January 30, 1968

ENGINEERING INSTRUMENT SPECIFICATION GUIDELINE

PART 1

CONVENTIONAL OSCILLOSCOPES

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CONTENTS

Abbreviations and symbols appearing in this guideline conform to Tektronix Standard No. A-100, Recommended Short Forms. Technical terms conform to Tektronix Standard No. A-101, Glossary of Technical Terms - Electronic.

INTRODUCTION

PURPOSE

The purpose of this document is to guide the Engineer and Writer in the preparation of the Engineering Instrument Specification (EIS). The Engineering Instrument Specification is the reference document for all company activity concerning the electrical, environmental and physical characteristics of Tektronix products.

DEFINITION OF TERMS

Characteristics are defined as attributes or capabilities of a product described in terms of acceptable qualitative or quantitative limits. They are categorized as Electrical, Environmental and Physical.
The tables in Section 1 of the EIS provide pertinent electrical, environmental and physical characteristics in appropriately identified columns:

1. ITEM

Titles of specific attributes or capabilities of a product.

2. QUOTABLE

Characteristics describing the measurement capabilities or limitations and physical attributes of a product. These characteristics are considered necessary to qualify a product for a particular application. These characteristics are a commitment between Tektronix, Inc. and the customer.

3. MAINTENANCE AND OPERATION

Characteristics that, when met, will insure optimum instrument operation. These characteristics may be given to a customer as maintenance or operational aids, but are not a commitment between Tektronix, Inc. and the customer.

4. TEST RATE

Engineering's recommendations (not binding on Manufacturing) regarding the minimum percentage of instruments e.g. 100%, 10%, 1% or 0.1%, which are tested for specific characteristics. These recommendations are based upon confidence level, and the importance of the characteristic.

5. VAL STEP

The step number in Section 2 or 3 where the validation procedure for the characteristic can be found.

6. ENGINEERING NOTES

Reserved for Engineering information. This information is not to be printed in any publication normally available to the customer and may not be given to a customer except under special circumstances. This information is not intended to be a commitment between the customer and Tektronix, Inc.

GENERAL CONSIDERATIONS

When describing characteristics not specifically outlined in this guideline, use the following criteria:

1. Describe each characteristic fully, including worst case within the range stated, e.g. worst case bandwidth VOLTS/DIV setting.

2. Characteristics stated as QUOTABLE should be verifiable by direct measurement within state-of-the-art limitations. If a characteristic cannot be verified by direct measurement it must be verified by calculation or indirect measurement and calculation. (See Appendix A1.)

3. When discrete points within a wide area of performance are described in a QUOTABLE column, include also—in MAINTENANCE AND OPERATION—a graphical illustration describing overall performance (see Fig. 1-1, Overall Frequency Response). This does not preclude the use of graphical illustrations as QUOTABLE information.

4. When a graphical illustration with discrete verification points is used to describe a QUOTABLE characteristic, only the information at the verification points is intended to be QUOTABLE.

5. Characteristics which require removal of instrument covers for performance validation should not be listed as QUOTABLE.

6. When a reference signal is used to verify a characteristic, pertinent parameters of the reference signal (risetime, frequency, amplitude, etc.) or appropriate test equipment shall be stated as conditions of the specified quantitative or qualitative limits. In the case of frequency response characteristics, the reference frequency shall be at least 20 times greater for the lower bandwidth limit and at least 20 times less for the upper bandwidth limit than the limit frequency. The upper and lower reference frequencies are not required to be the same.

7. When selecting limits for a characteristic, the general intent will be to provide broad enough limits so that performance will stay within those limits for about 1000 operating hours after calibration. Adjustment of externally accessible controls is permissible.

8. If a standard accessory probe has been designated, state the applicable characteristics both without and with the probe. It may be desirable to include the best of the available probes.

9. Laboratory instruments should meet their electrical characteristics when operated from 0° C to +50° C ambient. However, if tighter limits are preferred, do not specify a range less than +15°C to +35°C.

10. Environmental instruments should meet their electrical characteristics when operated from —10° C to +55° C ambient. However, if tighter limits are perferred, do not specify a range less than 0° C to +40° C.

11. Any mention of graticule divisions is understood to be major divisions. Minor divisions are stated as decimal fractions of a major division.

12. If it is desired that certain useful information not be given to the customer except under special circumstances, use the ENGINEERING NOTES column.

13. Any exceptions to the conditions expressly stated in this guideline should be noted.

SECTION 1
ELECTRICAL CHARACTERISTICS

NOTE

The electrical characteristics in this section are applicable for an instrument calibrated with line voltage between _____ and _____ VAC, ambient temperature between +20°C and +30°C, and after a _____ minute warm-up. Unless otherwise stated, electrical characteristics apply over an operating temperature range from _____ °C to _____ °C and to an altitude of _____ feet.

VERTICAL

A. Deflection Factor

The ratio of the input signal amplitude to the resultant displacement of the indicating spot when measured with a sinusoidal signal of at least 20 times the lower bandwidth limit and 1/20th or less of the upper bandwidth limit.

1. Calibrated Range

   QUOTABLE: State the total deflection factor range between the calibrated end settings of the deflection factor switch(es) without and with the standard accessory probe(s). Also, include switching sequence.

2. Accuracy

   QUOTABLE: State percent deviation between displayed deflection factor and each deflection factor setting throughout calibrated range, without and with the standard accessory probe(s) in all applicable operating modes.

3. Uncalibrated (Variable) Range

   QUOTABLE: State the effect of the Variable control both on deflection factor between calibrater settings and total range.
   MAINTENANCE AND OPERATION: State the ratio by which the display is changed when the Variable control is at the extreme end of its uncalibrated range. See example (1). If the deflection factor is variable in both directions from the calibrated setting, state the ratio from fully ccw to calibrated position and the total ratio. See example (2).

4. Low-Frequency Linearity

   QUOTABLE: State maximum compression or expansion of a 2 division centered display in graticule divisions when the top of the display is positioned to the top of the graticule and the bottom to the bottom of the graticule. Additional statements applying to restricted portions of the graticule area, e.g. center 8 div, may also be included.

5. Gain Range

   MAINTENANCE AND OPERATION: State the percent of variation in display amplitude from the calibrated setting if: (1) the Gain control is internal, and (2) the Gain control is external and driving a variable sensitivity amplifier. If the Gain control is external but not in a plug-in unit, state: (1) the percent of variation in display amplitude from calibrated setting and (2) the voltage variation measured differentially at the vertical deflection plates.

B. Frequency Response

A statement of response characteristics over a specific frequency spectrum.

1. Bandwidth

   A statement of the frequencies defining the upper and lower limits of a frequency spectrum where the amplitude response of an amplifier to a sinusoidal waveform becomes —3 dB (.707) of the amplitude of a reference frequency. When only one number appears, it is taken as the upper bandwidth frequency.

   (a) DC (Direct) Coupled (_____ Div Reference)
   QUOTABLE: State the upper bandwidth frequency for each deflection factor setting or range of deflection factors at a reference amplitude greater than 60% of graticule height. Also

NOTE

The electrical characteristics in this section are applicable for an instrument calibrated with line voltage between ___ and ___ VAC, ambient temperature between +20°C and +30°C, and after a ___ minute warm-up. Unless otherwise stated, electrical characteristics apply over an operating temperature range from __°C to __°C and to an altitude of ___ feet.

1.1 ELECTRICAL

1.1.1 VERTICAL CHANNEL

ITEM	QUOTABLE		MAINTENANCE AND OPERATION	TEST RATE	VAL. STEP	ENGINEERING NOTES
Deflection Factor	Without Probe	With P____		100%		
Calibrated Range	__ mV/div to __ V/div in 1,2,5 sequence	__ mV/div to __ V/div in 1,2,5 sequence				
Accuracy	Within __% throughout calibrated range	Within __% throughout calibrated range				
Added Mode	Within __% throughout calibrated range	Within __% throughout calibrated range				
Uncalibrated (Variable) Range						
(1) *Deflection factor variable in one direction*	Continuously variable between calibrated deflection factor settings. Extends the deflection factor range to at least __ V/div		At least __:1			
(2) *Deflection factor variable in both directions*	Continuously variable between calibrated deflection factor settings. Decreases deflection factor when turned cw from calibrated position, and extends deflection factor range to __ V/div or less at fully cw position. Extends deflection factor range to at least __ V/div at fully ccw position		Calibrated position __:1 to __:1 from fully ccw position, at least __:1 total range			
Low-Frequency Linearity						
(1) *Full graticule*	__ div or less compression or expansion of __ div signal positioned over __ div					
(2) *Partial graticule*	__ div or less compression or expansion of __ div signal positioned over __ div					
Gain Range				100%		
GAIN (front panel)			+__% to -__% from calibrated setting			
R__ (internal)						
Fully Cw			At least __ V P-P at CRT vertical deflection plates at __ mV/div with __ V input			
Fully Ccw			__ V or less P-P at CRT vertical deflection plates at __ mV/div with __ V input			
Frequency Response				100%		
Bandwidth (Variable VOLTS/DIV at CAL)						
DC (Direct) Coupled (__ Div Reference)	Without Probe	With P____				
__ mV/Div to __ V/Div	At least __ MHz	At least __ MHz				

include upper bandwidth frequency with full graticule reference amplitude without and with standard accessory probe(s). Additional statements applying to operation in specialized modes or with other selected probes may also be included.

(b) Overall Frequency Response, DC (Direct) Coupled

MAINTENANCE AND OPERATION: Graphically illustrate the following frequency response information for each deflection factor setting or range of deflection factors without and with the standard accessory probe(s) (see Fig. 1-1):
(1) Frequency spectrum over which response is essentially flat, e.g. within 5% at 30 MHz or less.
(2) Frequency at which the response rolloff does not exceed —1 dB.
(3) —3 dB point
(4) —6 dB point
(5) —12 dB point
(6) Reference amplitude
Use minimum performance values, not typical values.

(c) AC (Capacitive) Coupled Lower Bandwidth Frequency (_____ Div Reference)

QUOTABLE: State the lower bandwidth frequency for each deflection factor setting or range of deflection factors with a full graticule reference without and with the standard accessory probe(s).

C. Step Response (See Appendix A4)

The response of a system to a step input. Elements of a step response most commonly specified are: risetime, falltime and aberrations (e.g. overshoot, undershoot, preshoot, ringing and DC shift).

1. Risetime, t_r

QUOTABLE: State the maximum time required for the displayed waveform to go from 10% to 90% of the reference amplitude (A_o) as illustrated in Fig. 1-2. A qualification should be stated if risetime depends on an operating condition such as polarity of the input step or the direction of the transition in the display.

2. Aberrations

QUOTABLE: State the maximum plus or minus percent (see Appendix A3) of deviation from the reference amplitude (A_o) within two or more specified aberration intervals as described below and illustrated in Fig.1-2.

(a) First Aberration Interval

The First Aberration Interval begins 1 t_r after t_o. The duration of the First Aberration Interval is specified and should be sufficient to include the worst short-term effects (e.g. overshoot and ringing).

(b) Second Aberration Interval

The Second Aberration Interval begins at the end of the First Aberration Interval and extends for a specified interval thereafter. The duration of the Second Aberration Interval should be sufficient to include long-term effects (e.g. tilt or droop).

(c) Other Aberration Intervals

When desired, other aberration intervals may be established to include isolated predictable effects or those not included within the First and Second Aberration Intervals (e.g. preshoot or DC shift).

3. Position Effect on Aberrations

QUOTABLE: State the maximum change in the displayed plus and minus percent deviations within the First Aberration Interval as Interval 4 is positioned vertically according to the graticule height indicated in the following table:

Graticule Height (Div)	Positioning Range About Graticule Centerline (Div)	Displayed Waveform Amplitude (Div)
4	+1½ to —1½	3
6	+2 to —2	4
8	+3 to —3	6
10	+4 to —4	8

4. Probe Effect on Aberrations

QUOTABLE: State the maximum change in the displayed plus and minus percent deviations within the First Aberration Interval when the standard accessory probe is connected to the input.

5. Overdrive Recovery

QUOTABLE: State the maximum time required for the trace to stabilize to within 0.2 division of reference after a plus and then a minus deflection of a specified number of graticule-heights (e.g. 10X) has been applied for a specified time (e.g. 10 seconds).

D. Common-Mode Rejection Ratio

The ratio of the deflection factor for a common-mode sinewave to the deflection factor for a differential sinewave.

1. DC (Direct) Coupled

QUOTABLE: State and graphically illustrate the minimum acceptable common-mode rejection ratio for each deflection factor setting or range of deflection factors. Include the ranges of frequency and DC + peak AC voltage of common-mode sinewave over which the ratios apply (see Fig. 1-3).

2. AC (Capacitive) Coupled

QUOTABLE: State and graphically illustrate the minimum acceptable ratio at the minimum deflection factor. Include frequency and DC + peak AC voltage over which the ratios apply (see Fig. 1-3). Include other deflection factors, if pertinent.

1.1 ELECTRICAL

1.1.1 VERTICAL CHANNEL (cont'd)

ITEM	QUOTABLE		MAINTENANCE AND OPERATION	TEST RATE	VAL. STEP	ENGINEERING NOTES
DC (Direct) Coupled (Full Graticule Reference)	Without Probe	With P___		100%		
__ mV/Div to __ V/Div	At least __ MHz	At least __ MHz				
Added or A-B Modes (__ Div Reference)	At least __ MHz	At least __ MHz				
Overall Frequency Response DC (Direct) Coupled			See Fig. 1-1			
__ mV/Div to __ V/Div						
AC (Capacitive) Coupled Lower Bandwidth Frequency (__ Div Reference)	Without Probe	With P___		100%		
__ mV/Div to __ V/Div	__ Hz or less	__ Hz or less				
Step Response				100%		
Risetime	__ ns or less with a plus step input					
Aberrations	(1) +__% -__% or less, total of __% or less P-P within __ ns from t_o with __ Ω source impedance (*First Aberration Interval*), +__% -__% or less, total of __% or less P-P within __ ns after first __ ns with __ Ω source impedance (*Second Aberration Interval*)					
	(2) +__% -__% or less within __ ns after t_o with __ Ω source impedance (*First Aberration Interval*), +__% -__% or less within __ ns after first __ ns with __ Ω source impedance (*Second Aberration Interval*)					
Position Effect on Aberrations	__% or less change within __ ns from t_o (*First Aberration Interval*)					
Probe Effect on Aberrations	__% or less change within __ ns from t_o (*First Aberration Interval*)					
Overdrive Recovery	__ μs or less after a +__ div and -__ div deflection for __ s					
Common-Mode Rejection Ratio				100%		
DC (Direct) Coupled						
__ μV/Div to __ mV/Div	At least __:1 from DC to __ MHz with a __ V P-P sinewave. See Fig. 1-3					
__ mV/Div to __ V/Div	At least __:1 from DC to __ MHz with a __ V P-P sinewave. See Fig. 1-3					
AC (Capacitive) Coupled						
__ μV/Div to __ mV/Div	At least __:1 at __ MHz with a __ V P-P sinewave. See Fig. 1-3					
__ mV/Div to __ V/Div	At least __:1 at __ MHz with a __ V P-P sinewave. See Fig. 1-3					

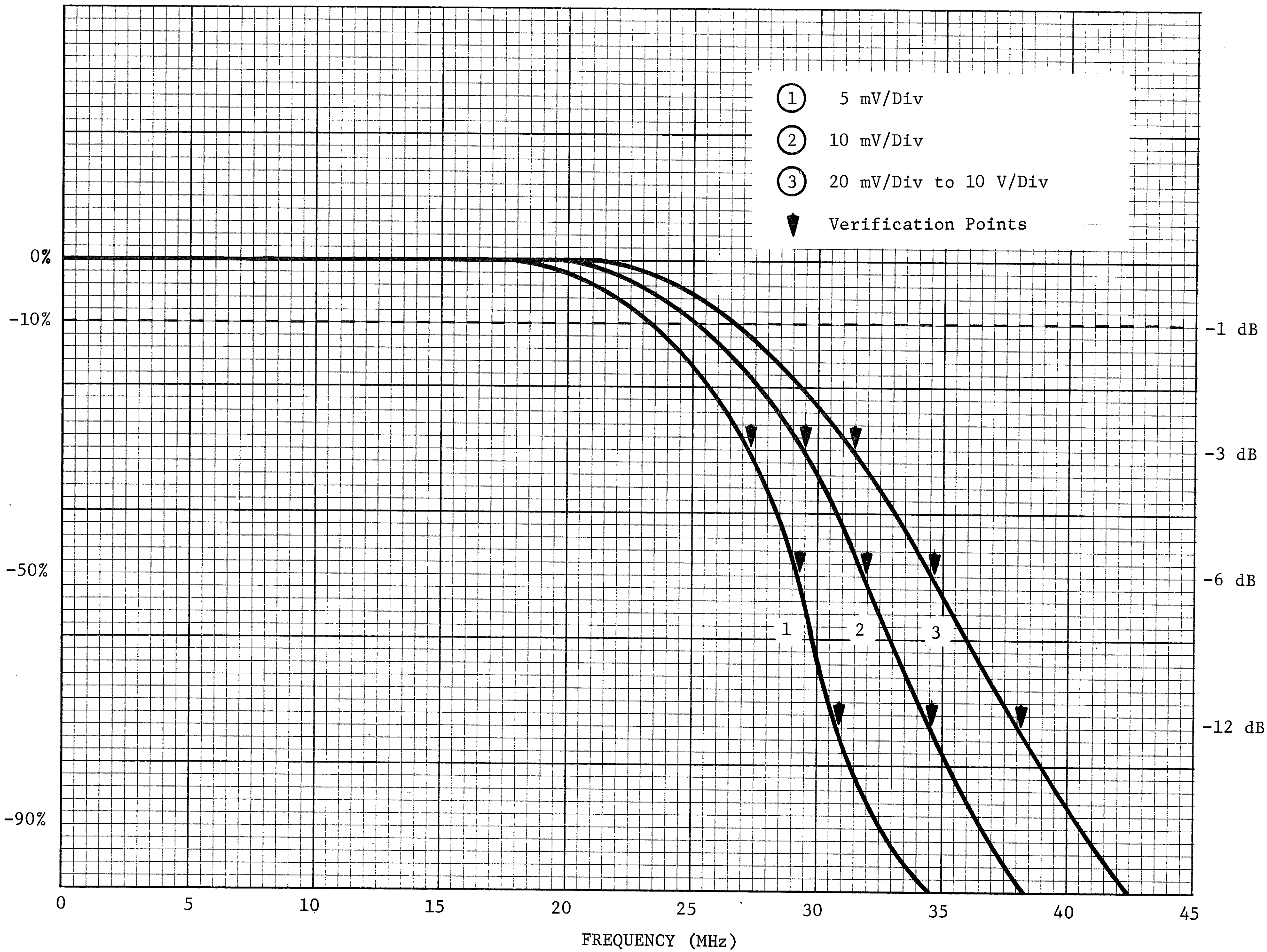
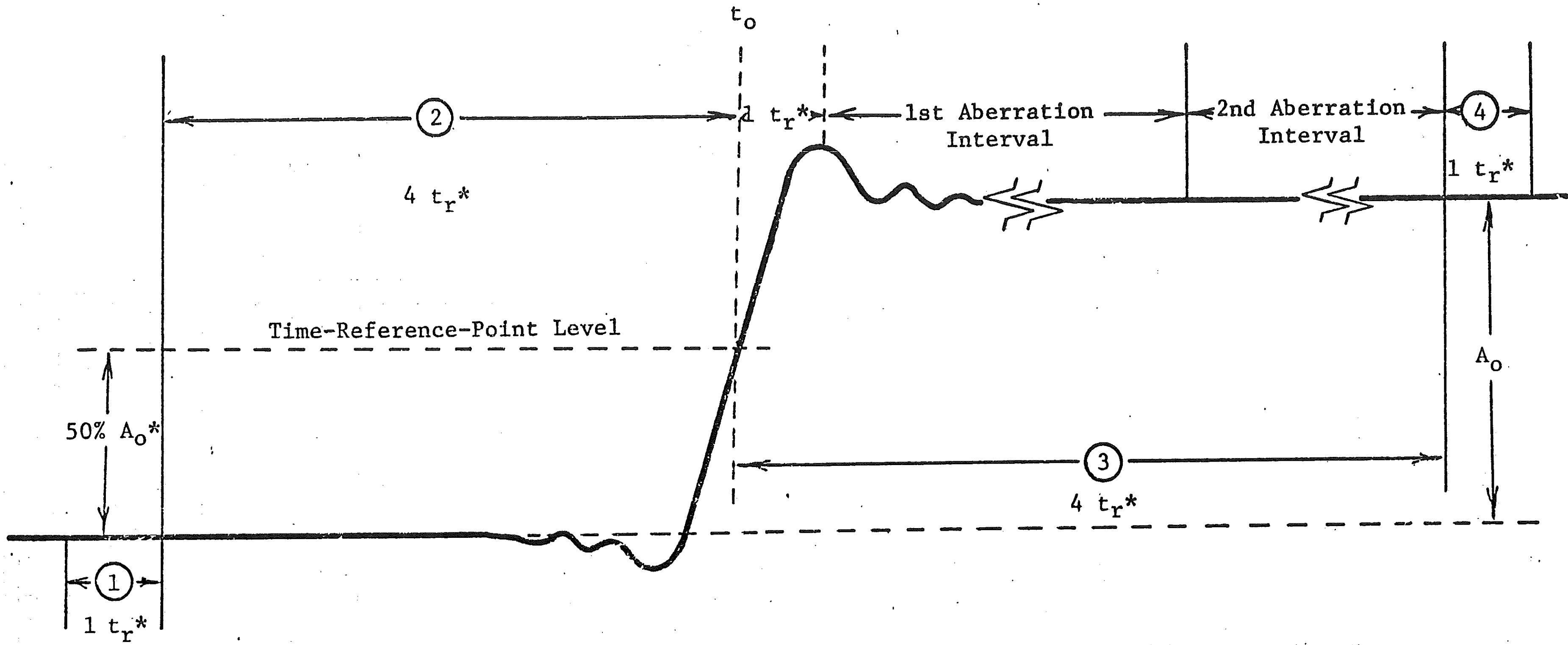


Fig. 1-1 Overall Frequency Response With P____



t_r = Specified risetime

t_o = Time reference. Computed as the point where the rising portion of the input step intersects the Time-Reference-Point Level (50% A_o).

A_o = Reference amplitude as measured between reference levels and computed as the average of the minimum and maximum excursions within Interval 1 and Interval 4.

Interval 1 and **4** = 1 t_r. Where possible, Interval 1 shall be the time corresponding to one division of the specified calibrated horizontal sweep rate. Normally this sweep rate will be the one which most nearly causes the quoted risetime (t_r) to occupy one horizontal division in the display.

Interval 2 = 4 x (Interval 1)

Interval 3 = Interval 2

*Unless otherwise specified.

Fig. 1-2 Determining Time and Amplitude References for Step Response

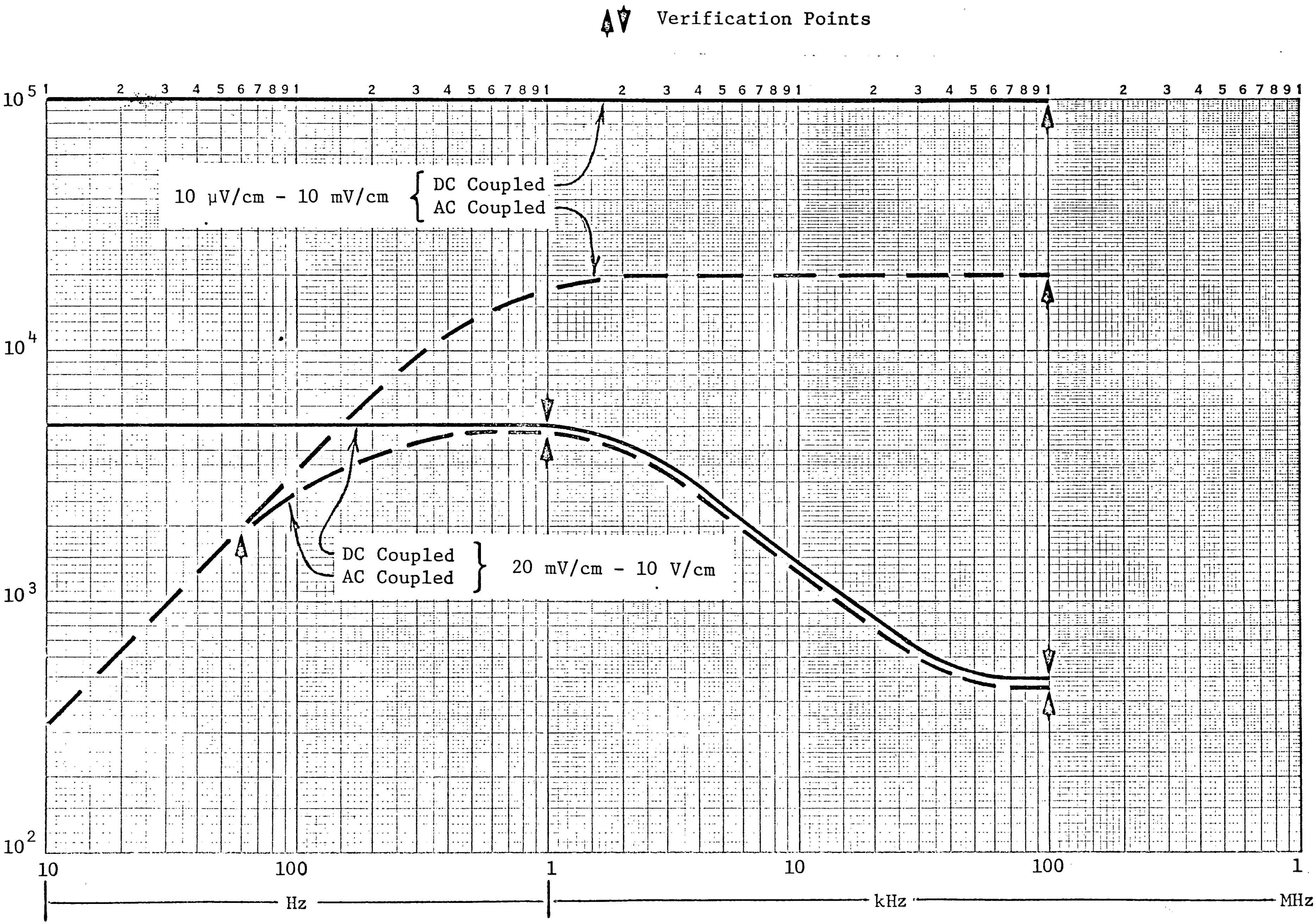


Fig. 1-3 CMRR vs Frequency

NOTES

E. Maximum Input Voltage

The total voltage, either polarity, which the input circuitry will withstand without permanent damage or change in value of any component beyond its rated tolerance and after which the instrument will still meet its performance characteristics.

1. DC (Direct) Coupled DC + Peak AC

   QUOTABLE: State the maximum plus or minus DC + peak AC and maximum peak-to-peak AC for each deflection factor setting or range of deflection factors without and with the standard accessory probe(s). Provide a derating graph that indicates the maximum amplitude of the AC component at various frequencies (see Fig. 1-4).

2. AC (Capacitive) Coupled DC Voltage

   QUOTABLE: State the maximum DC voltage.

3. AC (Capacitive) Coupled DC Rejection

   ENGINEERING NOTES or MAINTENANCE AND OPERATION: State a ratio of maximum input DC voltage to that value of voltage indicated by the trace movement after a specified time, e.g. with 200 VDC applied the trace moves a maximum amount equivalent to a 10 mV DC signal (a leakage current of 100 mA with a 1 MΩ input resistance). DC rejection, then, is 200 V divided by 10 mV and would be stated as at least 20,000:1.

F. Input R and C

The DC resistance and capacitance to ground present at input terminals.

1. Resistance

   QUOTABLE: State the input resistance value for each deflection factor or range of deflection factors and a percent tolerance without and with the standard accessory probe(s).

2. Capacitance

   QUOTABLE: State the input capacitance value for each deflection factor or range of deflection factors and a tolerance expressed in capacitance value or percent without and with the standard accessory probe(s).

3. Time Constant

   QUOTABLE: State the time constant and percent tolerance for each deflection factor and, if applicable, the tolerance between channels.

G. Input Gate (Grid) Current

A DC current, either polarity, that might be present at the input terminals of an amplifier when the input terminals are short-circuited.

1. Maximum Current

   QUOTABLE (in high-gain instruments) or MAINTENANCE AND OPERATION: State the maximum DC current at the input terminal(s) when the input is grounded or, in the case of a differential amplifier, both when the ungrounded terminals are connected together and when each input is grounded. Also, include corresponding display change at minimum deflection factor.

   MAINTENANCE AND OPERATION: Graphically illustrate the maximum DC current over the operating temperature range (see Fig. 1-5).

H. Variable Balance

A statement of trace movement in graticule divisions when changing gain with the Variable Deflection Factor control.

1. Front Panel

   MAINTENANCE AND OPERATION: State the maximum trace movement in graticule divisions when the Variable Deflection Factor control is turned from the fully cw to the fully ccw position after the Variable DC Balance (if applicable) has been adjusted for minimum trace movement.

2. Range

   MAINTENANCE AND OPERATION: State the minimum trace movement in graticule divisions when the Variable DC Balance control is turned from the fully cw to the fully ccw position.

I. Step Attenuator Balance

A statement of trace movement when changing the deflection factor.

QUOTABLE: State the maximum trace movement in graticule divisions when the deflection factor is switched throughout its range.

MAINTENANCE AND OPERATION: State the minimum trace movement in graticule divisions as the Step Attenuator DC Balance control is turned from the fully cw to the fully ccw position. If there is more than one control, state the minimum range for each.

J. Invert Shift

Trace movement from a reference level when display is inverted by the Invert switch.

MAINTENANCE AND OPERATION: State the maximum trace movement in graticule divisions from a reference level when the display is inverted by the Invert switch.

K. Position Range

The range over which the trace can be positioned by turning the Position control.

MAINTENANCE AND OPERATION: State a minimum position range in graticule divisions above and below graticule center.

1.1 ELECTRICAL

1.1.1 VERTICAL CHANNEL (cont'd)

ITEM	QUOTABLE		MAINTENANCE AND OPERATION	TEST RATE	VAL. STEP	ENGINEERING NOTES
Maximum Input Voltage	Without Probe	With P____		0.1%		
DC (Direct) Coupled, DC + Peak AC	__ VDC + peak AC to __ MHz	__ V, P-P to __ MHz				
Derating With Frequency	See Fig. 1-4					
AC (Capacitive) Coupled, DC Voltage	__ V					
AC (Capacitive) Coupled, DC Rejection			At least __:1 after __ s			
Input R and C	Without Probe	With P____		100%		
Resistance	__ MΩ within __%	__ MΩ within __%				
Capacitance	__ pF within __ pF	__ pF within __ pF				
Time Constant	Normalized for __ μs within __% between channels					
Input (Gate) Grid Current				100%		
Maximum Current	__ nA (__ div at __ mV/div)		See Fig. 1-5			
Variable Balance				100%		
Front Panel			__ div or less trace movement when VARIABLE VOLTS/DIV is turned from fully cw to fully ccw			
Range			At least __ div trace movement when Variable DC Balance is turned from fully cw to fully ccw			
Step Attenuator Balance	__ div or less trace movement between calibrated VOLTS/DIV settings		At least __ div trace movement as step attenuator DC balance is turned from fully cw to fully ccw	100%		
Invert Shift			Within __ div from graticule center	100%		
Position Range			At least +__ div to -__ div from graticule center	100%		

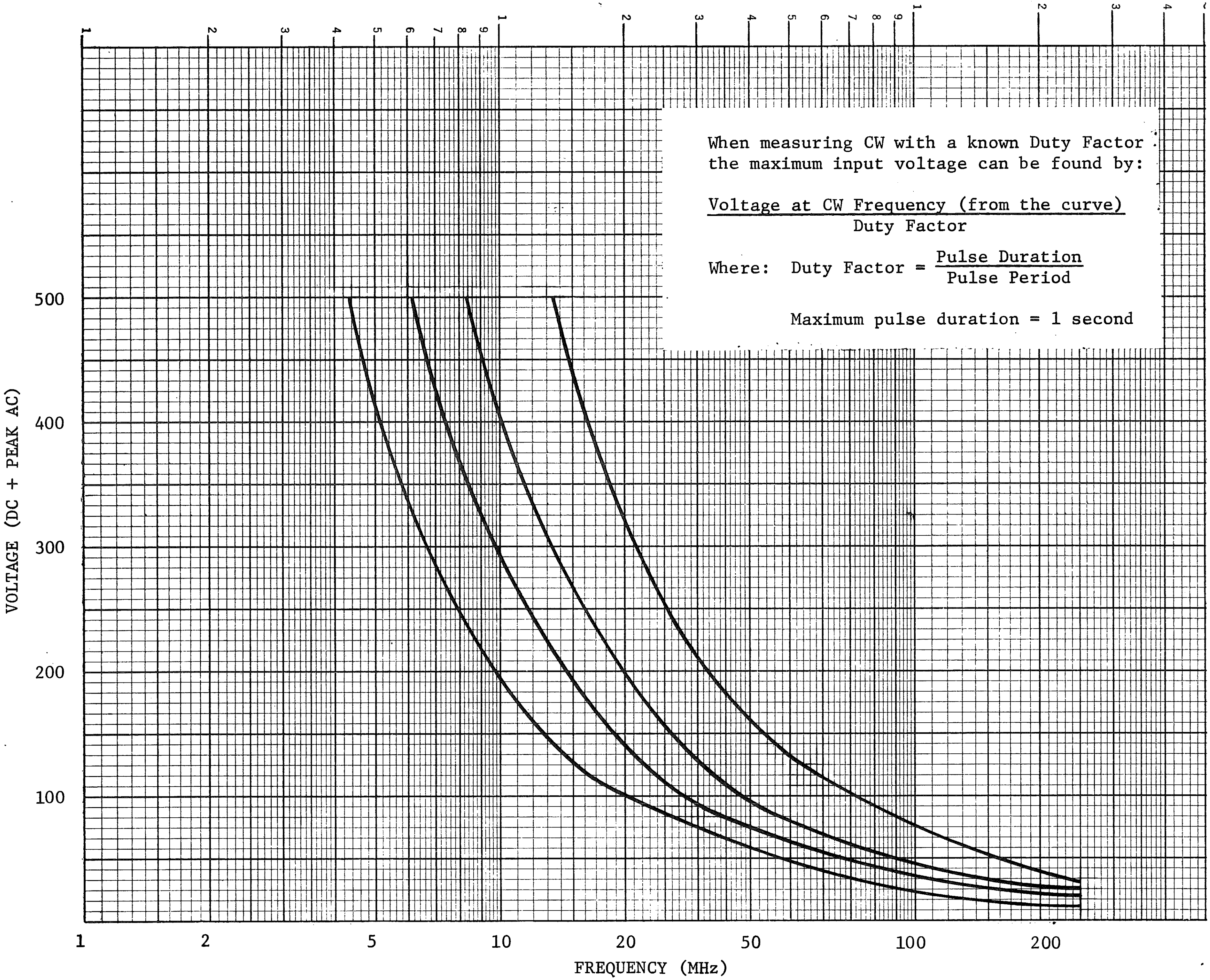


Fig. 1-4 Maximum Input Voltage Derating

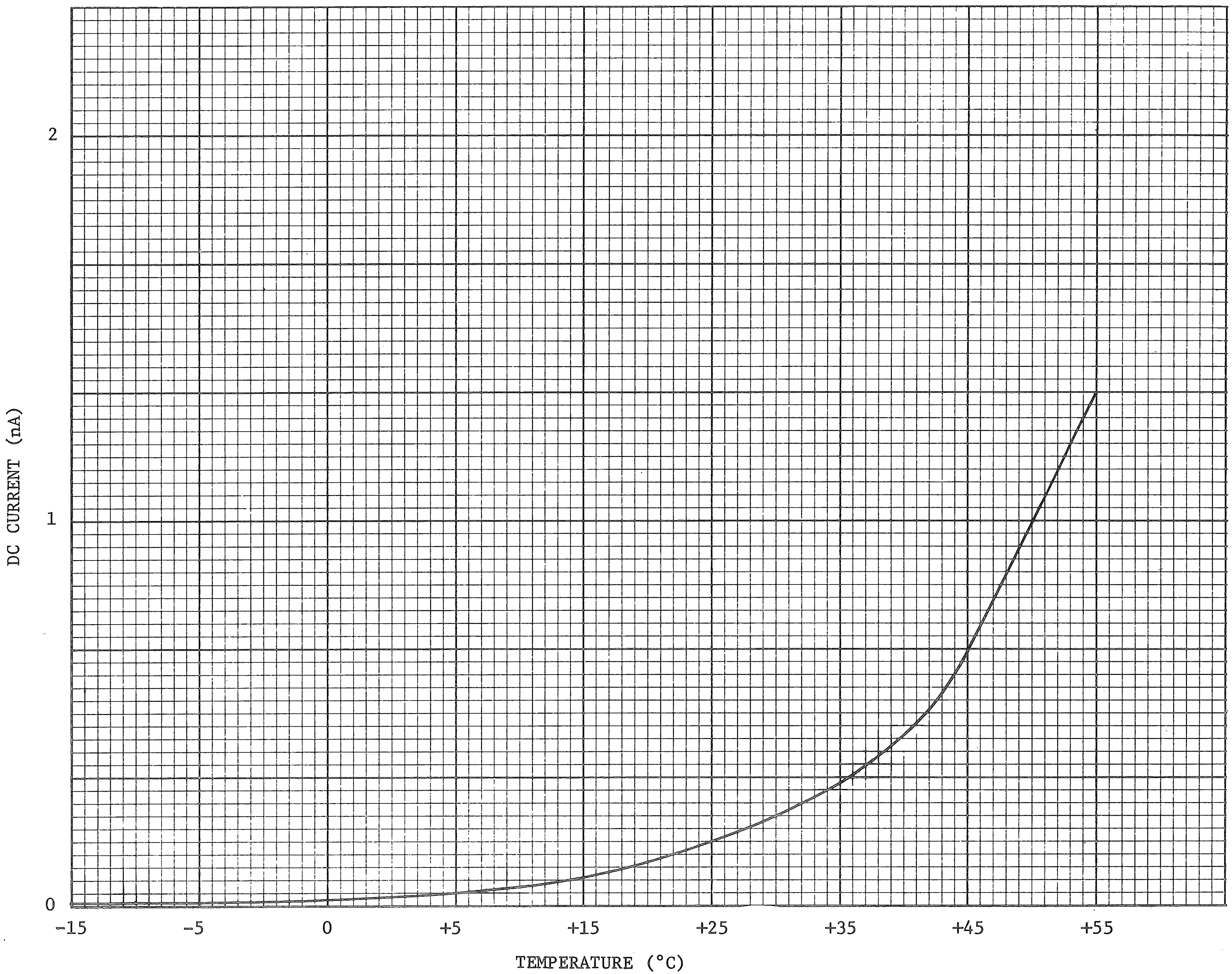


Fig. 1-5 Maximum DC Current vs Temperature

L. Displayed Noise, Tangentially Measured (see Appendix A2)

Any unwanted trace deflection, electrically or mechanically induced from inside an instrument.

QUOTABLE: If the apparent width of the noise display is less than 0.2 divisions by visual inspection, so state; if it is more than 0.2 divisions, state the maximum displayed noise (measured by the "tangential" method) in volts referred to the input at the minimum deflection factor. If the displayed noise does not become proportionally less with increasing deflection factors, state the maximum displayed noise in graticule divisions at higher deflection factors. Include statements of displayed noise: (1) with the standard accessory (or recommended) probe(s) driven by a properly terminated 50 Ω system and (2) with a properly terminated 50 Ω system driving the input directly.

ENGINEERING NOTES: State gross deviations (if any) from the following: Displayed Noise $\simeq$ 2 X RMS Equivalent Noise or

$$\simeq \frac{\text{Apparent Width of Noise Band}}{3}$$

M. Microphonics

Any trace deflection induced by mechanical vibrations originating outside the instrument. Trace deflection caused by fans in the instrument not included.

ENGINEERING NOTES: State maximum peak-to-peak trace deflection in graticule divisions (not volts) that occurs for a specified duration with the input grounded through a probe as a result of a shock from a 100 gram mass with a 1 square inch contact surface dropped 10 cm.

N. DC Drift

Vertical movement of the trace within a specified time with the input terminated into at least 50 Ω.

1. Drift With Time (Ambient Temperature and Line Voltage Constant)

(a) Short Term

QUOTABLE: State the maximum peak-to-peak drift of the vertical center of the trace in graticule divisions and/or μvolts over the full deflection factor range. Also state that: (1) the drift occurs during any 1-minute interval within any hour after a specified time from turn-on, and (2) the input is terminated into at least 50 Ω.

(b) Long Term

QUOTABLE: State the maximum peak-to-peak drift of the vertical center of the trace from a reference level in graticule divisions and/or μvolts over the full deflection factor range. Also state that: (1) the drift occurs during any hour after a specified time from turn-on, and (2) the input is terminated into at least 50 Ω.

2. Drift With Line Voltage Change (Ambient Temperature Constant)

QUOTABLE: State the maximum peak-to-peak drift of the vertical center of the trace in graticule divisions and/or μvolts over the full deflection factor range. Also state that: (1) the drift occurs within the first minute after the line voltage is changed from nominal to high line, then from nominal to low line, and (2) the input is terminated into at least 50 Ω.

3. Drift With Ambient Temperature Change (Line Voltage Constant)

QUOTABLE: State the maximum peak-to-peak drift of the vertical center of the trace in graticule divisions and/or μvolts per 10°C over the full deflection factor range. Also state that: (1) the drift occurs within the temperature range specified for the electrical characteristics (not the total operating range), and (2) the input is terminated into at least 50 Ω.

O. Channel Isolation

The ability of a multiple-channel system to display a signal without interaction.

(a) Equal Deflection Factors

QUOTABLE: With all channels at the same deflection factor, state the minimum isolation ratio between a full-graticule signal applied to one channel and the displayed amplitude of the remaining channel(s) with their inputs grounded through a 10X probe. State the frequency at which the isolation ratio is 100:1 or better and also the frequency at which the isolation ratio is 10:1. If the isolation ratio does not diminish to 10:1, state the isolation ratio at the upper bandwidth frequency.

(b) Unequal Deflection Factors

QUOTABLE: State the maximum displayed signal amplitude expressed as an isolation ratio referred to the input with one channel in the straight-through position and its input grounded through a 10X probe and with a signal applied to the other channel(s) at: (1) a specified deflection factor(s), (2) a specified amplitude, and (3) at the frequency specified for a 100:1 isolation ratio in paragraph (a). Determine the isolation ratio from the following formula:

$$\frac{\text{Driven Channel}}{\text{Displayed Channel(s)}} = \frac{2 \text{ Div X (D.F.)}}{\text{(CRT Deflection in Div) X (D.F.)}}$$

1.1 ELECTRICAL

1.1.1 VERTICAL CHANNEL (cont'd)

ITEM	QUOTABLE		MAINTENANCE AND OPERATION	TEST RATE	VAL. STEP	ENGINEERING NOTES
Displayed Noise, Tangentially Measured	With P____ (__ ft) Connected to 50 Ω	With 50 Ω Connected Directly to Input		100%		Displayed Noise ≈ 2 X RMS Noise or ≈ Apparent Width of Noise Band / 3
__ V/Div to __ V/Div	__ div or less	__ div or less				
__ V/Div to __ V/Div	__ μV or less referred to input	__ μV or less referred to input				
Microphonics				100%		__ div or less P-P for __ s with __ g shock and input grounded through a P____ probe
DC Drift				100%		
Drift With Time (Ambient Temperature and Line Voltage Constant)						
Short Term						
__ V/Div to __ V/Div	__ div P-P or less during any 1 minute interval within any hour after __ minutes from turn-on					
__ V/Div to __ V/Div	__ μV or less during any 1 minute interval within any hour after __ minutes from turn-on					
Long Term						
__ V/Div to __ V/Div	__ div or less during any hour after __ minutes from turn-on					
__ V/Div to __ V/Div	__ μV or less during any hour after __ minutes from turn-on					
Drift With Line Voltage (Ambient Temperature Constant)						
__ V/Div to __ V/Div	__ div or less with line voltage varied from __ V to __ V or to __ V					
__ V/Div to __ V/Div	__ μV or less with line voltage varied from __ V to __ V or to __ V					
Drift With Ambient Temperature (Line Voltage Constant)						
__ V/Div to __ V/Div	__ div or less/10°C					
__ V/Div to __ V/Div	__ μV or less /10°C					
Channel Isolation				100%		
(1) *Equal Deflection Factors*	At least *(100)*:1 with a __ MHz signal on Channel __					
	At least *(10 or __)*:1 with a __ MHz signal on Channel __					
(2) *Unequal Deflection Factors*	At least __:1 referred to input with a __ div, __ MHz signal on Channel __ at __ V/div; on Channel __ at __ V/div					

P. Chopped Mode (See Appendix A7)

A time-sharing method of displaying output signals of two or more channels with a single CRT gun, in sequence, and at a rate not referenced to the sweep.

1. Chopped Repetition Rate

   QUOTABLE: State the rate in Hz at which each displayed channel or combination of channels completes a displayed cycle, i.e. goes from channel X and back to channel X again. See examples (1) through (3).

2. Channel Time Segment

   QUOTABLE: State the duration of the time segments for each channel. See examples (1) through (3).

3. Display Factor

   QUOTABLE: State in percent the minimum portion of the Channel Time Segment which is usefully displayed. See examples (1) through (3).

Q. Beam Finder

A provision for compressing the display to within the graticule area, independent of Position control setting or applied signal.

QUOTABLE: State the effect on the display when the Beam Finder control is operated.

R. Delay Line

ENGINEERING NOTES: State the electrical delay line length in time.

S. Signal Delay Difference Between Channels

QUOTABLE: State the maximum signal delay difference between channels.

1.1 ELECTRICAL

1.1.1 VERTICAL CHANNEL (cont'd)

ITEM	QUOTABLE	MAINTENANCE AND OPERATION	TEST RATE	VAL. STEP	ENGINEERING NOTES
Chopped Mode			100%		
(1) *Dual-Trace Units*					
Chopped Repetition Rage	__ MHz within __%				
Channel Time Segment	__ ns to __ ns				
Display Factor	At least __%				
(2) *Multichannel Units, 3A74 or M Logic*					
Chopped Repetition Rate	__ kHz within __% for two channels __ kHz within __% for three channels __ kHz within __% for four channels				
*Channel Time Segment	__ μs within __%				
Display Factor	At least __%				
(3) *Multichannel Units, 1A4 Logic*					
Chopped Repetition Rage	__ kHz within __% for two channels __ kHz within __% for three or four channels				
*Channel Time Segment	__ μs within __%				
Display Factor	At least __%				
Beam Finder	Compresses display to within graticule area		100%		
Delay Line			0.1%		≃ __ ns
Signal Delay Difference Between Channels	__ ns or less		0.1%		

*In three-channel operation the one channel displayed from either of the pairs (1 and 2, or 3 and 4) occupies two successive __ μs segments.

APPENDIX A
REFERENCE INFORMATION

This appendix contains copies of the following:

A1. Risetime-Bandwidth Specification for Real Time Oscilloscopes (Inter-Office Communication dated 11-8-66/Russ Fillinger)

A2. A Simple Method for Measuring Preamp Noise (Proposal dated 10-13-66/Val Garuts)

A3. Proposed Specification Method for Maximum Percent of Aberration (Proposal dated 12-9-66/Warren Collier)

A4. Modified Proposal for Step Response Specification (Proposal dated 11-18-66/Al Zimmerman)

A5. A Proposal for Specification Notation (Inter-Office Communication dated 5-24-67/Al Zimmerman)

A6. "Range" vs "Limits" and Use of the Notation $<$, $>$, $\leq$, and $\geq$ (Inter-Office Communication dated 5-31-67/Al Zimmerman)

A7. Chopped Mode Specification (Proposal dated 8-7-67/Warren Collier)

Inter-Office Communication

To: Please see below **Date:** November 8, 1966

From: Russ Fillinger, Chairman
Specifications Guideline Committee

BEAVERTON

Subject: Risetime-Bandwidth Specification for Real Time Oscilloscopes

1. The bandwidth measurement accuracy of a system including operator and test equipment in use at Tektronix is limited to about 5%. Bandwidth measurement should therefore be not only conservatively specified but also limited to one or two significant figures. The figure specified is the minimum figure including consideration for one year's normal usage.

2. Risetime measurements are subject to additional problems of accuracy. Pulse generators have finite risetimes and have certain aberrations. Input circuitry and layout can cause a mismatch and reflections. Typically the display of risetime is much less than 1 major division, therefore CRT othogonality is an important consideration. The problem of a risetime standard for oscilloscope use is unobtainable from NBS (10 ms present limit.) The statement of risetime should not be for

   less than the calculated value of $t_r = \frac{0.35}{\text{specified bandwidth}}$; the figures obtained to be rounded off to one or two significant figures.

   eg. $\frac{0.35}{23\ \text{MHz}} = 15.2 = \underline{\underline{16\ \text{ns}}}$

   $\frac{0.35}{2\ \text{MHz}} = 175\ \text{ns} = \underline{0.18\ \mu\text{s}}$ not 180 ns

   Each unit is checked in a manner to verify its max capability. The figures stated in the advertising and manual are based on valid electrical and mathematical models and are therefore considered quotable.

   At the request of Bob LeBrun we have deleted the statement about indicating that the risetime figures are calculated values.

RVF:as
Encl. 1

Distribution list attached.

A SIMPLE METHOD FOR MEASURING PREAMP NOISE

Introduction

The ideal way of measuring preamp noise would be to use a true RMS-reading voltmeter with a bandwidth large enough to encompass that of the preamp. A meter such as the HP3400A may be suitable for low frequency applications but its use requires that the source have a low output impedance (to drive the input and cable C at 10 MHz.) Alternately the main frame "vertical signal out" jack (if there is one) could be used to drive the meter; however, the output signal level is usually not accurately calibrated, and calibration procedures would have to be followed. What is desired is a quick, simple method of estimating the noise amplitude, preferably taking readings directly from the CRT screen of the scope embodying the preamp.

Method

The method to be described is useful provided the following conditions are satisfied:

(i) The noise should be easily visible on screen, i.e., apparent width of noise band at least 0.2 cm.

(ii) The amplitude distribution should be reasonably close to Gaussian at least near the mean of the distribution (i.e., for amplitudes less than ± the rms value.)

(iii) The preamp + scope bandwidth should be large enough so that the contribution of the highly colored 1/f noise is not significant.

Procedure

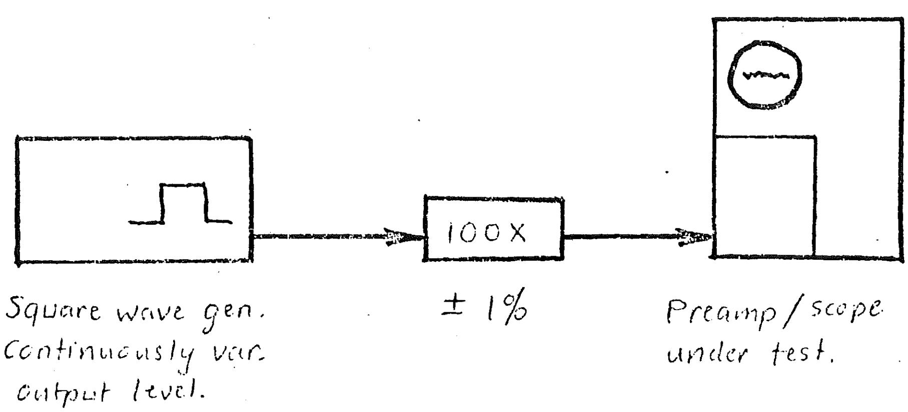


FIGURE 1. Equipment Setup

The procedure is as follows:

1. Adjust test scope intensity for comfortable viewing and adjust focus and astigmatism controls if necessary.

2. Set test scope vertical volts/div to the sensitivity where noise is to be measured (e.g., 100 μV/div.) Observe two bands of noise on screen (noise + free-running square wave.)

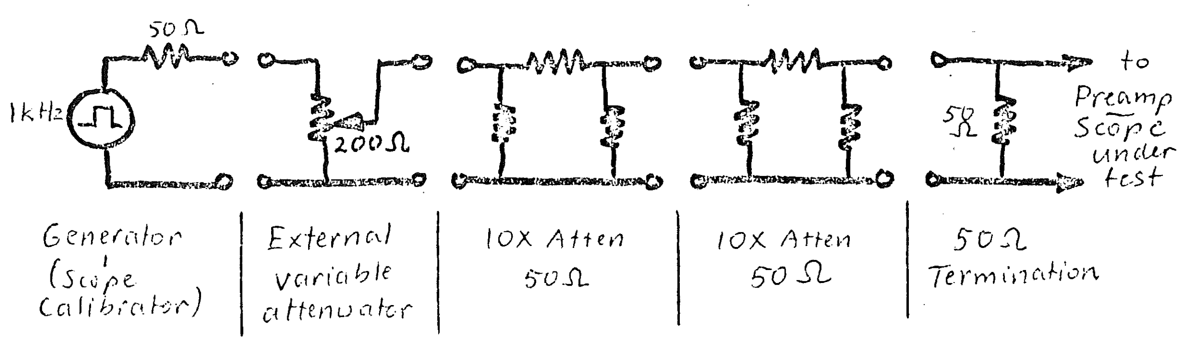
3. Reduce the square wave generator output till the two noise bands merge to the point where the darker band between the noise bands just vanishes.

4. Remove the 100X attenuator from square wave path, and increase scope deflection factor by 10 (e.g. to 1 mV/div.) Measure square wave amplitude. Then

$$\text{rms noise voltage} \approx \frac{1}{20}(\text{square wave amplitude}) \qquad (1)$$

Notes:

(a) When removing the 100X attenuator, care must be taken to keep the load seen by the generator constant, so that its output amplitude is not disturbed. A setup such as:



was found satisfactory, and was used during the experiments to be described. Clearly the square wave frequency must be well below the amplifier cutoff ($< 0.1\ f_c$), but otherwise is of no great importance.

(b) The setting of the CRT controls (intensity, focus) is not particularly critical -- any suitable intensity may be used, for comfortable viewing. Similarly the sweep speed can have any value that does not produce flicker, or does not accidentally display the square wave.

(c) The final adjustment of amplitude should be made quite slowly, as it was found that the eye tends to adapt itself to the pattern, and to observe a residual dark band where none was observed a few seconds previously. A total adjustment time of ≃ 1 minute was found to be typical.

Mathematical Justification

It is assumed that the noise is basically "colored" Gaussian, with an amplitude distribution

$$p(v) = v_0 \exp\left(-\frac{v^2}{2\sigma^2}\right) \quad \ldots\ldots \quad (2)$$

where σ is the standard deviation, or rms noise voltage.

In the following discussion v_0 is normalized to 1 and $v = \frac{v}{\sigma}$, i.e., σ is normalized to 1.

$$p(v) = \exp\left(-\frac{v^2}{2}\right) \quad \ldots\ldots \quad (3)$$

Some derivatives will be found useful:

$$\left.\begin{aligned}
p^{(1)}(v) &= -v \exp\left(-\frac{v^2}{2}\right) \quad \ldots\ldots \quad a\\
p^{(2)}(v) &= (v^2-1) \exp\left(-\frac{v^2}{2}\right) \quad \ldots\ldots \quad b\\
p^{(3)}(v) &= v(1-v^2) \exp\left(-\frac{v^2}{2}\right) \quad \ldots\ldots \quad c\\
p^{(4)}(v) &= (1-4v^2+v^4) \exp\left(-\frac{v^2}{2}\right) \quad \ldots\ldots \quad d
\end{aligned}\right\} \quad (4)$$

etc.

In the test method two uncorrelated noise bands of the same amplitude distribution are set up, so the total amplitude distribution will be the sum of the two, thus:

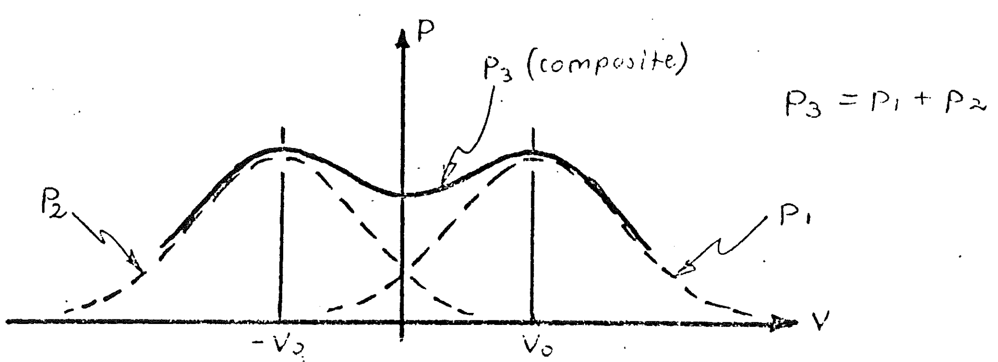


FIGURE 2. Composite Amplitude Distribution

$$p_1(v) = exp\left(-\frac{(v-v_0)^2}{2}\right) \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; a \tag{5}$$

$$p_2(v) = exp\left(-\frac{(v+v_0)^2}{2}\right) \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; b$$

$$p_3(v) = exp\left(-\frac{(v+v_0)^2}{2}\right) + exp\left(-\frac{(v-v_0)^2}{2}\right) \ldots\ldots \tag{6}$$

It is desired to find for what value of v_0 does the composite distribution p_3 have a flat top, i.e., becomes maximally flat. This is equivalent to asking--for what v_0 will the first n derivations of p_3 (at $v = 0$) become zero, i.e.

$$p_3^{(n)}(0;v_0) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{7}$$

clearly from symmetry, $p_3^{(n)}(0) = 0$ for n odd, i.e., all odd-order derivatives are zero. For n even,

$$p_3^{(n)}(0) = p_1^{(n)}(0) + p_2^{(n)}(o) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{8}$$

$$= p^{(n)}(-n_0) + p^{(n)}(v_0) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{9}$$

when the $p^{(n)}$'s are given by (4). For n even, v appears only as v^2, hence $p^{(n)}(-v_0) = p^{(n)}(v_0)$, and $p_3^{(n)}(o) = 2\, p^{(n)}(v_0)$. .... (10)

hence

$$p^{(2)}(0) = 2\,(v_0^2 - 1)\, exp\left(-\frac{v_0^2}{2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; a \tag{11}$$

$$p^{(4)}(0) = 2\left(1 - 4v_0^2 + v_0^4\right) exp\left(-\frac{v_0^2}{2}\right) \ldots\ldots\ldots\ldots\; b$$

Now $p^{(2)}(o) = 0$ for $v_0 = 1$, but $p^{(4)}(o)$ does not equal zero there. Thus the distribution $p_3(v, v_0)$ achieves third-order maximal flatness at $p_3(0, 1)$. In the unnormalized case,

$$\sigma = v_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{12}$$

and the spacing between the original distributions,

$$2v_0 = 2\sigma$$

so, σ = 1/2(spacing between centerlines of the original distribution,)

= 1/2 (square wave amplitude.)

Since in Step (4) the square wave amplitude on screen was increased by X10, the equation (1) is justified.

Sensitivity

A parameter of interest is the rate of change of amplitude in the center, with v_0 for $v_0 = 1$, i.e., near the end point of the adjustment. We have

$$p_3(0, v_0) = 2 \exp\left(-\frac{v_0^2}{2}\right) \quad \text{.......} \quad (13)$$

So that

$$\frac{dp_3}{dv_0} = -2 v_0 \exp\left(-\frac{v_0^2}{2}\right) \quad \text{.......} \quad (14)$$

$$\frac{dp_3(0,1)}{p_3(0,1)} = -\frac{dv_0}{v_0} \quad \text{.......} \quad (15)$$

This means that a 10% error in the flatness of the top of p_3 will result in a 10% error in v_0 and hence σ.

The function p_3 gives the distribution of electron density, (within a constant factor) hitting the CRT screen. The surface brightness of the screen is a non-linear function of this density.

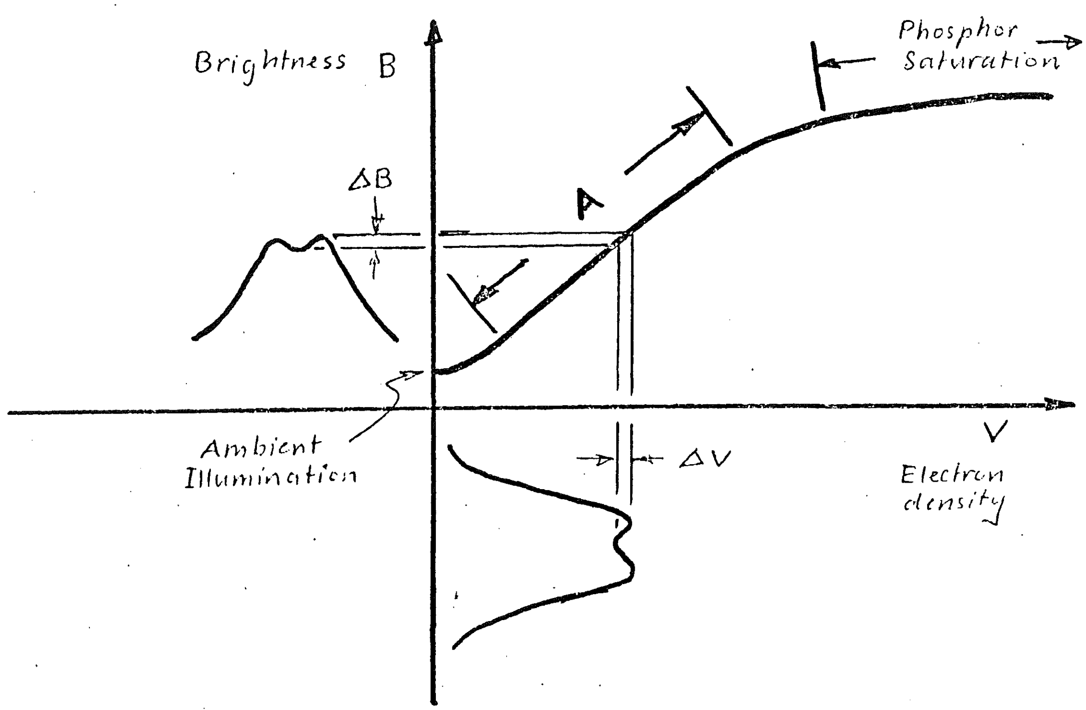


FIGURE 3. Phosphor Transfer Characteristic

It is desirable that $\Delta B/_B$ be as large as possible, given $\Delta v/_v$. Clearly $\Delta B/_B$ is always less than $\Delta v/_v$, but can be made to approach it very closely. The peaks of the distribution should be made to fall in the linear region A, which in practice is usually at least two decades of B in width. Intensity should not be so high as to approach the saturation region; and should not be so low that the ambient illumination contributes significantly to the trace brightness. In very intense ambient light a viewing hood should be used. Other than these considerations, the brightness setting is not important, since all that it is desired to observe is a constancy of brightness over a fairly small screen area.

In the useful region then,

$$\frac{\Delta B}{B} \simeq \frac{\Delta v_o}{v_o} = \frac{B\sigma}{\sigma} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

where B = surface intensity of the phosphor.

Accuracy and Repeatability

The value of the method is determined by the accuracy with which the measurement can be made, and this in turn depends primarily on how well the eye can detect small differences in the brightness of two adjacent regions. This difference threshold depends upon many factors: e.g., the absolute brightness of the regions, the brightness relative to background, the closeness of the regions (rate of change of brightness with dimension), the absolute angular size, etc. Under optimal conditions brightness differences as small as 2% can be seen; and generally, a 2:1 brightness difference can almost always be easily perceived. Considerable experimentation has been carried out, but the large number of variables involved means that no experimental results are directly applicable to the present case. As an estimate little better than a guess a 20% brightness difference should be perceivable, since since conditions such as absolute and relative brightness, and size, are under the operator's control.

A small experiment was carried out, designed to yield statistical data from which the repeatability and possible fixed bias (if adjustment is consistently stopped before maximal flatness is obtained, for example) might be estimated. A number of people were asked to carry out the measurement after two practice runs; each operator was asked to adjust the CRT brightness and sweep speed, as well as the display size, for his own best results. The table below gives the results (square wave amplitude.)

Operator	μV ⎍
1	26
2	32
3	26
4	29
5	28
6	30
7	30
8	32
9	33
10	29
11	29
12	31

Table mean v_s = 29.8μV

Standard dev. $_s$ = 2.18 μV

σ_s/v_s = 0.073

S.D. of the mean $\sigma_{ms} \approx$ 0.63 μV

Estimate of parent $\sigma_p \approx$ 2.28 μV

On the basis of these numbers, 99%of all observations should lie within $\pm$ 6 μV of the population mean, i.e., within $\pm$ 20% of the true value.

Attempting to check for fixed bias, the actual noise present in the system was measured using a HP 3400 A (TEK 000-273) true RMS voltmeter with an accuracy of better than $\pm$ 2%. The results were

Simple method	---	14.9 μV rms
HP 3400 A	---	15.3 μV rms

There is approximately 40% probability that the difference between these two numbers is accidental. Hence, lacking further data, it cannot be concluded that the method has or has not any fixed bias.

Conclusion

A simple noise measurement method has been described, requiring practically no auxiliary equipment; the accuracy of a single measurement appears of the order of $\pm$ 20%. Provided a particular observer has no fixed bias, the mean of 5 observations should be accurate to $\pm$ 10%.

Val Garuts

10-13-66

Warren Collier
PE/PE&M
12- 9-66

PROPOSED SPECIFICATION METHOD
for
MAXIMUM PERCENT OF ABERRATION (STEP RESPONSE)

The notation "plus or minus" (±) is to be used with respect to quantities that the operator considers to have a single fixed value, under one set of conditions. For example:

Vertical Deflection Factor 10 V/div Accuracy ±3%

This is to mean that the nominal factor is 10, but that the actual factor may be any value from 9.70 to 10.30, both values included. This factor is specified exclusive of time domain effects. Preferably, all limiting conditions, such as applicable temperature range are also specified.

<u>Note</u>: It may be argued that the 3% rating is a statement of maximum <u>error</u>, rather than <u>accuracy</u>, but by convention the meaning is understood.

The notation "plus and minus" (+ and -) is to be used when a quantity is variable above and below some reference value. The vertical deflection factor referred to above may be variable above and below the nominal value by some amount. Suppose it may be varied over a range having nominal limits of 8.0 and 12.0. This could be expressed as follows:

Vertical Deflection Factor 10 V/div
Accuracy ±3% at calibrated setting
Variable + and - 20% of calibrated value

The wording used here is intended to mean that the applicable 20% is 20% of the actual calibrated deflection factor (not necessarily 10, but any value from 9.70 to 10.30) and that the low setting is below the actual factor by an amount equal to or greater than 20% of the actual calibrated factor. Likewise, at the high setting the factor is increased by an amount equal to or greater than 20% of the actual calibrated factor.

Neither of the above notations is considered satisfactory for expressing transient response aberrations with respect to the reference level. This is because the first notation may be interpreted to mean either that:

a) the aberrations can be at a level only above or below the reference level, but not both (which is typically not the case), or
b) may be both a full X% above and a full X% below the reference level (which is frequently not the case).

PROPOSED SPECIFICATION METHOD FOR MAXIMUM PERCENT OF ABERRATION (STEP RESPONSE)

Therefore, it is recommended that the permissible aberrations be noted as follows:

+ x %
- y   Total peak-to-peak z %

For example:

+3%
-3%   Total peak-to-peak 4%

This example indicates that the aberrant level may be 3% above the reference level, but if it is, it may be only 1% below, and so on. It is at the designer's discretion whether the plus and minus values are equal or not, and whether the total peak-to-peak aberration allowed is less than the sum of the permissible plus and minus aberrations.

Examples of aberration in and out of specification.

Specification: Maximum aberration $^{+3\%}_{-3\%}$ peak-to-peak 4%

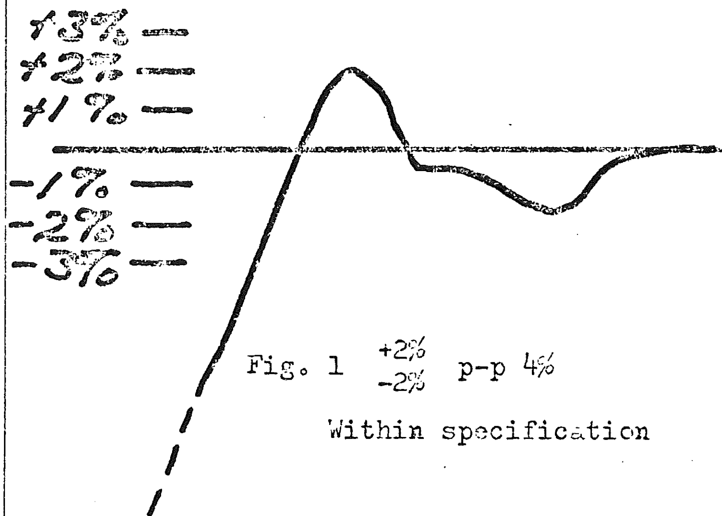


Fig. 1 $^{+2\%}_{-2\%}$ p-p 4%

Within specification

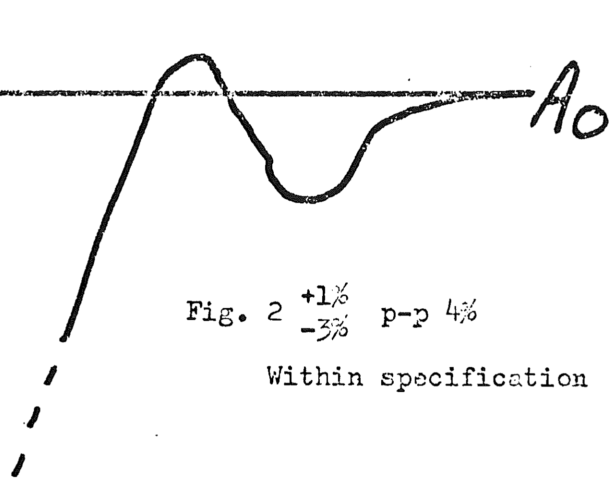


Fig. 2 $^{+1\%}_{-3\%}$ p-p 4%

Within specification

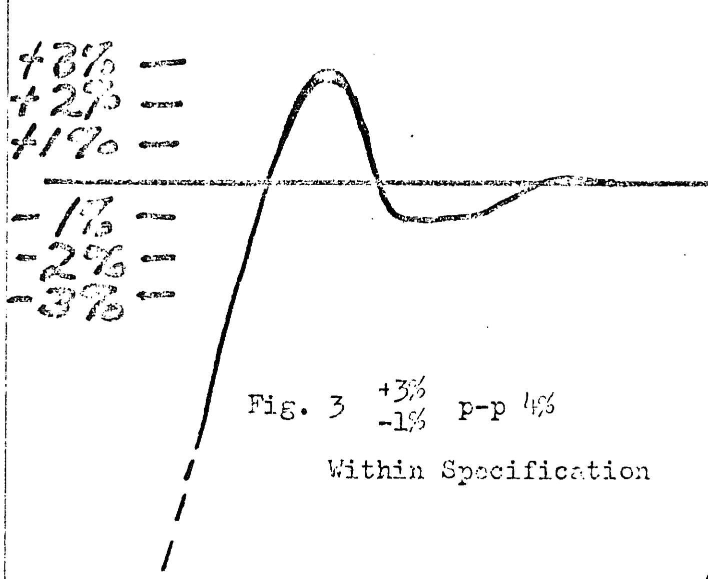


Fig. 3 $^{+3\%}_{-1\%}$ p-p 4%

Within Specification

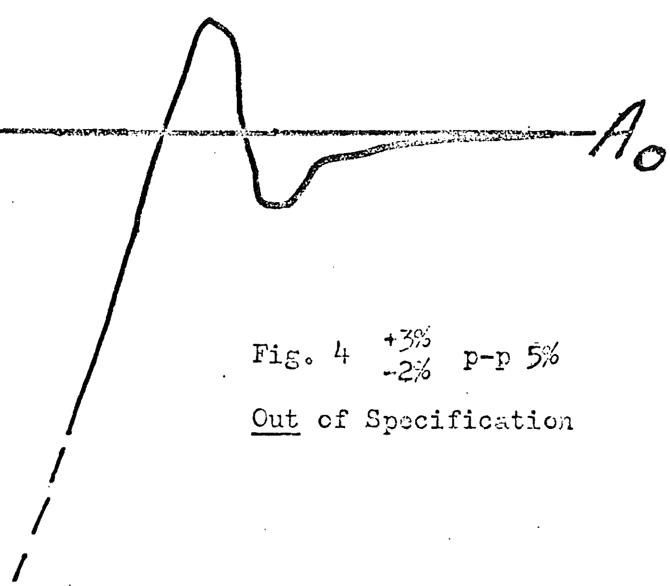


Fig. 4 $^{+3\%}_{-2\%}$ p-p 5%

Out of Specification

12.9.66
Collier

3. Step Response

The characteristics response to a step input.

Note A - The following information shall be included with any statement of step-response limits.

*1. Specification of step generator by type including control settings.

2. All relevant control settings of the oscilloscope for each limit specified. Limits should be specified for all deflection factors. Unless otherwise specified, limits are assumed to apply at all deflection factors.

3. Unless otherwise specified, a ~~terminated~~ 25 ~~50~~-ohm source (terminated 50-ohm) shall be used.

4. All step response limits shall indicate whether they apply to the oscilloscope alone or to the oscilloscope together with a specified probe. Where a companion probe can be identified , limits shall be specified with and without the probe.

*OR describe the step generator used and control settings including: repetition rate, duty factor, DC level, source impedance, risetime, aberrations, type and SN range of oscilloscope which should be used to verify these characteristics of the step generator.

Note B - Appropriate amplitude and time references shall be included with any statement of step-response limits. The references, A_o and t_o, are defined by the diagram in Figure 1 and shall be specified with respect to a displayed waveform. A_o shall be measured between reference levels computed as the average of the minimum and maximum excursions within intervals (3) and (4). Unless otherwise specified, the four intervals indicated in Figure 1 shall have the following mutual relationship:

Internal 1 = Internal 2

Internal 3 = Internal 4

Internal 1 = 4 x (Internal 3)

Where possible and unless otherwise specified, Internal 3 shall be the time corresponding to one division of the specified calibrated horizontal sweep rate. Normally this sweep rate will be the one which most nearly causes the quoted risetime, Tr, to occupy one horizontal division in the display.

Note C - Wherever a statement of step response limits is given, a graphical representation of references and limits is desirable in addition to a statement of numerical factors.

a. Risetime, Tr.

The time required for the displayed waveform to go from 10% to 90% of the reference amplitude.

QUOTABLE: State Tr. Unless otherwise specified, interval (1) shall be approximately 4 Tr and interval (2) shall be approximately 4 Tr. A qualification should be stated if risetime depends on an operating condition such as polarity of the input step or on the direction of the transition in the display.

b. Aberrations

The deviations of the displayed waveform from an ideal step.

QUOTABLE: State the maximum permissible plus and minus percentage of A_0 deviation from reference levels within two or more specified time intervals as follows:

1) First Aberration Interval

Unless otherwise specified beginning approximately 1 Tr (See Note B) after t_o, and extending to the end of Interval 2; this period should be of sufficient duration to include the worst, short-term effects such as overshoot, rounding, and ringing.

2) Second Aberration Interval

Beginning at the end of the First Aberration Interval and extending for a specified period thereafter; this period should be of sufficient duration to include long-term effects such as tilt or droop.

3) Other Aberration Intervals

Beginning and extending for specified periods; these intervals may be established when desired to include isolated predictable effects or effects not covered by the above intervals such as preshoot or DC shift.

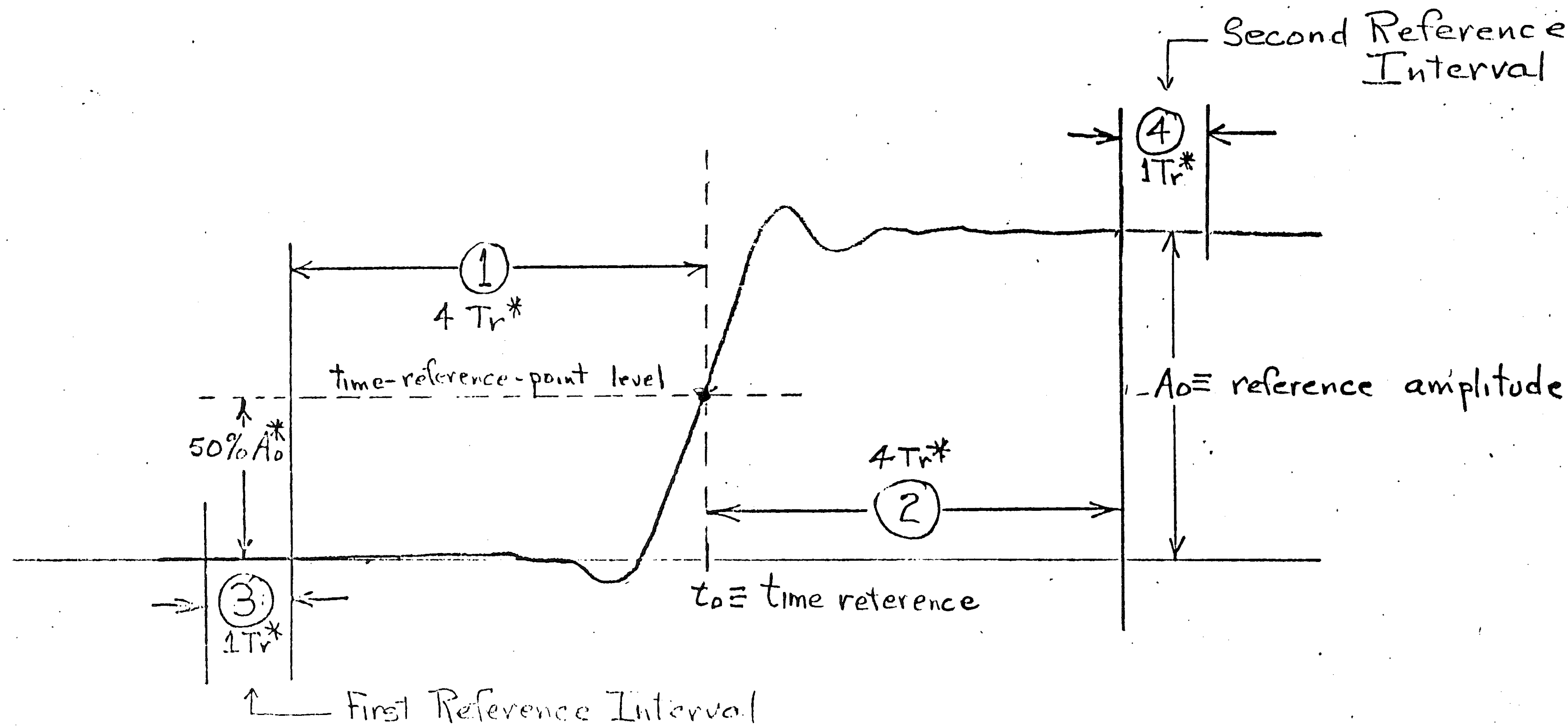
c. Position Effect on Aberrations

QUOTABLE: State the maximum permissible change in the actual plus and minus percentage deviations within the First Aberration Interval as the second average reference level (during (4)) is positioned vertically over the range indicated below. Unless otherwise specified, displayed step height shall be as indicated below:

Graticule Height	Positioning Range (about center)	Displayed Step Height
4 div.	± 1 1/2 div.	3 div
6	± 2	4
8	± 3	6
10	± 4	8

d. Overload Recovery

QUOTABLE: State the maximum time required for the trace to stabilize to within .2 major division of the level it reaches at 10 seconds after application of a step corresponding to 10 screen diameters in amplitude. The condition of overload shall have existed for 10 seconds prior to application of the step.



Notes: a) "Tr" is the specified risetime.

b) * means unless otherwise specified.

Revision to Proposal of 10-21-66

11-18-66
Rev. 11-22-66

Inter-Office Communication

BEAVERTON

To: Specification Committee

Date: May 24, 1967

From: Al Zimmerman

Subject: A Proposal for Specification Notation

Introduction

The following proposal has been developed as an attempt to correct ambiguities and misunderstandings which have arisen out of the notations "+ and -" and "±" and to provide a clearer and more precise means by which to represent instrument performance and specifications.

Proposal

Be it proposed that the Specifications Committee suggest and recommend the following notation for use at Tektronix and in documents intended to reach customers.

1. To describe or define the range of a parameter* (see footnote) use the following notation:

   a. "+x to -x" in descriptive text where the range limits are equal numerically.

   Example: DC offset range: +2V to -2V.

   b. "±x" on a front panel where "range" is clearly inferred by the presence of a continuous control and where the range limits are equal.

   Example: DC offset ±1V

   c. "x to y" where the range limits are unequal.

   Example 1: Dynamic Range: +2V to -10V

   Example 2: Trigger Amplitude Range: +10mV to +200mV

---

* The term parameter as used here is broadly defined to include control functions, input or output signals and other instrument characteristics. A particular parameter may be constant, a function of time, or a function of temperature, line voltage, frequency or some other parameter. There appears to be no need to distinguish this functional dependence in relation to the notational methods proposed herein.

d. Multiple use of the symbols $<$, $>$, $\leqslant$ and $\geqslant$ is discouraged.

<u>Example</u>: Minimum Position Range: +10cm to -10cm.

(NOT -10cm $\leqslant$ Position Range $\leqslant$ +10cm)

(NOT Position Range $<$ -10cm to $>$ +10cm)

2. To describe or define <u>limits</u> of possible values of a parameter with respect to a stated or understood nominal value use the following notation:

a. "±x" when the limits are <u>equal</u> numerically.

<u>Example 1</u>: Maximum Input ±3V

<u>Example 2</u>: Deflection Factor: 20mV/div to 100V/div, ±3%, 1-2-5 sequence

<u>Example 3</u>: Transient Response: $<$ ±2% aberrations within 10ns following a $\leqslant$ 75ps transition

OR

Less than ±2% aberrations . . .

b. "+x, -y" when the limits are <u>unequal</u> numerically.

<u>Example 1</u>: Timing Accuracy: +5%, -2%

<u>Example 2</u>: Output Pulse Flatness: Less than +3%, -1% aberrations within 100ns following negative-going transition.

(<u>NOT</u> Output Pulse Flatness $<$ +3%, -1% aberrations . . .)

<u>Example 3</u>: (Compound usage) Offset Monitor Range: +104.5 Volts +10%, -5% to -100 Volts ±5%

c. Where it is desirable to identify a peak-to-peak value other than the limit difference, the phrase "total peak to peak" z may be added. (±x, total peak-to peak z or +x, -y, total peak-to-peak z).

<u>Example 1</u>: Transient Response: Less than +4%, -2%, total peak-to-peak 3% aberrations within 100ns following a 75ps transition.

<u>Example 2:</u> Transient Response: Less than ±2%, total peak-to-peak 1% aberrations within 100ns following a $\leqslant$ 75 ps transition.

3. To describe or define a [illegible] (or [illegible]) parameter use the following notation:

a. "+x or -x" when the values of a double-valued parameter are <u>equal</u> numerically.

<u>Example</u>: Pulse Amplitude: (Type III) At least +10V or -10V. (<u>NOT</u> > +10V or > -10V.)

b. "x or y" when the values of a double-valued parameter are unequal numerically.

<u>Example 1</u>: Output Frequency: 100 kHz or 10 kHz

<u>Example 2</u>: Output Voltage: +3V or -2V

c. "x, y, ... or z" for discrete, multivalued functions.

<u>Example</u>: Pulse Amplitude: +10, +1, -1 or -10V.

4. To describe a qualitative parameter (such as Deflection Polarity or Triggering Slope) the notation "±" may be used when the literal intent is "plus or minus". Similarly, the notation "+ and -" may also be used when the literal intent is "plus and minus".

<u>Example 1</u>: The ± SLOPE switch was omitted.

<u>Example 2</u>: Display Modes: ± A only, ± B only, Dual-trace

<u>Example 3</u>: Check triggering with SLOPE in both + and - positions.

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TEKTRONIX

Inter-Office Communication

To: Specification Committee

Date: May 31, 1967

BEAVERTON

From: Al Zimmerman

Subject: "Range" vs "Limits"
Use of the notation <, >, ≤ and ≥

Range vs Limits

Since my IOC of May 24, 1967, the question has arisen why distinguish between "range" and "limits" of a range since both can be defined by a statement of the limits themselves. Then we are led to ask when should a parameter be described or defined as a range and when should it be described or defined in terms of the limits of its range. Or, in other words, what is the conceptual difference between "range" and "limits."

These questions seem pertinent since the proposal for specification notation we are studying offers substantially different notational forms for ranges and limits.

I would offer (with Bob LeBrun's support) the following distinction in an attempt to resolve the matter:

> A parameter should be described or defined as a range when the operator has direct, voluntary control over the values of the parameter
>
> ~~OR~~
>
> ~~when (for whatever reason) it~~ seems advisable to use the ~~word "range" in the term describing~~ a ~~parameter~~ (e.g. Dynamic Range).

No further distinction seems necessary.

<, >, ≤ and ≥

In my proposal of May 24 <u>multiple</u> use of the symbols <, >, ≤ and ≥ was discuraged in range notation. It now seems wise to limit use in another area where misunderstanding often occurs.

Everybody seems to agree that "<" means "less than," but disagreement occurs when it is used in several other ways:

1. in the mathematical sense of a continuum from $-\infty$ at the left to $+\infty$ at the right

Example

$$-4 < -3$$

2. in the literal (or absolute) sense:

Example B

< 2 volts

meaning a. less than 2 volts (literally)

b. between 0 and + 2 volts

c. less than $|+2|$ volts.

Example C

< - 5 volts

meaning
a. less than - 5 volts (literally)
b. between 0 and - 5 volts
c. less than $|-5|$ volts

PROBLEM

d. between $-\infty$ and - 5 volts.

Example D

< $\pm$ 6 volts

meaning
a. less than + 6 volts or - 6 volts (literally)
b. between + 6 volts and - 6 volts
~~c. less than $\pm$ 6 volts~~

PROBLEM (confusion at least)

c. between + 6 and 0 AND
between - 6 and $-\infty$.

SUGGESTION

My suggestion would be to avoid all use of the symbols <, >, ≤ and ≥ EXCEPT with quantities whose algebraic sense is always positive (e.g. Risetime). The phrases "less than," "within," "at least," etc. would be recommended in lieu of the symbols in all other cases.

AZ:kn

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CHOPPED MODE SPECIFICATION

The primary specification for the chopped mode is Chopped Repetition Rate, expressed in Hertz. Chopped Repetition Rate is defined as the rate at which any one displayed channel displays information, when the instrument is operated in the chopped mode. This is synonymous with saying that it is the rate of completion of a display cycle, or getting from channel n back to channel n again.

The second important characteristic of chopped mode operation is the Displayed Channel Time Segment. This depends on the combined effect of the Channel Time Segment and the Display Factor, which are the items that are actually specified.

The Channel Time Segment clarifies the meaning of Chopped Repetition Rate, particularily for multichannel units. It is derived as follows:

$$\text{Channel Time Segment} = \frac{1}{(\text{Chop rep rate}) \times (\text{no. channels})}$$

Display Factor is the minimum (worst case) portion of the Channel Time Segment which is usefully displayed, and is expressed as a percentage. Display Factor takes into account the effect of switching or blanking time.