Designation: E1324 – 11

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

This standard is issued under the fixed designation E1324; 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 E317, D2548 and is not intended for evaluating the performance characteristics of ultrasonic testing instruments on the inspection/production line.

NOTE 1—No access to internal circuitry is required.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2548 Method of Test for Analysis of Oil Soluble Petroleum Sulfonates by Liquid Chromatography; Replaced by D 3712 (Withdrawn 1979)[3]

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

E1316 Terminology for Nondestructive Examinations

2.2 *ISO Standard:*

ISO 10012 Measurement Management Systems—Requirements for Measurement Processes and Measuring Equipment[4]

2.3 *ANSI Standard:*

Z540-1 General Requirements for Calibration Laboratories and Measurement and Test Equipment[5]

2.4 *Other Standard:*

IEEE Std. 100, IEEE Standard Dictionary of Electrical and Electronics Terms[6]

3. Summary of Guide

3.1 The electronic performance of each section is measured by identifying that portion of the electrical circuit of the

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

Current edition approved Aug. 1, 2011. Published August 2011. Originally approved in 1990. Last previous edition approved in 2005 as E1324 - 00(2005). DOI: 10.1520/E1324-11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331

***A Summary of Changes section appears at the end of this standard**

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 testing 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 display 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 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 display 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 testing 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 testing 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 testing 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 testing 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 (≥10 kΩ) attenuating (100× or 50×) 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 testing 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 ISO 10012 or ANSI Z540-1, 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

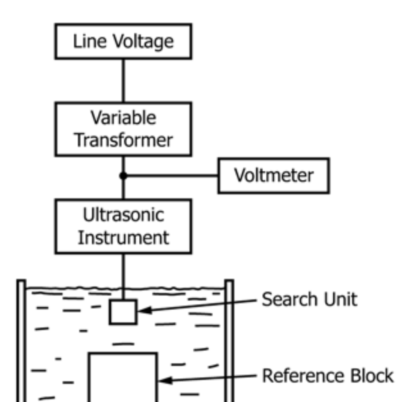


FIG. 1 Setup for Voltage Regulation Measurements

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 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, display 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 display 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. 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 100× or 50× 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

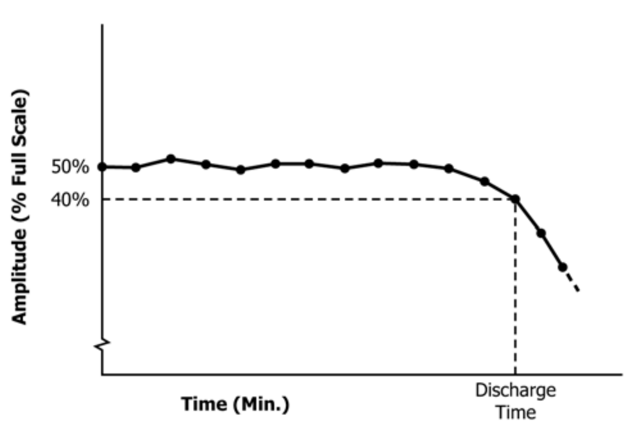


FIG. 2 Battery Discharge Characteristics—Typical

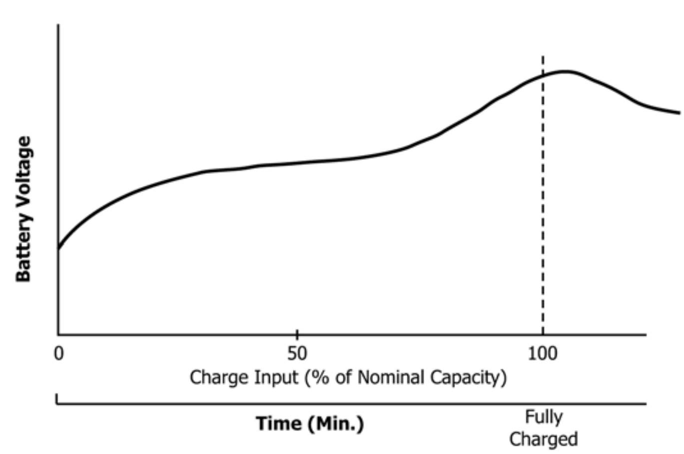
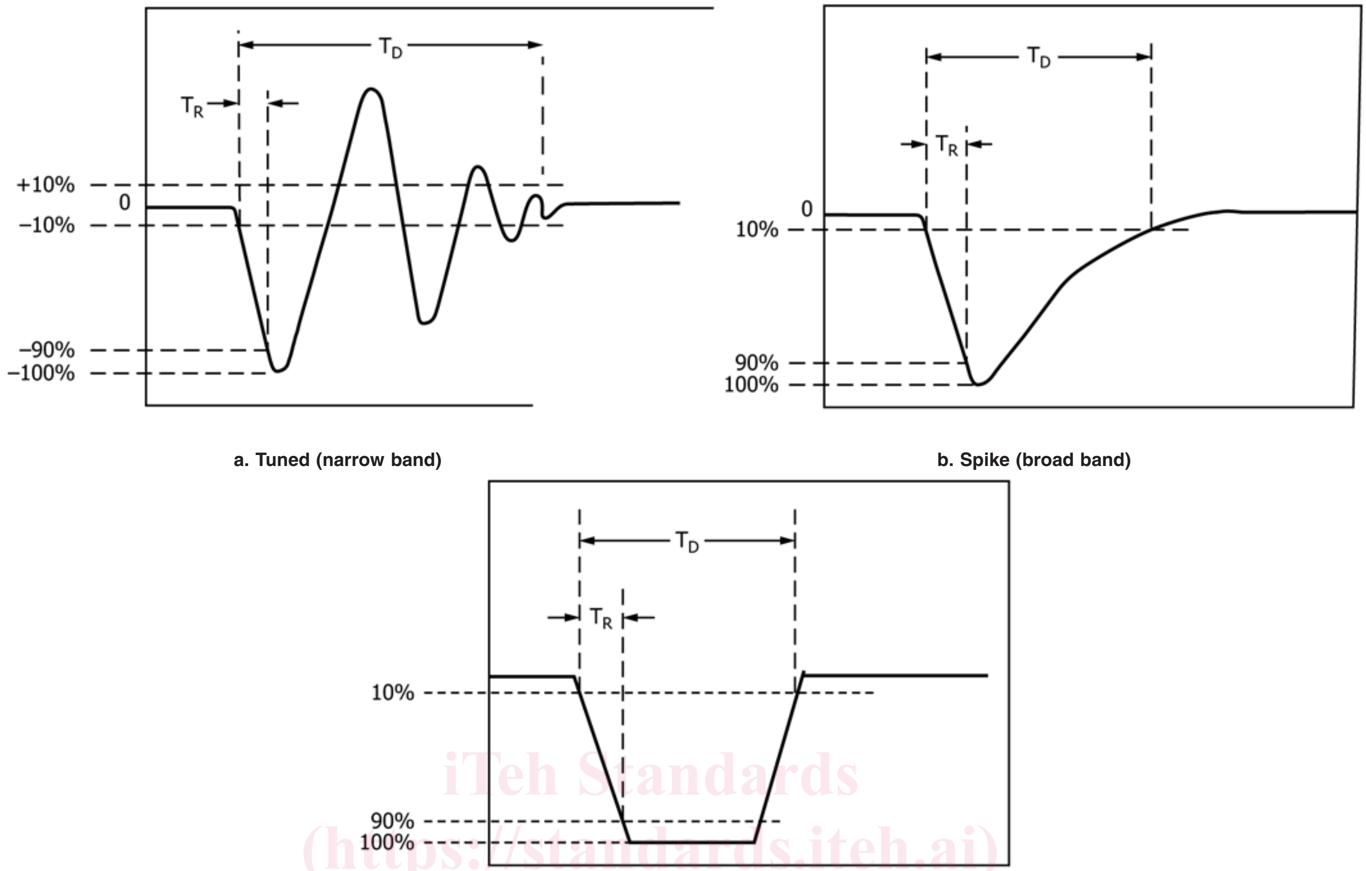


FIG. 3 NiCd and Lead Acid Battery Charge Characteristics—Typical

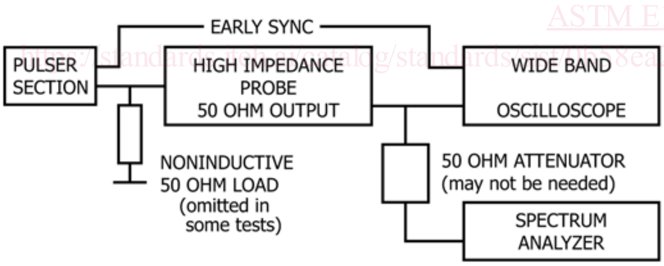


a. Tuned (narrow band)

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

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 nanoseconds) 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

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

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.[7,8]

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

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

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:*

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.

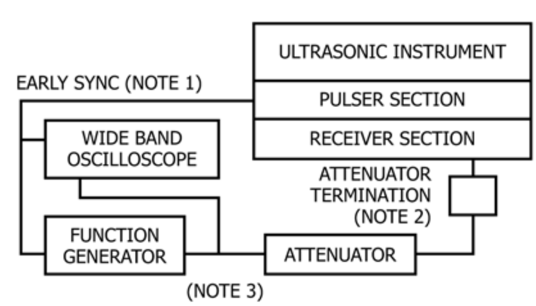
9. Receiver Section Measurements

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.

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



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