA equivalent 3000) film.

High Writing Speed System

1. Camera with 1:0.5 object-to-image ratio f/1.2 lens
2. Polaroid ® Type 410 (ASA equivalent 10,000) film.

Data taken with any other system should specify: the lens, the object-to-image ratio, the film, and the ASA film speed. The JEDEC phosphor type should also be specified.

METHOD: Set the oscilloscope under test for a single sweep, or set triggering controls so there is no sweep. Slowly increase intensity control setting until the spot is just visible. Decrease intensity setting so spot is no longer visible. (If the oscilloscope has deflection blanking, no spot will be visible by adjusting intensity control. In this case increase intensity setting until some light (background) is seen on the phosphor screen and decrease intensity until this light disappears.)

If the oscilloscope was set for a single sweep, return it to normal operation (take care to not burn phosphor or mesh when doing this). Apply a damped sine-wave of convenient amplitude to the vertical input; adjust triggering and sweep time controls for a stable display of about two or three damped sine-wave cycles per major graticule division. Adjust focus and astigmatism for maximum waveform definition. Attach camera to oscilloscope and set lens opening; focus camera on the waveform. Close camera shutter. Turn graticule illumination off.

Reset oscilloscope controls for a single sweep, remove signal, and arm the sweep. Wait 5 minutes for phosphor to decay to a low level. Open the camera shutter, operate the pulser for a single display, wait 5 seconds and close the shutter. Develop the film for the standard time (10 seconds). Make an exposure on each of five different rolls of film.

Make a measuring scale by taking a photograph of the graticule with the same camera set-up and cut the photograph in half. Mask out the sine-wave peaks on the photographs leaving the central third visible. Back-light and view the photographs. Determine the first central segment that is just visible on each photograph. Calculate writing speed in divisions per microsecond (WS) from the formula $WS = \pi a f$ where a is the peak to peak vertical amplitude of the segment as measured with the scale previously prepared, and f is the frequency in megahertz. Average the results from the five photographs.