Designation: E 1324 – 00

Standard Guide for Measuring Some Electronic Characteristics of Ultrasonic Examination Instruments[1]

This standard is issued under the fixed designation E 1324; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes procedures for electronically measuring the following performance-related characteristics of some sections of ultrasonic instruments:

1.1.1 *Power Supply Section*:

line regulation,
battery discharge time, and
battery charge time.

1.1.2 *Pulser Section*:

pulse shape,
pulse amplitude,
pulse rise time, pulse length, and
pulse frequency spectrum.

1.1.3 *Receiver Section*:

vertical linearity,
frequency response,
noise and sensitivity, and
dB controls.

1.1.4 *Time Base Section*:

horizontal linearity, and
clock (pulse repetition rate).

1.1.5 *Gate/Alarm Section*:

delay and width,
resolution,
alarm level,
gain uniformity,
analog output, and
back echo gate.

1.2 This guide complements Practice E 317, and is not intended for evaluating the performance characteristics of ultrasonic examination instruments on the inspection/production line.

NOTE 1—No access to internal circuity is required.

2. Referenced Documents

2.1 *ASTM Standards:*

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *Military Standard:*

MIL-STD-45662A Calibration System Requirements[3]

2.3 *Other Standard:*

IEEE Std. 100, IEEE Standard Dictionary of Electrical and Electronic Terms[4]

3. Summary of Guide

3.1 The electronic performance of each section is measured by identifying that portion of the electrical circuit of the instrument which comprises the section, applying the recommended stimulus or load, or both, and performing the required measurements using commercially available electronic test equipment. These data are then summarized in tabular or graphical form as performance-related values which can be compared with corresponding values of other ultrasonic examination instruments or of values for the same instrument obtained earlier (see Section 12 for a suggested reporting format).

3.2 The following describes the sections of the ultrasonic instrument and their interrelations during measurement:

3.2.1 *Power Supply Section*—The power supply section is that portion of the total instrument circuitry which supplies the regulated DC voltages required to power all other sections of the ultrasonic instrument, including the high voltage (that is, pulser and CRT voltage) circuitry.

3.2.2 *Pulser Section*—The pulser section is that portion of the total instrument circuitry which generates the electrical pulse used to energize the ultrasonic search unit. The pulser

[1] This guide is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] Available from Institute of Electrical and Electronic Engineers, 345 E47th St., New York, NY 10017.

section may also include the pulse-shape modification controls such as pulse length, damping, or tuning controls.

3.2.3 *Receiver Section*—The receiver section is that portion of the total instrument circuitry which amplifies, or modifies, or both, the radio frequency (RF) pulses received from the ultrasonic search unit. This includes the RF amplifiers, detectors, video amplifiers, suppression and filtering, and the CRT vertical deflection circuits. Some instruments may not contain all of these circuits.

3.2.3.1 *Time Variable Gain (TVG)*, (alternatively referred to as Distance Amplitude Correction (DAC), Time Controlled Gain (TCG), etc.) and reject or threshold, while part of the receiver section, should be turned off while making measurements unless otherwise specified by the user.

3.2.4 *Gate/Alarm Section*—This section monitors the signals in the receiver section to detect the presence or absence of significant indications. The gate may include attenuation or gain controls. This section is considered separate from the receiver section for the purposes of this guide. The alarm signal may be audible, a voltage proportional to the indication amplitude, or a mark on voltage or current sensitive paper or some combination of these.

3.2.5 *Time Base Section*—The time base section provides the linear horizontal sweep, or baseline. It includes the horizontal deflection circuits and the clock and delay circuits that control repetition rate and positioning of signals on the baseline.

4. Significance and Use

4.1 The recommended measurement procedures described in this guide are intended to provide performance-related measurements that can be reproduced under the specified test conditions using commercially available test instrumentation. These measurements indicate capabilities of sections of the ultrasonic examination instrument independent of specific transducers or examination conditions. Measurements are made from normally available connectors or test points so that no access to internal circuitry is required. Further, this guide is not intended for service, calibration, or maintenance of circuitry for which the manufacturer's instructions are available. It is intended primarily for pulse echo flaw detection instruments operating in the nominal frequency range of 100 kHz to 25 MHz, but the procedures are applicable to measurements on instruments utilizing significantly higher frequency components.

4.2 These procedures can be applied to the evaluation of any pulse-echo ultrasonic examination instrument which can be described as a combination of the electronic sections discussed in this guide.

NOTE 2—These procedures are not intended to preclude the use or application of equipment for which some or all of the measurement techniques of this document are not applicable.

4.3 An ultrasonic examination instrument that cannot be completely described as a combination of the electronic sections discussed in this practice can be partially evaluated. Each portion of the ultrasonic examination instrument that is evaluated must fit the description for the corresponding section.

4.4 This guide is meant to be used by electronic personnel to evaluate the electronic system components and not the ultrasonic system characteristics.

5. Apparatus

5.1 *Ultrasonic Instrument*—Any electronic instrument comprised of a power supply, pulser, clock, receiver, and a sweep and display section to generate, receive, and display electrical signals related to ultrasonic waves for examination purposes.

NOTE 3—Some ultrasonic instruments do not include a cathode ray tube display. Some sections of this guide may not apply to these instruments, or may be applicable only with modifications. Such modifications should be made only by personnel competent in electronics.

5.2 *Voltmeter*—Any instrument(s) capable of measuring the AC line and DC battery voltages required for 7.1 or 7.2.

5.3 *Variable Transformer*—An autotransformer or other device capable of supplying variable AC power to the ultrasonic instrument over the full range of voltages and waveforms specified by the manufacturer.

5.4 *Pulser Load*—Unless otherwise requested by the using parties, the pulser load should be a 50-ohm noninductive resistor, preferably mounted in a shielded coaxial assembly. The resistor must be able to withstand the maximum peak pulser voltage. The impedance of the resistor should be checked at the anticipated operating frequency to ensure that it is noninductive. Other impedances may be used if specified.

5.5 *Spectrum Analyzer*—Any spectrum analyzer (and probe assembly if required) that is capable of analyzing the electrical pulse from the pulser module and displaying the frequency components of the pulse as described in 8.3. A recording of the display (photograph or chart recorder) is desirable.

5.6 *Probe*—A wide band high input impedance ($\geq$10 kΩ) attenuating (100X or 50X) probe to reduce the pulse amplitude, as delivered to the oscilloscope and the spectrum analyzer, to a level that (*a*) will not harm the equipment and (*b*) will allow for frequency and time analysis without significantly altering the pulse shape. The probe output impedance should match the input impedance of the measurement instrument. (If the impedance is high, a terminating resistance may be required at the input to match the output impedance of the probe.) The frequency bandwidth should be at least as wide as that of the measuring instruments. The probe must be able to withstand the pulser output voltage.

NOTE 4—More than one probe may be needed to match the various test instruments used.

5.7 *Function Generator*—The function generator should be capable of producing a single-cycle sine wave or a five-cycle sine wave burst (as required in 9.1.3, 9.2.3, 9.3.1, 10.1.1, and 11.1), the frequency of which is variable over the range of the frequency capabilities of the ultrasonic instrument. The frequency read-out should be accurate to 1.0 %. It must be capable of being triggered from a signal derived from the instrument clock to provide wave trains coherent with the display. An adjustable delay of at least 10 µs is required.

5.7.1 A free-running (that is, non-triggered) single-cycle sine wave may not be used for receiver evaluation.

5.8 *Calibrated Oscilloscope*—The oscilloscope should be capable of displaying all portions of the pulser output with sufficient timebase expansion, triggering capability, and frequency response to enable measurement of the pulse rise time, amplitude, and duration, as well as fulfilling the requirements of other measurements.

5.9 *Calibrated Attenuator*—The attenuator should provide a measuring range of 60 dB in 1 dB steps with an accuracy within± 0.5 dB and have a frequency bandwidth at least as wide as the highest frequency of interest. Most attenuators have a nominal input and output impedance of 50 Ω, but other impedances may be specified. Proper termination rules must be observed. An impedance matching probe should be used to protect the attenuator if it is to be used to reduce pulse output.

5.10 *Terminators*—Terminators are used to match the impedances of instruments and cables used (see 5.4.). They should be non-inductive, feed-through style.

5.11 *Cables*—Cables should be coaxial, with maximum length of 6 ft (2 m) and a 50-ohm characteristic impedance. Other lengths, or impedances, or both, may be used if authorized, but lengths should be kept as short as possible to minimize the effects of cable capacitance on measurements.

5.12 *Search Unit*—An ultrasonic search unit of the desired type, size, and frequency required for the procedures and test block selected for 5.14, 7.1.1, 7.2.1, 10.2, or 10.3.

5.13 *Immersion Tank (Optional)*—An ultrasonic immersion system that will enable continuous variation of the distance between the ultrasonic search unit and a reflector over a water path range that will provide a time range comparable to the end use of the ultrasonic instrument. A distance (position) scale of precision needed for the procedure in 10.2 must be incorporated.

5.14 *Test Block*—A block of any suitable material which can be used to provide ultrasonic echo signals.

5.15 *Camera or Recorder*—This is particularly helpful in measuring pulse characteristics, and is useful in making other measurements.

6. Precautions and Limitations

6.1 This guide describes procedures that are applicable to laboratory measurement conditions using, in most instances, commercially available electronic test equipment.

6.2 This guide is not intended, nor is it applicable, as a specification defining the performance of ultrasonic examination systems. If such performance criteria are required, they must be agreed upon by the using parties.

6.3 Implementation of this guide may require more detailed procedural instructions. Competence in the use of the electronic measurement instrumentation specified is a prerequisite for effective use of these procedures.

6.4 Careful selection of the specific measurements to be made is recommended. If the related parameter is not relevant to the intended application, its measurement may be unnecessary. For example, vertical linearity may be irrelevant for an application using a single-level flaw alarm, while horizontal linearity might be required only for accurate flaw-depth or thickness measurement from the instrument screen.

6.5 No minimum interval between instrument evaluations is recommended or implied.

6.6 The accuracy of each measurement is dependent upon the combined accuracies of each of the electronic measuring instruments (which should be described in the specifications and calibrations for these instruments), and the precisions associated with reading the values of each part of the measurement system. It is assumed that the precision of measuring the vertical and horizontal values from the ultrasonic instrument screen is ±0.04 in. (±1 mm).

6.7 All measuring instrumentation should have current calibration certificates. A calibration control system, such as that described in MIL-STD-45662A, is suggested.

7. Power-Supply Section Measurements

7.1 *AC-Powered Instrument Line Regulation*:

7.1.1 Connect the variable transformer, the voltmeter and a search unit which matches the nominal frequency of the instrument, to the ultrasonic instrument as shown in Fig. 1. While Fig. 1 shows an immersion set-up, the evaluation may be performed by either the contact or immersion method. The primary requirement is that the signal from the reference reflector does not vary due to coupling or position variations during the evaluation. Contact tests may require clamping of the search unit to the test piece. A block with permanently bonded search unit(s) is quite useful.

7.1.2 Adjust the variable transformer for 100 % nominal line voltage and obtain a 50 % full-scale indication from the reference block. Decrease the variable transformer output voltage until the reference reflector indication changes its amplitude, width, or horizontal position by 10 %.

NOTE 5—Damage may result from going beyond the manufacturer's line voltage specifications in either direction.

7.1.3 The ultrasonic instrument display may turn off before any significant signal change is noted.

7.1.4 Record the variable transformer output voltage(s) at which the 10 % change or turn-off occurs. These are the input voltage limits.

NOTE 6—If a regulating transformer is always used to supply power to the instrument, the procedures in 7.1 may not be needed.

7.2 *Battery-Powered Instruments*

7.2.1 *Discharge Time*:

7.2.1.1 With the battery in the full charged condition, connect a search unit to the instrument and obtain a 50 % full-scale indication from a suitable reference block. This

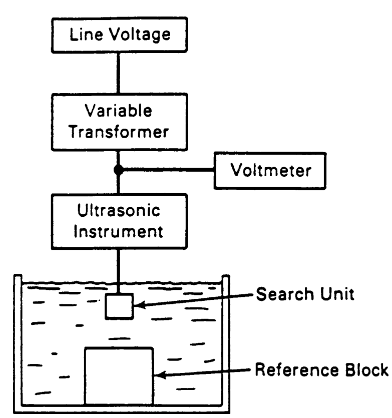


FIG. 1 Setup for Voltage Regulation Measurements

evaluation may be performed by either the contact or immersion method. The primary requirement is that the signal from the reference reflector does not vary due to coupling or position changes during the battery discharge time period.

7.2.1.2 Instrument controls that affect power drain, such as pulse repetition rate, CRT brightness, sweep range, etc., should be set to the maximum levels corresponding to good examination practices to provide the maximum practical power supply loading condition.

7.2.1.3 At time intervals ≤15 min, record the amplitude of the signal from the reference block and graph these values versus time as shown in Fig. 2 until the horizontal sweep length or position or amplitude of the indication changes 10 %, or until the instrument CRT turns off. The discharge time is the time required for a change of the stated amount or until the display turns off, whichever occurs first. Record this value.

7.2.1.4 The data recording may be minimized by making an initial reading and then beginning the periodic measurements at a later time near the anticipated discharge time.

7.2.2 *Charge Time*:

7.2.2.1 With the instrument battery discharged in accordance with 7.2.1, turn the instrument power switch to the OFF or CHARGE position, connect the battery charger to the battery, and begin charging the battery.

7.2.2.2 At time intervals ≤15 min, disconnect the charger, connect the DC voltmeter to the battery terminals, and record the battery voltage versus time as shown in Fig. 3. The battery charge curve shown in Fig. 3 is typical for NiCd and sealed lead batteries used in most ultrasonic instruments. The fully charged condition corresponds to the maximum voltage value shown in Fig. 3. Record this value in minutes.

7.2.2.3 The data recording may be minimized by making an initial reading and then beginning the periodic measurements at a later time near the anticipated charge time. Enough data should be acquired to reliably indicate the shape of the charge curve (see Fig. 3) in the region of full charge.

8. Pulser Section Measurements

8.1 *Pulse Shape*—Pulses are generally classed in two types, Tuned and Untuned, or Narrow Band and Broad Band.

8.1.1 Tuned pulsers are tuned to match the frequency of the search unit to be used. The output of a tuned pulser (without search unit) will be a damped sinusoid as is shown in Fig. 4a.

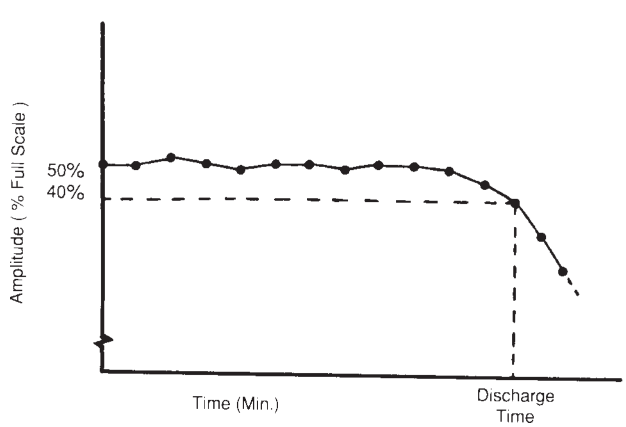


FIG. 2 Battery Discharge Characteristics—Typical

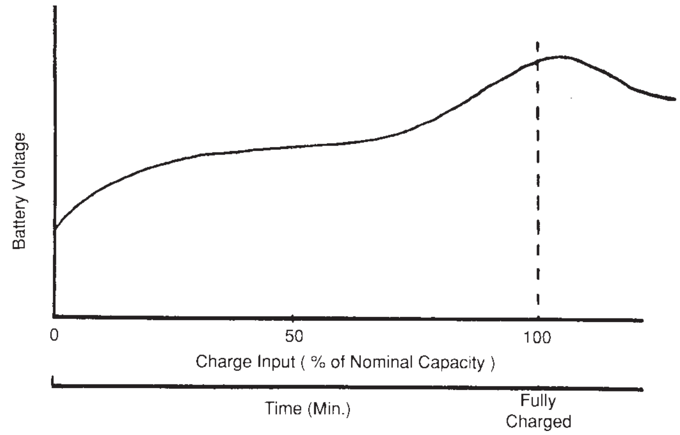


FIG. 3 NiCd and Lead Acid Battery Charge Characteristics—Typical

If the pulse is highly damped, only a half or one and a half cycle may appear. At minimum damping (Pulse Length maximum), there may be many cycles.

8.1.2 Untuned pulsers generally produce negative spikes, such as is shown in Fig. 4b. If highly damped (Pulse Length minimum), the exponential tail will be quite short. Another type of untuned pulse used in some instruments is a "rectangular" pulse (sometimes square), shown in Fig. 4c.

8.1.3 With the instrument turned on and no load connected to the pulser section output, connect the oscilloscope to the pulser section using a 100X or 50X probe if needed. Adjust the oscilloscope gain and triggering controls to obtain a display of a pulser-module output pulse. Fig. 5 shows the set-up. The Early Sync Trigger should be used, but if it is not available, an oscilloscope with built-in vertical signal delay will be needed in order to observe the leading edge of the pulse.

NOTE 7—Pulses involve very high frequency components. It is important to keep ground connections of probes short and close to the point of contact. Verify that probe frequency compensation is properly adjusted.

NOTE 8—In some commercial instruments, the pulse repetition rate is under microprocessor control and not accessible to the operator. In such instruments the repetition rate does not necessarily follow a clock schedule and the oscilloscope display may appear unstable.

8.2 *Pulse Rise Time, Duration, and Amplitude*

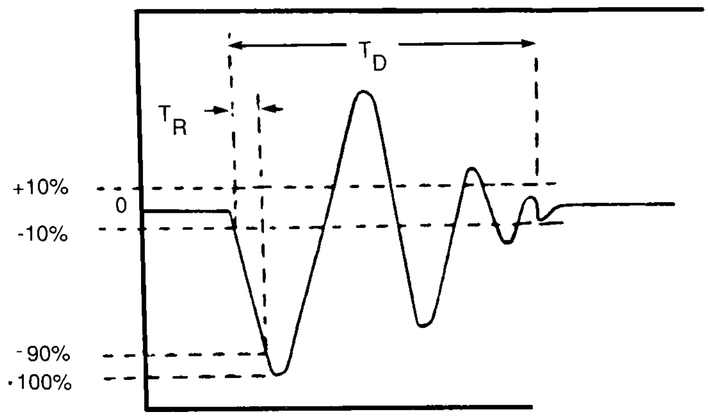
8.2.1 Start with the set-up of Fig. 5 with the 50-ohm load connected. Obtain a display on the oscilloscope screen that clearly shows the leading edge of the pulse.

8.2.2 *Pulse Rise Time*:

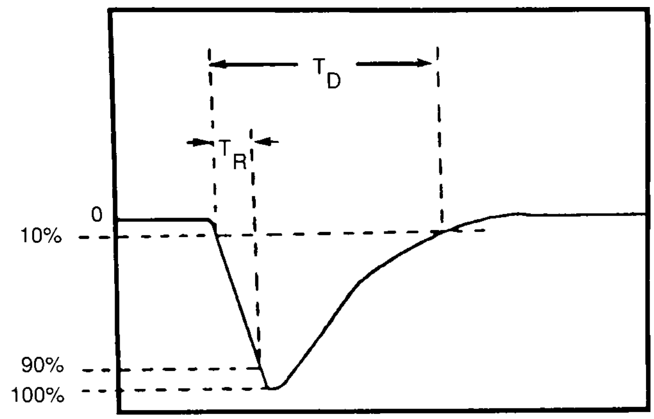
8.2.2.1 The rise time of the broadband pulse is the time interval T_r (in nanosecs) between the 10 % and 90 % points (relative to peak amplitude) on the leading edge of the pulse (Fig. 4a). Note that "rise time" and "fall time" refer, respectively, to the leading and trailing edges of the pulse, whether the deflection is positive or negative.

NOTE 9—The measured rise time includes the inherent rise times of the oscilloscope and probe if used. The actual rise time is given by

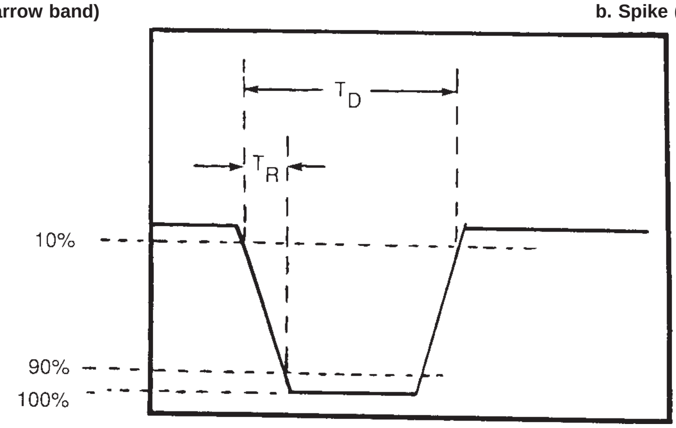
$$T_r^2 = T_m^2 - T_s^2 - T_p^2 \quad (1)$$



a. Tuned (narrow band)

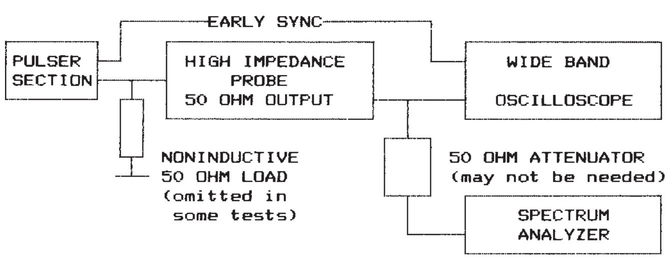


b. Spike (broad band)



c. Square (broad band)

FIG. 4 Pulse Shapes (Slopes exaggerated)



NOTE 1—Signal leads must be kept as short as possible.

NOTE 2—Probe needs 50 ohm output to match input to attenuator or spectrum analyzer, or both.

FIG. 5 Instrumentation for Pulse Measurements

where:

T_m = measured rise time,
T_s = oscilloscope rise time, and
T_p = probe rise time.

If only the bandwidths of the oscilloscope and probe are known, a close approximation to their rise times in nanoseconds can be obtained by dividing 350 by their bandwidths in MHz.[5,6]

Some manufacturers provide a combined rise time for their own oscilloscope/probe combinations. This rise time, whether given as such or calculated from the bandwidth, is used for T_s in the equation, for T_r above, and T_p is omitted.

NOTE 10—It is a general rule for measurement of transients, that the bandwidth of an oscilloscope be at least twice the highest frequency component of the signal to be displayed. Put in other terms, the oscilloscope should have an inherent rise time no more than half that of the signal (pulse) to be measured.

Amplitude and shape (width) will also be affected because the amplitude response of the amplifier begins to drop off and phase shifts become significant about mid-frequency, causing shape distortions.

Because of these considerations, the squared-term formula in Note 9 should be used with caution. Too narrow a bandwidth could cause pulse shape distortion that would lead to the misreading of pulse characteristics and cause rejection of a useful pulser.

8.2.2.2 Measure and record the Pulse Rise Time MIN at minimum Pulse Length and Pulse Rate Time MAX at maximum Pulse Length.

8.2.2.3 Remove the 50-ohm load and repeat 8.2.2.2.

8.2.2.4 For a tuned pulse, rise time is less meaningful because it is basically limited by the tuning Q. However, the measurement may be made as in Fig. 4a. Measurement may be confusing because the first half-oscillation may not be the strongest and may indeed be quite weak. Some judgement will be needed.

8.2.2.5 Repeat 8.2.2.2 and 8.2.2.3 for the tuned pulse.

8.2.3 *Pulse Duration*:

[5] Terman, F. E. and Pettit, J. M., *Electronic Measurements*, McGraw-Hill, 2nd Ed., 1952, pg. 327.

[6] Matick, R. E., *Transmission Lines for Digital and Communications Networks*, McGraw-Hill, 1969, pg. 191.

8.2.3.1 The pulse duration of a tuned pulse is measured from 10 % of the peak amplitude of the first large half cycle to the end of the last cycle that exceeds the 10 % level. This is illustrated in Fig. 4a.

8.2.3.2 The pulse duration of the untuned pulse is the time between 10 % of peak on the leading edge and 10 % of peak on the trailing edge as illustrated in Fig. 4b and Fig. 4c.

8.2.3.3 With the 50 Ω load in place, for either pulse, measure and record Pulse Length MIN and Pulse Length MAX.

8.2.3.4 Remove the 50 Ω load and repeat 8.2.3.3.

8.2.4 *Pulse Amplitude*:

8.2.4.1 The pulse amplitude of a tuned pulse is the amplitude of the strongest half-oscillation as shown in Fig. 4a. (The strongest half-oscillation may be positive.)

8.2.4.2 The pulse amplitude of an untuned pulse is the peak amplitude as shown in Fig. 4b and Fig. 4c.

8.2.4.3 With the 50 ohm load connected, (see Fig. 5) for either pulse, measure and record the Pulse Amplitude MIN for minimum pulse length and Pulse Amplitude MAX for maximum pulse length.

8.2.4.4 Remove the 50 Ω load and repeat 8.2.4.3.

8.3 *Pulse Frequency Spectrum*:

8.3.1 Use the set-up of Fig. 5. Start with sufficient attenuation to ensure that the Spectrum Analyzer input circuits will not be damaged or overloaded. The same frequency characteristics are measured for both tuned and untuned pulses, at MAX and MIN damping. Other conditions may be prescribed.

8.3.2 Adjust the spectrum analyzer to obtain a linear display of amplitude versus frequency. Measurements are to be made with and without the 50 Ω load.

8.3.3 *Peak Frequency*—On the spectrum analyzer display, the peak frequency is the frequency corresponding to the highest amplitude. Record this frequency with and without the 50 Ω load.

8.3.4 The Pulse Upper Frequency Limit is the highest frequency that corresponds to 70.7 % of the amplitude at peak frequency. Measure pulse upper frequency limits F_{UMAX} and F_{UMIN} with pulse length controls at MAX and MIN respectively.

8.3.5 The Lower Pulse Frequency Limit is the lowest frequency that corresponds to 70.7 % of the amplitude at peak frequency. Measure and record F_{LMAX} and F_{LMIN} at MAX and MIN pulse length controls, respectively.

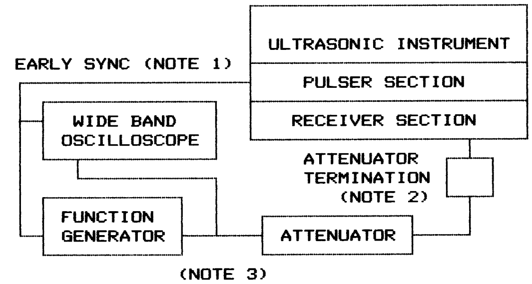
NOTE 11—In some instruments, the setting of the Pulse-Echo/Thru Transmission Switch may affect the results. If so, tests should be made with each setting.

9. Receiver Section Measurements

9.1 *Vertical Linearity*—The receiver section vertical linearity should be evaluated first because some other characteristics require vertical linearity for their measurement.

9.1.1 Connect the ultrasonic instrument and the measuring equipment as shown in Fig. 6. If the function generator cannot produce delayed gated pulse bursts, suitable auxiliary delay and gating circuits may be used.

9.1.2 The ultrasonic instrument should be in the Thru Transmission mode to avoid possible damage to the function generator by the pulse voltage. If Thru-Transmission operation is not available or if a substantial portion of the receiver is located before the Thru-Transmission input, means should be provided to protect the function generator from the pulser output. Consult the manufacturer's data. Also, unless otherwise specified, reject and time controlled gain should be disabled.



NOTE 1—If Early or Pulse Sync is not available, use pulse output with suitable voltage reduction to prevent damage to following instruments.

NOTE 2—In some modern instruments, the receiver section input impedance may be low enough to require consideration in arranging the attenuator termination.

NOTE 3—All signal leads after the function generator should be kept as short as possible.

FIG. 6 Instrumentation for Receiver Section Bandwidth, Sensitivity, Noise, and Vertical Linearity, and Time Base Section Horizontal Linearity

9.1.3 If the receiver provides variable video filtering, the filtering control should be set for minimum filtering. Also, unless otherwise specified, set the receiver reject control to off or minimum and disable the time-controlled gain. Set the receiver frequency to the frequency range of interest and adjust the function generator to provide a sine wave burst of at least five cycles, of rectangular envelope, the frequency of which corresponds to the ultrasonic instrument frequency setting.

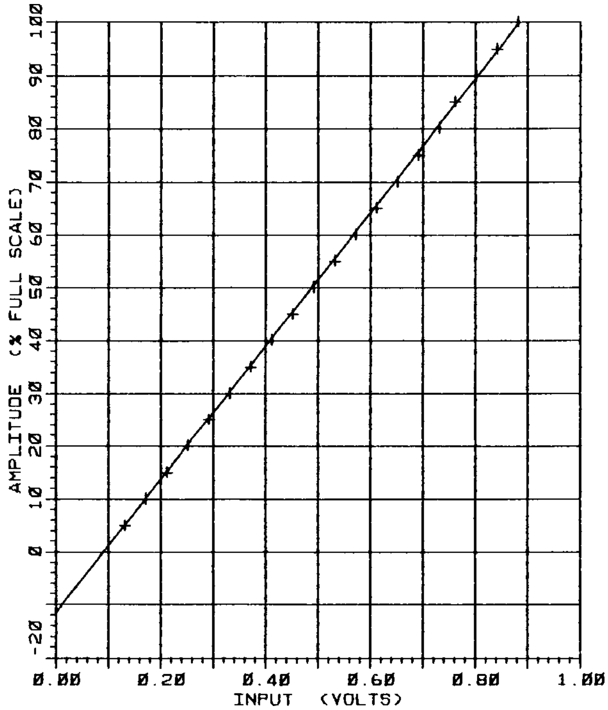
9.1.4 If the receiver section gain control is comprised of a course and fine control, set the coarse control to its lowest setting and the fine control to its middle setting. If the receiver gain control is comprised of a single control, set it for approximately 25 % of its range. The input signal amplitude must not exceed the manufacturer's recommendation.

9.1.5 Vary the function generator output or the attenuator to provide a deflection on the ultrasonic instrument screen from 5 % to 100 % of full scale in increments of 5 % of full scale. Other increments may be used as convenient. Record and graph the instrument CRT deflection amplitude versus the input amplitude as shown in Fig. 7. (It is recommended that multiple readings be taken and averaged at each input amplitude level to reduce operator reading errors.)

9.1.6 Repeat the measurements of 9.1.5 at other gain settings.

NOTE 12—Very low gain may lead to serious nonlinearity due to overdriving the input circuits, and measurement at maximum gain may be difficult because of noise interference.

9.1.7 It will be noted that there are no tolerance limits shown on Fig. 7. This curve is a performance characteristic of the vertical amplifier. While it may show linearity or lack of it, it is not the function of this guide to set tolerance limits. This is the responsibility of the user in accordance with such documents as apply.



NOTE 1—Offset is due to detector threshold and other biasing components.

NOTE 2—Data points were taken using an actual instrument.

FIG. 7 Receiver Section Vertical Linearity

9.2 *Receiver Section Frequency Characteristics*:

9.2.1 Connect the ultrasonic instrument and measuring equipment as shown in Fig. 6. The oscilloscope is used to monitor the function generator output, which is the unattenuated input signal to the ultrasonic instrument receiver section. The ultrasonic instrument CRT is used to monitor the receiver output. Care should be taken to properly match the impedances of each portion of this system.

9.2.2 The ultrasonic instrument should be in the Thru-Transmission mode to avoid possible damage to the function generator by the pulse voltage.

9.2.3 If the receiver provides variable video signal filtering, the filtering control should be set for minimum or zero filtering. Set the receiver reject control to minimum or off. Set the receiver frequency control to the frequency range of interest and adjust the function generator to provide a five-cycle sine wave burst whose frequency corresponds to the ultrasonic instrument frequency setting. Set the calibrated attenuator to 20 dB attenuation and adjust the delay to provide a signal located midway across the instrument screen. (The ultrasonic instrument sweep rate is irrelevant to these measurements.) By means of the receiver section gain controls and the function generator output, adjust the signal amplitude to 80 % full scale or 80 % of the upper linearity limit, whichever is less. A preliminary scan of the frequency range may be desirable to determine the frequency at which response is maximum.

9.2.4 Vary the function generator frequency in 0.5 MHz increments above and below the receiver module frequency setting until the signal indication decreases to 10 % of its maximum value. At each frequency increment the function generator output should be adjusted, if necessary, to ensure a constant amplitude input to the receiver. At each frequency record the signal amplitude and frequency and plot the results as in Fig. 8.

9.2.5 If the ultrasonic instrument is to be operated with video filtering, the measurements described in 9.2 should be repeated at the required filter settings.

9.2.6 *Receiver Frequency Results*:

9.2.6.1 *Peak Frequency*—The peak frequency is the frequency at which the instrument CRT indication is maximum. The peak frequency should be determined within ±0.1 MHz by decreasing the frequency increments in the region near the peak frequency. The peak frequency should be determined for each setting of the receiver frequency control.

9.2.6.2 *Bandwidth*—The bandwidth is the response range between the frequencies at which the signal deflection is 3 dB below the amplitude at peak frequency. Record these frequencies as upper and lower frequency limits.

9.3 *Noise and Sensitivity*:

9.3.1 Connect the ultrasonic instrument, function generator, trigger delay, oscilloscope, attenuator, and terminator as shown in Fig. 6. Set the receiver frequency control to the range of interest and set the function generator control to the same frequency. Adjust the function generator to provide RF bursts of five or more cycles, but not more than ten. Note the instrument bandwidth if it is variable. (Noise is bandwidth dependent.)

9.3.2 *Sensitivity*—Sensitivity is defined in Terminology E 1316 as a measure of the smallest ultrasonic signal which will produce a discernable indication on the display of an ultrasonic system.

9.3.2.1 *Sensitivity Index*—A more useful quantity is a sensitivity index, which may be defined as the value of input signal that produces a predetermined signal to noise ratio. For purposes of this guide, a signal to noise ratio of three is chosen for illustration.

9.3.2.2 *Method A*—Noise is customarily measured in terms of power, but in an ultrasonic instrument it is manifested only as an amplitude on the oscilloscope screen. Since measurement of noise on the screen is highly subjective, Method A is presented as a way to remove the subjective aspect and to provide a quantitative signal to noise measurement which we have defined as the sensitivity index. Set the instrument gain to maximum. With the function generator disconnected, but leaving the 50 ohm terminator in place, lower the alarm level

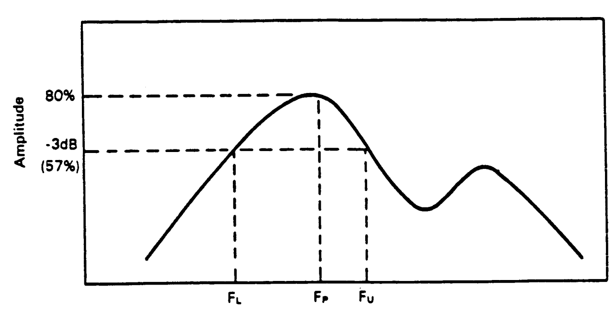


FIG. 8 Receiver Section Frequency Characteristics

until the alarm is just triggered by the noise. Note the alarm level and increase it by a factor of four but not above 80 % fs. Reconnect the function generator and adjust the output to trigger the alarm. The signal on the screen will include noise. Record the peak voltage at the receiver input. (Function generator output after attenuation.) This voltage is the sensitivity index for a 3:1 signal to noise ratio:

$$(S + N = 4N) \quad (2)$$

9.3.3 *Method B*—If the instrument does not have a gate/alarm, the following method may be used. Increase the instrument gain to MAX. Connect the function generator and adjust the output to make the signal just blend with the noise on the instrument screen. Record the peak voltage at the receiver input. This is the instrument noise referred to the input. This value, multiplied by three, is the sensitivity index. The resulting index will not necessarily be the same as was determined using Method A.

9.4 *dB Controls*:

9.4.1 Connect the ultrasonic instrument and measuring equipment as shown in Fig. 6. Adjust the receiver attenuator to mid range. Set the external attenuator to a value at least as great as the amount of attenuation left in the receiver attenuator. Set the function generator for a single cycle sine or square wave and adjust the output to provide a signal at mid-screen, of amplitude approximately 50 % full screen. Note the starting value of each attenuator. Increase the receiver attenuation by 6 dB and reduce the external attenuation to bring the signal back to its starting amplitude. Proceed in this manner through the full range of the receiver attenuator, using the function generator output to reset the signal to 50 % full scale after each step if necessary.

9.4.2 Make a table or plot a graph of receiver attenuator settings against the external attenuator settings. This is your attenuator calibration table or curve.

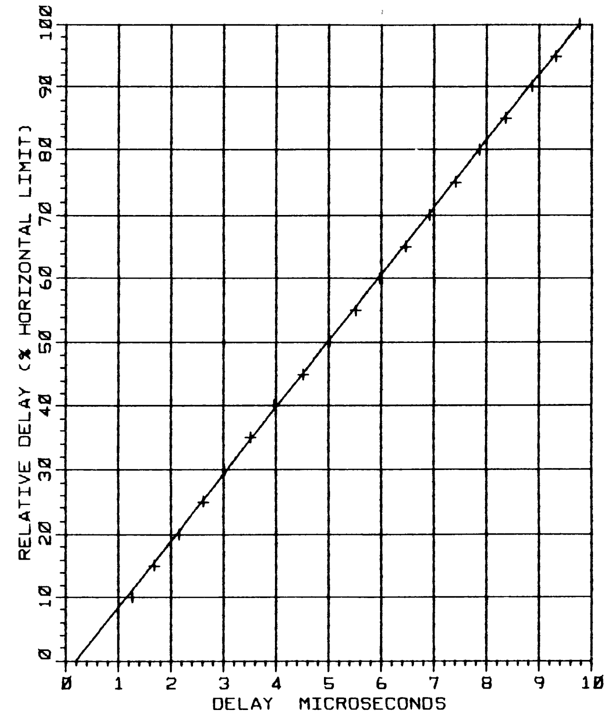
10. Time Base Section Measurements

10.1 *Horizontal Linearity (Method A)*:

10.1.1 Connect the ultrasonic instrument and measuring equipment as shown in Fig. 6. The ultrasonic instrument should be in the thru-transmission mode. Set the function generator to produce a single-cycle sine wave whose frequency corresponds to the ultrasonic instrument frequency setting. (Since this evaluation is independent of the instrument frequency, any instrument frequency setting may be chosen.) Adjust the display section coarse sweep range control to its minimum range position and the fine range control approximately to its middle position. Adjust the ultrasonic instrument and the calibrated attenuator to obtain an indication with at least a 50 % full scale amplitude located midway across the instrument CRT screen.

10.1.2 Vary the trigger delay in increments that move the indication in increments of ≤5 % of the sweep width and record each delay (as measured on the oscilloscope) and the corresponding location of the leading edge of the indication on the receiver module CRT. Plot the location versus delay as shown in Fig. 9.

10.2 *Horizontal Linearity (Method B)*:



NOTE 1—Data points were taken by Method A using an actual instrument.

FIG. 9 Horizontal Linearity

10.2.1 Connect an ultrasonic immersion search unit that is mounted in a conventional immersion scanning system, to the ultrasonic instrument. Orient the search unit over any reflector. Adjust the ultrasonic instrument sweep controls to settings corresponding to the end use of this system and adjust the receiver gain and the water path between the reflector and the transducer to provide a 50 % full scale indication midway across the instrument CRT display.

10.2.2 Vary the water path to move the indication in increments of approximately 5 % of the sweep width and record each water path distance and the corresponding location of the leading edge of the indication in percent of full width. Plot the signal position versus water path distance as shown in Fig. 9 and as described in 10.1.1.

10.3 *Horizontal Linearity (Method C)*— Connect the ultrasonic instrument and a search unit for conventional contact or immersed operation as desired. Orient the search unit over a flat plate of suitable thickness to provide at least ten back reflections on the screen. Adjust controls to place the second reflection on the 10 % horizontal graticule line, and the tenth on the 90 % line. Plot the graticule positions of all the echoes versus echo number on a graph similar to Fig. 9.

10.4 *Horizontal Linearity Results*—As was stated in 9.1.7, this guide does not define tolerance limits. The graph of Fig. 9 is thus simply a calibration curve of the horizontal base line.

10.5 *Repetition Rate*—Connect the oscilloscope to the ultrasonic instrument pulse section output using a 100X or 50X probe. Adjust the oscilloscope to display at least two pulses. The repetition rate is the reciprocal of the time between pulses. Because of possible interaction between the repetition rate and the sweep length control, verify that the repetition rate is not limited by the sweep length. If other functions, such as a DAC curve, Gate Strobe, etc. are displayed simultaneously with the ultrasonic signals on the instrument screen, the rate as measured this way may be a submultiple of the time base repetition rate. To be sure of measuring the true repetition rate, these functions should be disabled. (See Note 8.)

10.5.1 Measure and record the instrument repetition rate, REP-max and REP-min (in pulses per second) for the maximum and minimum positions of the pulse repetition rate control.

10.5.2 If the ultrasonic instrument has switch-selectable rates, record each switch value versus the measured repetition rate.

10.5.3 If the ultrasonic instrument has both switch-selectable rates and a variable control, record the maximum and minimum repetition rates at each switch setting.

11. Gate/Alarm Section Measurements

11.1 *Delay and Width*—Connect the ultrasonic instrument and measuring equipment as in Fig. 6. Adjust the function generator to one cycle of a high frequency (within the bandwidth of the ultrasonic instrument) and position this signal, in the Gate, and mid-screen on the ultrasonic instrument. Set the alarm level as low as possible, and the gate width at minimum. Move the signal toward the leading (left) edge of the gate. Continue until the alarm is deactuated. Move back until the alarm is just reactuated. Note on the oscilloscope the delay time of the signal. Move the signal to the other end of the gate and continue until the alarm is deactuated. Move back until the alarm just comes on. Note the delay time on the oscilloscope. The difference between the delay times on the oscilloscope is the minimum gate width. Increase the gate width to MAX (adjusting the sweep length appropriately) and repeat. Delay MAX and MIN may be determined similarly: Set delay control to MAX. (Again with sweep length adjustment, if necessary.) Move the function generator signal to the leading edge of the gate. Read the delay time on the oscilloscope. This is the MAX delay. In most instruments, leading edge of the gate will be obscured by the "main bang" at minimum delay. If it is not, set the delay at MIN and move the signal to the leading edge again. The delay time on the oscilloscope is MIN delay. If the Gate strobe is available at a separate jack, it may be displayed on the oscilloscope and the delay times measured directly. There may be a small error in the times, due to internal circuitry in the instrument, that may be significant in the minimum delay measurement.

NOTE 13—If thru-transmission is not available, means should be provided to protect the function generator output circuits from the pulser output. The manufacturer's data should state allowable signal levels to be fed in at the generator output.

11.2 *Resolution*—This term is used to refer to closeness of approach of a gate to an indication that is not to be gated.

11.2.1 Arrange the equipment to obtain a strong indication such as from a front or back surface reflection or a strong signal from the function generator. Adjust the sweep delay to position the indication about mid-sweep. Move the gate from left to right toward the indication until the indication actuates the alarm. Note the delay on the oscilloscope. Back off until the alarm is no longer actuated. Note the delay. The difference in delays is the time resolution. This may be converted to space resolution by multiplying by the velocity in the material.

11.2.2 Closeness of approach to the rear edge of a strong signal depends on the alarm level and the shape of the signal. For this reason it is not quantifiable.

11.3 *Alarm Level*—Set up the ultrasonic instrument and obtain an indication from a suitable target or from a signal from the function generator. Position the gate to include the indication. Reduce the signal level to zero. Reduce the alarm level to minimum. Increase the indication height until the alarm is actuated. Record the amplitude of the indication relative to the gate step, if present, in percent of full scale. This is the minimum alarm level. Readjust the alarm level control to maximum. Increase the indication amplitude until the alarm is again actuated. This is the maximum alarm level. Repeat these measurements for negative alarm (negative alarm indicates absence of signal in the gate). All measurements should be repeated several times to obtain an average.

NOTE 14—For negative alarm, levels are determined by reducing the indication until the alarm is actuated.

11.3.1 *Alarm Level Hysteresis*—Set the indication level to about 50 % of full scale. Position the Gate to include the indication. Reduce the alarm level to just actuate the alarm. Reduce the indication amplitude until the alarm is deactuated. Note the amplitude. Increase the amplitude until the Alarm is reactuated. Note the change in amplitude. This is alarm level hysteresis. Repeat to get an average change, if measurable. (Ideally, the change would be zero, and it may well be too small to measure.) Do this for both positive and negative alarm. Hysteresis can cause exaggeration of size of indications in C-Scan recording.

11.4 *Gain Uniformity in the Gate*—Set up the equipment as in 11.3. Adjust the gate width to several times the width of the indication. Set the level so that the alarm is just actuated and move the gate back and forth "through" the indication and note whether the alarm remains actuated. Repeat with the alarm just not actuated. Change of alarm status indicates lack of uniformity of gain in the gate. Record the gain change necessary to keep the alarm actuated (or deactuated).

NOTE 15—Alarm level hysteresis may obscure any gain variation.

11.5 *Analog Output*—Using the procedures of 9.1, record the analog output voltage as a function of input amplitude. Plot a graph of output versus input such as Fig. 7.

NOTE 16—On some instruments the analog output may be "go-no-go" to indicate whether a screen deflection is above or below the alarm level setting. Proportional output also may depend on the alarm level setting. Not all instruments provide an analog output.

11.6 *Back Echo Gate*—Some instruments provide multiple gates, at least one of which may incorporate an independent gain control or attenuator. This gate is often used to monitor the amplitude of the strong reflection from the back surface of the test piece. It is necessary that any change in amplitude of the back reflection be repeated by the indication in the gate. To test the performance of the gate, the arrangement of Fig. 6 may be used. (The oscilloscope is not needed.)

11.6.1 Arrange for a saturated indication on the screen. Position it in the gate and, using the gate gain control, bring the indication down to 80 % of full screen. Vary the input in measured amounts and note the variation of the indication in the gate. Plot a graph similar to Fig. 7, of the amplitude of the indication versus the input. Repeat for various starting input amplitudes.

12. Reporting Format

12.1 *Identification of Instrumentation*— The ultrasonic instrument main-frame and plug-in modules should be identified as to manufacturer, model, serial numbers, and any other pertinent descriptor. The manufacturer, model, and pertinent control settings of the electronic test instrumentation should also be reported.

12.2 *Power Supply Section Report*—The following is the recommended power supply section measurement reporting format:

Power Supply Type:

AC-powered ____ Battery-powered ____

AC-Powered Measurements:

Allowable Line Regulation ______ % ac line voltage

DC Powered Measurements:

Discharge time ____ h Charge time ____ h

12.3 *Pulser Section Report*—The following is the recommended format for the pulser section measurement report:

Pulse Shape:

Untuned ____ Tuned ____

Pulse Rise Time, Length, Amplitude, and Frequency Spectrum:

Pulser load			____Ω
	Min.	Max.	Units
Pulse length	______	______	µsec
Rise time	______	______	nsec
Amplitude	______	______	V
Lower bandwidth limit	______	______	MHz
Upper bandwidth limit	______	______	MHz
Peak frequency	______	______	MHz

Spectrum shape: Smooth__________ Irregular __________

12.4 *Receiver Section Report*—The following is the recommended format for reporting receiver section measurements:

Vertical Linearity:

Plot Fig. 7 for all frequency and gain settings of interest.

Frequency Characteristics:

Frequency control setting ____ MHz

Reject level ____ % of full reject (preferably zero)

Filtering ____

Lower frequency limit ____ MHz

Upper frequency limit ____ MHz Bandwidth ____ MHz

Peak frequency ____ MHz

(Repeat for each frequency control setting.)

Noise: ______ µv

Sensitivity Index: ______ µv (4:1 S/N)

12.5 *Time Base Section Report*:

Horizontal Linearity:

Plot Fig. 9 for all repetition rates and sweep lengths of interest.

Pulse Repetition Rate:

Continuously variable control:	Max. rate	________	pps
	Min. rate	________	pps
Switched control: Switch setting	____ Rate	________	pps
	________	________	pps
	________	________	pps

12.6 *Gate/Alarm Report*:

Width Range: Max ____ msec Min ____ µsec

Delay Range: Max ____ msec Min ____ nsec

Resolution:

Alarm just actuated: delay ____ µsec/msec

Alarm off: delay ____ µsec/msec

Resolution: (difference) ____ µsec/msec

Alarm Level:

Minimum level ____ % Full Scale

Maximum level ____ % Full Scale

Hysteresis ____ % Full Scale

Gain Uniformity: Gain change to maintain alarm. ___

Analog Output Plot a graph of output as a function of input such as Fig. 7 for all gain settings of interest, for both the main gate and the back surface gate.

13. Keywords

13.1 electronic characteristics; evaluation; instruments; linearity; pulsers; receivers; ultrasonic