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Electrical Performance Tests for True-RMS Voltmeters

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U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Electronics and Electrical Engineering
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Gaithersburg, MD 20899

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U.S. DEPARTMENT OF COMMERCE, C. William Verity, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ELECTRICAL PERFORMANCE TESTS FOR TRUE-RMS VOLTMETERS

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Electrical Performance Tests for True-RMS Voltmeters

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Abstract

Electrical performance test procedures for true-rms voltmeters were developed by the National Bureau of Standards for the U. S. Army Communications-Electronics Command. The report provides detailed, step-by-step test procedures that are based on the specifications supplied by the Army for the purpose of evaluating the bid samples of this type of instrument. Examples of the data sheets and tables for recording of interim data and the final results are given.

This report discusses the philosophy underlying each of the measurement procedures with from a point of view of the basic metrology required to perform the measurements. In addition, the sources of measurement error are discussed.

Key Words: test procedures; true-rms voltmeter; rf voltmeter; and voltmeter.

1. INTRODUCTION

This report describes test procedures that were developed by the National Bureau of Standards (NBS) for the U.S. Army Communications-Electronics Command (CECOM), Ft. Monmouth, N.J., for testing the electrical performance of true-rms responding voltmeters. The test procedures are based on meter performance specifications supplied by CECOM, and will be used by the Army in their Test Measurement and Diagnostic Equipment (TMDE) Modernization Program to evaluate bid samples for this type of instrument. The report focuses only on the test procedures for electrical performance that can be carried out without access to the interior of the instruments under test. The Army performance specifications, for the most part, represent performance levels attainable by modern state-of-the-art commercial wide-band, true-rms ac voltmeters.

The main objective in developing the test procedures has been to provide measurement techniques which are accurate, repeatable, and simple to perform. Most importantly, the procedures must be technically sound so as to provide an unbiased and objective evaluation of competitive instruments. The test equipment chosen has been selected not only to satisfy the requirements of each individual test, but within the broader context of building a laboratory at CECOM with an inventory of modern general-purpose test equipment that will serve a wide range of bid sample testing needs. Thus, most of the test equipment specified by make and model represent equipment that is a part, or will become a part, of the CECOM laboratory.

This report is divided into three sections: The first section gives a brief overview of the Army's TMDE Modernization Program. The second section contains general information on the principles of commercial wide-band, true-rms voltmeters. The third section discusses, in depth, the primary performance measurements with emphasis on a preferred method and a consideration of error sources. The information in this last section is intended to provide the theory and analysis to support the actual test procedures given in Appendix B. The detailed step-by-step procedures in Appendix B are intended for evaluation tests of bid samples by the Army to assure conformance with the set of Army specifications given in Appendix A. Also, included in Appendix B are samples of appropriate data sheets and tables for recording interim and final results.

As part of the test procedures, a computer program for testing the voltmeter efficiently is provided in Appendix C. Appendix D shows the design and characteristics of specialized fixtures that are used in some of the procedures, and Appendix E lists all the test equipment and accessories required for the test procedures. Although the test procedures described in this report were specifically developed for use by the Army TMDE Modernization Program, many of the tests can be considered generic in nature and perhaps could serve as the basis of an industry test standard for commercial, wide-band, true-rms voltmeters.

2. BACKGROUND

The Department of the Army has undertaken a Test, Measurement, and Diagnostic Equipment (TMDE) Modernization Program. The general goal of this program is to provide TMDE for the Army, eliminate the proliferation of numerous types and models of such equipment, and thus reduce the logistical burden. Specifically, the intent of the TMDE Modernization Program is to:

1. Introduce a minimum ensemble of different types and models of up-to-date TMDE into the Army inventory,

2. Replace multiple generic types of TMDE with a single new item, where feasible.

3. Periodically assess the Army TMDE inventory to identify individual or families of TMDE that require replacement.

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The acquisition of new TMDE items progresses through a two-step invitation-for-bid procedure. The first step begins with letter requests that are released to potential offerors for bid samples. The offeror has a period of 60 days to analyze the solicitation requirement and send bid sample equipment to the Communications-Electronic Command (CECOM), Ft. Monmouth, NJ for testing. Equipment is evaluated for performance, useability, maintainability, workmanship, ease of calibration, military suitability, safety, and environmental capability. After the bid sample testing, only the offerors with test equipment that meets the solicitation requirements are invited to submit bids.

The second step occurs when the bids are received, evaluated, and the lowest responsive bidder is awarded the contract. This procedure is believed by the Army to provide reliable and maintainable test equipment with superior performance characteristics for support of weapons systems. Bid sample equipment evaluation requires an established set of test procedures which can objectively determine conformance to specifications. Unlike some evaluations, such as safety and workmanship which are more general and widely applicable, test procedures for electrical performance are by necessity specific for each requirement. That is, for each particular electrical performance specification there must be a procedure. Although some equipment manufacturers provide performance check procedures for purposes of incoming inspection, or readjustment to specifications, there is a lack of generic test methods applicable to various classes of equipment that can be directly and objectively used by the Army. Therefore, before bid sample testing can proceed, appropriate test procedures must be developed and validated. This report describes the test procedures specifically developed by NBS for the Army to perform bid sample testing of commercial high-frequency, true-rms voltmeters.

3. AC VOLTMETER PRINCIPLES

3.1. General Considerations

Voltmeters are one of the commonest tools of the electronic engineer and technician. A decade ago, voltmeters for frequencies up to the order of kilohertz were predominantly analog in nature and essentially consisted of an analog meter movement together with a manual switching network to implement the various range capabilities of the meter. Generally, most analog voltmeters were limited to the measurement of ac voltages with accuracies on the order of 0.5 to 10 percent. The analog meters depended, generally, on the measurand to provide the power necessary for the movement of a meter pointer. Thus, older meters had relatively low input impedance, typically 1000 Ω/V, or less, for operation at the lower audio frequencies. Consequently, in some applications, the input impedance could affect the accuracy of the voltage readings obtained, since at least 500 μA was needed to provide a full-scale deflection of the meter. Most of the ac voltmeters, especially for higher frequencies, including high-impedance input vacuum-tube voltmeters were rectifier instruments responding to average or peak voltage, but calibrated to read rms voltage for sinusoidal signals. If distortion was present, large errors could be incurred with these instruments. With the development of complex, miniaturized, low-power electronic circuitry, more sensitive and accurate meters could be constructed, and, in turn, these meters filled the need to service the newer electronic circuits being designed [1].

The digital voltmeter has largely replaced analog instruments and is generally more accurate and more versatile. It can perform many additional functions such as automatic ranging, data averaging, unit conversions (e.g., dB), and others. The basic functional blocks of the digital ac voltmeter include an ac-to-dc conversion stage followed by a form of analog-to-digital converter. To measure the dc voltage resulting from the first stage, an integrating analog-to-digital converter is generally used. This can be either a dual-slope or voltage-to-frequency type. The integrating period is usually chosen to minimize line-frequency interference.

The digital part of the circuitry in the voltmeter provides a means for making logical decisions, such as automatic ranging (auto-ranging). With auto-ranging, the range setting is automatically or electronically selected to give the best resolution possible, except that hysteresis is provided between the up-range and down-range transitions to prevent hunting between ranges at the transition points. Most ac voltmeters also automatically display the decimal point and indicate the units of measurement as well. Many of the newer ac voltmeters make use of embedded microprocessors to provide features such as linearization of the response characteristic, correction for frequency response, capability for making relative measurements between the present reading and a previously stored value, or special displays such as "analog" bar-graph readouts. Also, some voltmeters are able to store calibration data in an internal memory and automatically correct the readings, making the customary screwdriver adjustments of trimmers unnecessary. The elimination of physical circuit adjustments tends to improve long-term stability.

Although the digital processing power embedded in modern ac voltmeters distinguishes them from their older analog counterparts, the analog circuitry which amplifies and conditions the input signals is still an important factor in the overall measurement accuracy. With typical input impedances of 10 MΩ made possible by high-performance amplifiers, careful design of the range changing attenuator is required to keep a flat frequency response over a wide band. The high input impedance reduces source loading and makes possible overload protection that was previously impractical. The input protection typically consists of a metal-oxide varistor or zener diode circuit, possibly in combination with fuses, which provides a voltage clamping action to prevent high voltages or voltage transients from reaching the voltmeter's solid-state circuitry. The major attribute of such clamping circuitry is speed of operation and the ability to withstand high voltages without impairing the accuracy of the instrument. In addition, the commercial ac voltmeter is also designed to withstand vibration and mechanical shocks that are encountered in field applications.

3.2. Principles of Operation

3.2.1. AC to DC Conversion

The specific principle of operation of an ac voltmeter is highly dependent on the manufacturer's choice of technology and design decisions. In general, ac signals are measured by scaling and converting the ac voltage present at the input of the ac voltmeter to a dc voltage level intended to be proportional to the root-mean-square (rms) of the ac signal. The dc voltage is then digitized and displayed as an ac-voltage amplitude.

The ac(rms)-to-dc conversion can be accomplished by several techniques. Most voltmeters obtain the root-mean-square value either by squaring and averaging of the input signal using an analog multiplier and averaging circuit, or by using thermal converters which compare the heat dissipated by the ac signal to that of an equivalent dc quantity.

The analog multipliers/dividers can employ either direct multiplication and division using variations of the Gilbert (transconductance cell) multiplying circuit [2], or can be based on logarithmic amplifiers. In either case, by connecting the same ac signal to both "multiply" inputs and feeding the averaged output back to the "divide" input, the arithmetic operation can compute the root-mean-square (rms) value of the input.

Both the transconductance type and the logarithmic amplifier type multiplier are available as integrated circuits; some manufacturers also supply specialized rms-computing integrated circuits.

An alternative means of rms-to-dc conversion is provided by thermal converters. These devices employ a voltage-ranging resistor in series with a low-resistance heating element to which a temperature sensor (thermocouple) is attached. The heating effect, and thus the dc voltage produced by the thermocouple, is approximately proportional to the square of the input signal current. To linearize the transfer characteristic, two similar thermoelements are used, one energized with the unknown ac signal and the other with a dc voltage which is adjusted in a servo loop until the thermoelement outputs are equal. The advantage of the thermal technique is that the instrument has a relatively wide bandwidth, is insensitive to waveform distortion, and can tolerate large crest factors. The big disadvantage is a relatively slow response time.

3.2.2. Analog-to-Digital Conversion

After the ac-to-dc conversion stage, most modern ac voltmeters use improved integrating dual-slope (sometimes called 'quad-slope') analog-to-digital converters that correct for zero offset errors and operate on the charge balance principle [3] [4] [5] [6], or the voltmeters use voltage to frequency converters. The dual-slope technique is based on a linear charge-discharge characteristic of a capacitor and arranged so that the discharge time, which is proportional to the input voltage, is measured by counting a train of clock pulses. In its simplest version, the input voltage is integrated by charging a capacitor for a predetermined time. Then, a reference voltage is switched to the integrating circuit and discharges the capacitor at a known rate until a level corresponding to "zero" input is reached. Figure 1 shows the voltage output of an idealized integrator for a typical measurement cycle. The time for the second integration process (discharge time) is proportional the average of the unknown signal over the predetermined integration period. The intergration time is measured by counting pulses generated with a constant clock frequency which is adjusted so that the count displayed on a readout provides a value in the appropriate measurement units.

Dual-slope techniques are widely used since the method does not require high-accuracy resistor networks to achieve high-accuracy measurements. The basis for accuracy resides in the precision reference source which is used during the reference integration time. The components, other than the reference source, are required to be stable only over the integration time in order for the ac voltmeter to hold the specified accuracy. There are many variations to the basic, dual-slope conversion technique. For example, additional circuitry may be added to provide compensation for zero offset during each measurement cycle.[7] [8] This zero compensation is accomplished by effectively shorting the input to the analog-to-digital converter, measuring the offset voltage and then subtracting it (in either an analog or digital manner) from the amplitude of the input signal being measured. Additional techniques may also be used to compensate for calibration errors, temperature errors, and frequency errors of ac measurements.

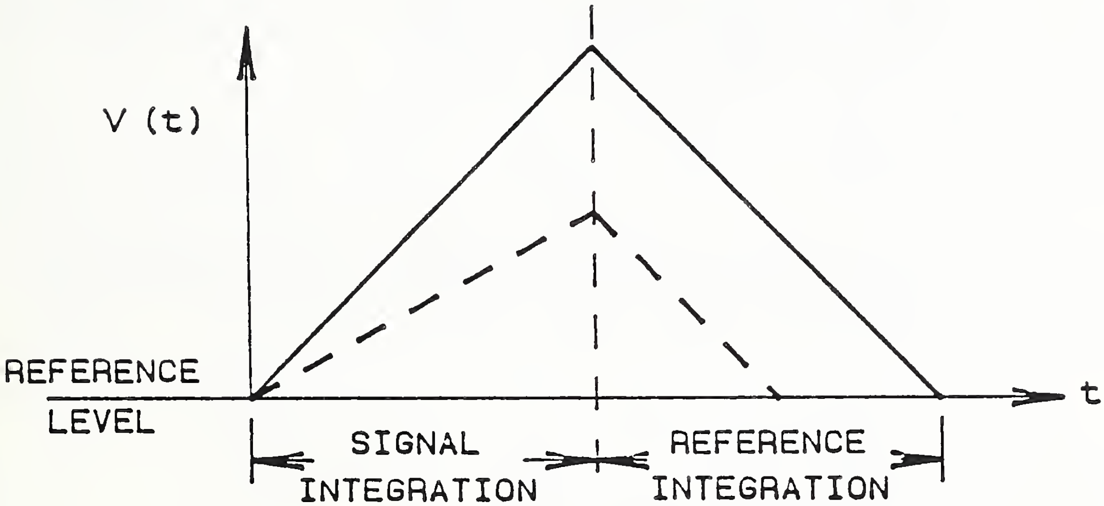

Fig. 1. Concept of dual-slope integration shown for two different input voltages. (The slope of each signal integration curve is proportional to the average of the corresponding input voltage.)

4. VOLTMETER PERFORMANCE MEASUREMENTS

4.1. Input Characteristics

The following sections describe the characteristics of the ac voltmeter input and how to measure them. The characteristics generally specified are: the input impedance, the common-mode rejection, the maximum input voltage and the input over-voltage protection.

4.1.1. Input Impedance

The input characteristics of wideband, ac voltmeters are designed to minimize disturbing the external circuit connected to the input terminals. Ideally, the voltmeter input should have an infinite impedance (zero loading) for ac and dc voltage measurements. In actual practice, the input impedance of the voltage measuring circuitry is typically a resistance of tens of megohms shunted by a capacitance of tens of picofarads. Since the capacitive reactance decreases with frequency, the effect of source loading by the input impedance increases with frequency. At low frequencies the effect of the input capacitance is usually negligible.

Measurement Technique

The input impedance is determined using a commercial digital LCR meter to measure the input resistance and capacitance directly. This instrument is generally a self-balancing bridge which can determine the resistance and capacitance of an impedance across the input terminals. These quantities can be determined without additional equipment or calculations.

Sources of Measurement Error

The errors associated with using a direct-reading LCR meter are attributable to uncertainties associated with the accuracy of the of the LCR meter and the stray capacitance of the leads connecting the LCR meter to the voltmeter under test. The basic calibration accuracy of the LCR meter used in the procedure is specified by the manufacturer to be

0.2 % of reading + 1 digit

for capacitance measurements, and

0.3 % of reading + 2 digits

for resistance measurements. The total errors associated with the LCR meter, considering the ranges used and the number of digits displayed, are ± 2.1 pF and 50 kΩ for the measurement of parallel capacitance and resistance, respectively.

4.1.2. Common Mode Rejection

Common-mode rejection is the degree to which the ac voltmeter measurement of the voltage drop across the input terminals remains unaffected by the presence of a "common" ac voltage at both terminals with respect to ground. This characteristic is particularly important for meters that are grounded by connection to the power line.

Measurement Technique

For the line-operated true-rms voltmeter, the calibrator is connected to the shorted input terminals and to chassis ground on the unit-under-test (UUT) as shown in Figure 2. Two measurements are made to determine the common-mode rejection (CMR); the first reading, V_1, on the unit-under-test is taken with the calibrator voltage set at or near zero, and the second reading, V_2, is taken with the calibrator set to the specified common-mode voltage, V_{CM}. The V_1 is necessary to establish the reading of the voltmeter under conditions of "zero" input. Because of the wide-band response of the meter, noise and other stray signals will result in a non-zero reading even though there is no intended input voltage. The common-mode rejection, in units of decibels, is then calculated using the following equation:

$$\mathrm{CMR} = 20 \log_{10} \frac{(V_2^2 - V_1^2)^{1/2}}{V_{CM}} .$$

This procedure can be carried out at the specified frequencies and repeated at other frequencies. (The most commonly encountered power-line frequencies are 50, 60, and 400 Hz.)

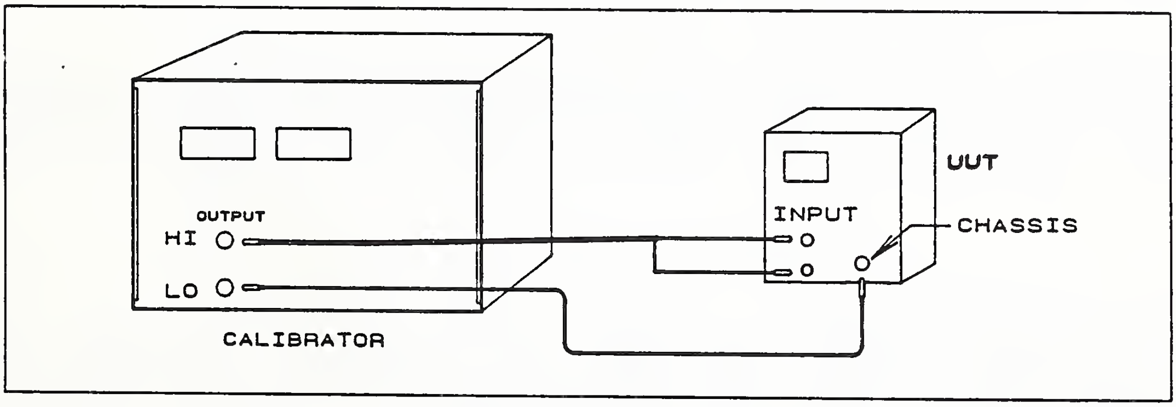

Fig. 2 Test setup for measuring ac common mode rejection ratio.

Sources of Measurement Error

The predominant source of measurement error is the voltmeter-under-test. If the common-mode voltage is small, the meter may not have sufficient resolution to provide more than a two-digit reading. Another, though usually negligible source of error, is the small but finite output voltage of the calibrator when its nominal output is assumed to be "zero." Since this voltage term, V_1, is squared in the calculation, its effect is normally small. (If V_1 is equal to 10% of V_2, it will produce only a 1% error [0.09 dB]).

4.1.3. Input Protection

The input protection circuitry of the ac voltmeter permits the unit to survive voltage overloads without damage. This characteristic is important since the ac voltmeter may accidentally be subjected to high voltages when the range switch is set to a low-voltage range.

Measurement Technique

The ability of the input circuity to withstand an overload condition is tested by applying to the voltmeter-under-test the specified overload voltage on all ranges. The overload protection tests are based on the tests for a maximum nondestructive input signal specified by the manufacturer as described in ANSI C39.6-1983 (paragraph 6.13)[1]. The meter passes the test if, after application of the specified voltage for the specified time (five minutes, if the specification is for continuous application), the meter still meets is rated accuracy requirements.

Sources of Measurement Error

The input protection tests are designed as pass/fail tests. As such, there is no source of meaningful measurement error. The uncertainty of the applied voltage, supplied by a high-accuracy meter calibrator, is negligible for this test.

4.2. AC Voltage Performance Tests

As pointed out in Section 3., measurement of ac quantities is usually a two-stage process. In the first stage, the ac voltage is converted to an equivalent dc voltage, and in the second stage the dc voltage is digitized and displayed. In the first stage of the process, the accuracy of the ac-dc conversion circuitry is frequency dependent, and the range resistor network may be both frequency and amplitude dependent. In the second stage, the dc voltage-to-digital-output circuitry is independent of the frequency, but can introduce amplitude errors due to the non-linearities and incorrect reference voltages in the converter. Therefore, it is necessary to determine the performance of the ac meter at various combinations of frequencies and voltage levels.

4.2.1. Range and Accuracy

Using the accuracy specifications as a guide, test points are selected over the frequency and amplitude ranges of the unit-under-test. Generally, test points are chosen along the upper or lower limits, or both, associated with a specified accuracy on a frequency-amplitude plot. Additionally, intermediate points may also be chosen so that at least one point is checked on each amplitude range of the unit-under-test at one or more frequencies.

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[1] American National Standard for Electrical Instrumentation - Digital Measuring Instruments, ANSI C39.6-1983, published by the American National Standards Institute, 1430 Broadway, New York, NY 10018.

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Measurement Technique

No single measurement technique is adequate to check the accuracy over the entire frequency band of the true rms-voltmeter at all voltage levels. Three different methods are recommended for voltage measurement:

1. Over the frequency range from 10 Hz to 1 MHz, and for amplitudes from 1 mV to 1000 V, a meter calibrator (with an associated high-voltage amplifier) can check the voltmeter directly.

2. Above 1 MHz, and for voltages from 1 V to 100 V, an uncalibrated test signal source is used, and a calibrated thermal converter is connected in parallel with the voltmeter input. The voltage source is then adjusted until the output of the calibrated thermal converter indicates that the desired voltage level has been reached. The voltage source is then effectively calibrated and the actual meter reading can be compared against the calibration voltage.

3. For voltages below 1 V, at all frequencies, the calibration voltage is obtained from a micropotentiometer. A micropotentiometer is essentially a thermoelement used as an rms current measuring device. The current passes through a special shunt resistor that has a very low ac-dc difference and the voltage drop across the shunt becomes a calibrated output voltage. Typically, the current is 10 mA and shunts are in the range from 0.01 to 10.0 Ω so that output voltages from 100 μV to 100 mV can be obtained.

Note: Thermal converters or micropotentiometers are assigned an ac-dc difference by the manufacturer or an independent calibration laboratory based on intercomparisons with similar devices with known or computable ac-dc difference. The value of this ac-dc difference is usually stable over long periods of time. However, the operating characteristic that links the current through a thermoelement with the output voltage of the temperature sensing device (thermocouple) is subject to drift. Therefore, before use in either method 2 or method 3 above, a preliminary calibration against a known dc or low-frequency ac reference standard is necessary.

Sources of Measurement Error

A source of error with electrical and electronic measuring instruments of any kind are currents that bypass the measuring circuit through ground loops or other stray paths. While it is relatively simple to avoid such stray currents with proper insulation when measuring dc, for ac the problem is more complex because of capacitive and inductive coupling. This is especially true for the true-rms voltmeter. Careful circuit design, grounding, and shielding are necessary to avoid this type of error. Each set-up has to be considered individually, and general rules can serve only as broad guidelines.

At low audio frequencies inductive coupling predominates, while capacitive coupling becomes more important with increasing frequencies. Any measuring circuit that produces a change in the reading when the operator comes near or touches part of the case or outside of a connecting cable is liable to give an incorrect measurement result. This is true even if care is taken not to touch or approach the equipment. A rearrangement of the measuring circuit, and in particular of the ground connections and shielding, is then advisable.

For performance tests on the true-rms ac voltmeter for signals above 10 MHz, the characteristic impedance of the connecting cables and connectors becomes important because of reflections at connectors and all other cable junctions. Careful placement of critical circuit components is necessary to be sure that the set-up measures the desired quantity. For instance, for a broad-band ac voltmeter at frequencies as low as 20 MHz, a few inches of coaxial cable between the high-impedance voltmeter input and the 50 Ω terminating resistor can make an appreciable difference in the voltmeter reading. Keeping leads as short as possible is desirable.

When calibrating thermoelements with dc, errors can arise if the dc reversal difference in the thermoelement response is not taken into account. Measurements should always be made with both polarities of dc applied, and the average of the two readings should be used as a reference for subsequent ac measurements. Also, devices containing thermoelements (thermal converters and micropotentiometers) tend to drift with changes in ambient temperature and should, therefore, be protected from such temperature changes during the measurement.

To compute the uncertainty in the calibration voltage or current using method 1 (calibrator) above, only the specified error limits of the calibrator have to be taken into consideration.

For method 2 (thermal converter), the following factors have to be considered:

i. Uncertainty in the reference voltage (u_r) (which can be dc or low-frequency ac).
ii. Uncertainty in the thermal converter ac-dc difference or frequency response correction (u_c).

The total uncertainty in the calibrating voltage u_T is then computed as

$$u_T = \sqrt{(u_r^2 + u_c^2)} \quad .$$

For method 3 (micropotentiometer) the same formula as that given in method 2 is used. The reference voltage in this case is the average of the two polarities of dc voltage across the shunt resistor of the micropotentiometer as measured by a calibrated dc microvoltmeter. The corresponding uncertainty, u_r, is the uncertainty in making this dc measurement. The uncertainty, u_c, in the frequency response is the uncertainty in the ac-dc difference of the micropotentiometer at the measurement frequency.

4.2.2. Frequency Range

Determination of the upper and lower limits of the frequency range of a true-rms responding voltmeter can be combined with the accuracy check of the unit-under-test by selecting test points at the upper and lower specification limits of frequency and signal amplitude.

Measurement Technique

The test method is the same as for section 4.2.1, Range and Accuracy.

The tests for accuracy of the ac voltage ranges of the true-rms ac voltmeter are performed over the specified frequency range including the end points of the range. Instruments that do not exhibit the required accuracy at the endpoints are considered to possess insufficient frequency range. Consequently, no separate "frequency range" tests need to be performed.

Sources of Measurement Error

For a discussion of errors, see Range and Accuracy.

4.2.3. True-RMS Detection

The basis for this test is taken from IEC Publication 51 (which has superseded ANSI C39.1. [9]) The ability of the unit-under-test to measure waveforms using true-rms detection is tested with a nonsinusoidal waveform generated by adding approximately 30% of third harmonic to a fundamental signal at 1 kHz. A true-rms responding meter will give an indication for this non-sinusoidal signal that is independent of the phase angle of the harmonic relative to the fundamental. (Note that an average or peak responding meter will give indications that will vary with the phase angle of the harmonic). To implement the test, a signal with a frequency that is somewhat greater than three times the fundamental by a small fraction of a hertz, is superimposed on the fundamental frequency. In this way the relative phase angle between the two signals increases slowly so that in a time interval of the order of half a minute, the phase angle has swept from 0° to 360°.

Measurement Technique

The test signal is generated by two independent signal generators, with stable frequencies, at least one of which should preferably be a synthesized waveform generator with a frequency adjustment in steps of fractional hertz. The choice of fundamental frequency for this test is arbitrary. For best results it is convenient to chose a frequency in a range where the specified meter error is smallest for both the fundamental and the third harmonic. The harmonic component is generated at about 3.0001 times the fundamental frequency so that the relative phase with respect to the fundamental sweeps through one cycle at a rate slowly enough so that the maximum and minimum meter response can be read. (With the ratio indicated, the phase of a 3-kHz waveform will sweep through 360° in 10 seconds.) The amplitude of the harmonic component should be set at about 20% (30% in the original ANSI standard) of that of the fundamental to conform to the IEC test specifications. To obtain good resolution on the readout of the meter, the amplitudes of the two signals should be chosen so that the meter indicates a value near full-scale on the range when relative phases are such that the combined signal is at a maximum. For instance, if the full-scale meter indication is 1.999 V, then if the fundamental is 1.500 V and the harmonic component is 0.450 (30%), the combined signal will not be greater than 1.950 volts; close to, but less than full-scale.

The simplest way to combine the two signals is to use a resistance network that acts as a summing junction for the inputs from the two generators as shown in the figure 3.

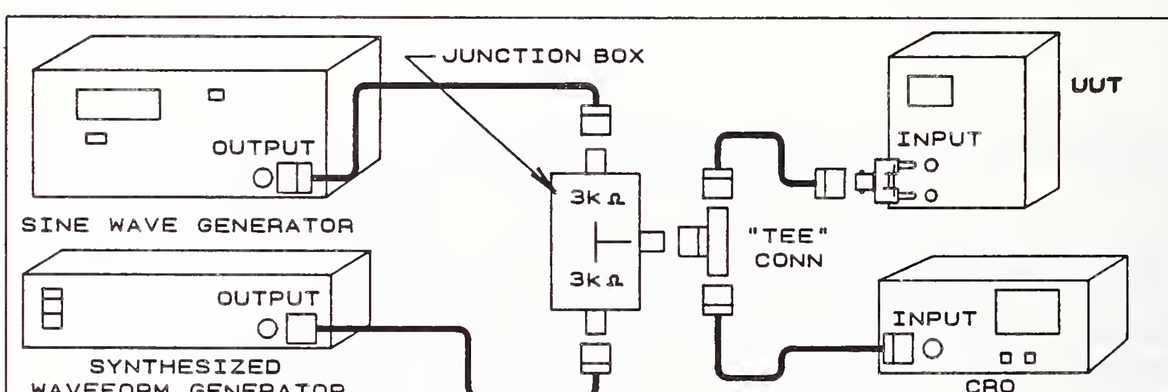

Fig. 3 Set-up to check for true-rms response

Sources of Measurement Error

Since the measurement is concerned only with the constancy of the indicated value within the response tolerance for the range, a calibrated ac voltage source is not required. Even the signal frequencies need only be approximate for this test. Uncertainty statements are therefore not applicable.

4.2.4. Crest Factor

A crest-factor test is an important performance measure of voltmeters employing true-rms detection. The crest factor is the ratio of the maximum value of a voltage waveform (the peak) to the effective or rms value. Crest-factor limitations introduce an error when measuring non-sinusoidal signals.

Typical true-rms voltmeter systems can accept signals at full scale with crest factors of 4:1 or higher. When a crest factor specification does not contain an accuracy degradation statement, it must be assumed that all accuracy specifications are applicable for signals with the specified crest factor . High crest-factor signals inherently have a broad spectrum of harmonics, but for a given crest factor the spectral distribution depends on the waveshape of the signal. By careful choice of the waveshape of the test signal, it is therefore possible to set an upper frequency limit for significant harmonic components. For each given accuracy specification of the voltmeter response, there is an upper and lower frequency limit, and it is advantageous for the crest factor response determination to choose a test signal that has all of its significant frequency components within those frequency limits. If some significant harmonic components fall into another accuracy specification region, it becomes difficult to assess whether the voltmeter has passed or failed the test. Thus, unless the crest-factor test signal is carefully chosen, consistent test results will not be obtained.

Measurement technique

A crest-factor measurement is made by applying a test waveform with the specified crest factor to the voltmeter-under-test and comparing the voltmeter's indication with the true-rms value of the test waveform determined by independent means. A worst case condition is ensured by setting the rms value of the test waveform near the full-scale value of a range. For an autoranging voltmeter, an amplitude adjustment is required so that the test waveform amplitude is close to the upper end of a range.

The bipolar triangle waveform, shown in figure 4, offers a good compromise between ease of generation and mitigation of the higher order harmonics. In the absence of any specified waveform, it is the test waveform used for the procedure described in Appendix B.

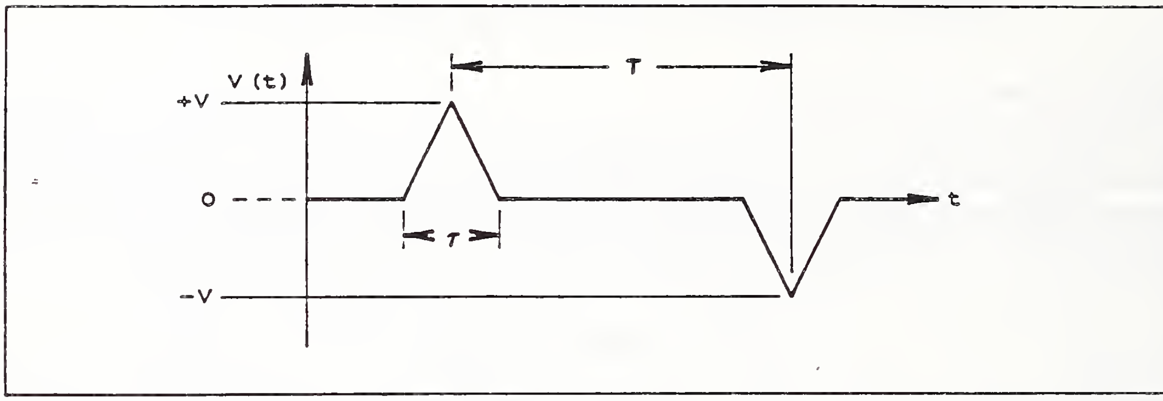

Fig. 4. Crest factor test waveform

The crest factor of this waveform is given by

$$CF = (3T/\tau)^{1/2} \quad . \tag{1}$$

For a 4:1 crest factor, the ratio of T/τ becomes 16/3. The average of the test waveform is zero and therefore exercises the full peak-to-peak dynamic range of the voltmeter-under-test. The test waveform of figure 4 is most easily generated by an arbitrary waveform generator, but this method limits the fundamental to audio frequencies. A more meaningful test for the wideband, true-rms voltmeter should be performed at a fundamental test frequency near mid-band, and at a frequency which is low enough to insure that all the significant harmonics are within the specified frequency band. A test fixture, which generates the waveform shown in figure 4 with a 4:1 crest factor, has been specifically designed for the crest-factor test procedure. The design was implemented using a few logic gates and an operational amplifier. The details of the circuit can be found in Appendix D. The width of the triangle pulse τ is set to 3 μs and the interval T to 16 μs. The output amplitude of the waveform generator is set to a nominal 1-volt rms level. In the test procedure, a power amplifier boosts the output of the crest factor generator to a nominal level of 100 volts rms and applies it to the voltmeter-under-test at a full scale range setting of 100 volts. Performing the crest factor test at high amplitudes will emphasize any slew-rate limitations existing in the voltmeter under test. The magnitude spectrum of the crest factor test waveform at the output of the power amplifier, Fig. D-2, Appendix D, shows that all significant harmonic energy is well within the bandwidth of the voltmeter.

Sources of Measurement Error

The main source of error for this measurement is the uncertainty with which the measurement of the rms value of the crest-factor signal can be made. Thermal converters offer the most accurate means of determining the rms value of high crest-factor waveforms. Thermal converters respond inherently to the rms value and have a flat frequency response over a wide range [10]. In the accuracy specification region on a frequency-amplitude plot, where the voltmeter accuracy is specified as ± 3%, the measurement uncertainty of the crest-factor waveform using a thermal converter can be conservatively estimated to be better than 0.1%. The sources of error and measurement uncertainty are generally the same as those discussed in Section 4.2.1.

4.2.5. Response Time

The response-time determination establishes whether a voltmeter reading within the specified accuracy limits can be obtained in the time interval specified.

Measurement Technique

The measurement of response time for instruments having only a visual readout is necessarily somewhat subjective and dependent on operator reaction time. The measurement is carried out with a bus controlled calibrator which applies a voltage to the unit-under-test, and, after a programmed time delay corresponding to the specified response time, the operator is signaled to read the meter. If the reading falls within the accuracy limits applicable for the range and frequency of the input, the test is deemed successful. Generally, it is beneficial to repeat the test several times to check the consistency of the result and to assure that the observer does not contribute excessive random errors to the outcome of the test.

Sources of Measurement Error

The predominant source of error is the reaction time of the observer. With practice, a skilled observer should be able to reduce the uncertainty in the time interval between application of the input signal and noting of the readout to ± 0.2 seconds. Additional timing delays introduced by the bus controller, usually of the order of a few milliseconds, are negligible.

5. REFERENCES

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[7] Mattera, L., Converter Stresses Stability, *Electronics*, p. 139-140, February 19, 1976.

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Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories, *IEC Publication 51 -1984*

[10] Hermach, F. L., AC-DC Comparators for Audio-Frequency Current and Voltage Measurements of High Accuracy, *IEEE Trans. on Instrum. & Meas.*, Vol. IM-25, No. 4, pp.489-494, December 1976.

APPENDIX A

PERFORMANCE SPECIFICATION FOR THE ME-545()/G TRUE-RMS VOLTMETER[2]

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2 Reprinted from the U. S. Army specifications for the TMDE modernization project.

10.1 Type of Response

Meter AC voltage measurement capability shall be true rms responding over the entire voltage range, (para. 10.3).

10.1.1 DC Coupling

Meter shall have the capability of being dc coupled, for measuring AC signals with DC components.

10.2 Frequency Range

Frequency response shall be at least 10 Hz to 20 MHz.

10.3 Voltage Range

Shall be from 100 micro-volts rms or less, to 300 volts rms or greater except where limited by the volt-hertz product of para. 10.12.

10.3.1 Selectable Ranges

Meter shall provide no less than seven selectable ranges, with the lowest full scale range no greater than 2 millivolts rms, and the greatest full scale range at least 300 volts rms.

10.3.2 Ranging

Shall be auto-ranging, also shall have the capability of manually setting the range. Shall provide at least 10% over-range, or 10% under-range when manually auto-ranged.

10.3.3 Voltage Resolution

Display resolution in voltage mode shall be at least as specified herein:

READING	RESOLUTION
for readings below 1.999 mV	1 microvolt
2.00 mV to 19.99 mV	10 microvolts
20.00 mV to 199.9 mV	100 microvolts
200 mV to 1999 mV	1 millivolt
2.00 V to 19.99 V	10 millivolts
20.0 V to 199.9 V	100 millivolts
200 V to 300 V	1 volt

10.4 Display Type and Units

Shall have a digital display with 3 1/2 digits, or more, in the voltage mode. Shall also have analog peak and null indicator. Analog peak and null indicator shall show changes in voltage equal to, or greater than 5% of full scale of range in use. The digital display shall have annunciators for volts, millivolts, decibels relative, dBm, and polarity.

10.5 Decibel Measurements

Meter shall have a minimum span of 130 dB and comply with the requirements herein.

10.5.1 Decibel Display and Resolution

Meter shall have at least 4-digit display with polarity indicator when in the decibel mode, decibel resolution shall be at least 0.01 dB.

10.5.2 dBm Reference Impedance

In dB mode, reference impedance shall be selectable, with a minimum of five selection: 50 ohms, 75 ohms, 124 ohms, 135 ohms, and 600 ohms.

10.6 Accuracy

Shall be at least as specified below over the operating temperature range from 18 to 28 degrees Celsius, for ac-coupled measurements. AC + DC measurement accuracy shall be within twice the tolerance for ac measurements.

RF-DC transfer difference from dc to 100 MHz at a voltage level of 100 microvolts

Shall be within ± 0.2% of dc input level.

Accuracy for frequencies from 10 Hz to 49.99 Hz for all input levels from 100 microvolts to 300 volts

Shall be within ± 5% of true input level.

Accuracy for frequencies from 100 Hz to 99.9 kHz for all input levels from 100 microvolts to 1 millivolt

Shall be within ± 5% of true input level.

Accuracy for frequencies from 100 kHz to 999.9 kHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Shall be within ± 5% of true input level.

Accuracy for frequencies from 1 MHz to 9.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Shall be within ± 10% of true input level.

Accuracy for frequencies from 10 MHz to 19.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Shall be within ± 15% of true input level.

Accuracy for frequencies from 10 Hz to 49.99 Hz for all input levels from 100 microvolts to 300.0 volts and for frequencies from 50 Hz to 99.99 kHz; for all input levels from 1 millivolt to 300 volts (200 volts from 20 kHz to 99.99 kHz).

Shall be within ± 3% of true input level.

Accuracy for frequencies from 100 kHz to 999.9 kHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Shall be within ± 5% of true input level.

Accuracy for frequencies from 1 MHz to 9.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Shall be within ± 10% of true input level.

Accuracy for frequencies from 10 MHz to 19.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Shall be within ± 15% of true input level.

10.7 Response Time

Shall be 3 seconds or less to rated accuracy.

Shall be within ± 3% of true input level.

10.8 Crest Factor

Meter shall handle crest factors of 4:1 for all input levels below 100 volts, increasing for downscale measurements.

10.9 Input Connector

Input connector of meter shall be selectable by a front panel switch, allowing the outer connector to be floating from chassis ground or to be connected to chassis ground. Connector type shall be BNC type female.

10.11 AC Common Mode Rejection

Shall be greater than 60 dB up to 400 Hz.

10.12 Maximum Input Protection

Shall be at least 420 volts peak (300 volts rms) on all ranges, and shall be at least 1×10^8 volts-hertz on all ranges above 1 volt.

10.13 Input Impedance

Input impedance shall be 1 megohm or greater, shunted by 50 picofarads capacitance or less.

10.14 DC Output

The meter shall have rear panel dc output. Output connector shall be BNC type female or dual banana female.

ELECTRICAL PERFORMANCE TESTS FOR TRUE-RMS VOLTMETERS

APPENDIX B

TEST PRODEDURES FOR THE ME-545()/G TRUE-RMS VOLTMETER

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Note:

The material in this Appendix has been prepared for use by the Department of the Army, CECOM, Fort Monmouth, New Jersey. Certain commercial equipment is identified with each test procedure listed. This identification does not imply endorsement by the National Bureau of Standards, nor does it imply that the equipment identified is necessarily the best available for the purpose.

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

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TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

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10.1 Type of Response

Specification:

Meter AC voltage measurement capability shall be true rms responding over the entire voltage range, (para. 10.3).

The test checks whether the meter is true-rms responding. The basis for this test is taken from ANSI 39.1 and consists of adding approximately 30% third harmonic to a fundamental signal at 1 kHz. A true-rms responding meter will give the same indication for this non-sinusoidal signal independent of the phase angle of the harmonic relative to the fundamental. (Note: an average or peak responding meter will give indications that are dependent on the phase angle of the harmonic.) To implement the test, a signal with a frequency that is greater than three times the fundamental by a small fraction of a hertz, is superimposed on the fundamental frequency. In this way the relative phase angle between the two signals increases slowly so that in a time interval of about one minute the phase angle has increased from 0° to 360°.

Test Condition :

The fundamental frequency (1 kHz) is generated with the Wavetek Model 275 Arbitrary Waveform Generator, and the harmonic component is produced using the Hewlett-Packard Model 3325A Function Generator.

Equipment:

Items	Model
Function Generator	Hewlett-Packard 3325A or equivalent
Arbitrary Waveform Generator	Wavetek 275 or equivalent
Oscilloscope	Tektronix 465 or equivalent
Cable with BNC connectors	
BNC tee connector	
Special Resistor Junction Box	Special part (NBS)

Procedure:

Set up the equipment as shown in figure 10.1a. Connect the output of the function generator and of the arbitrary waveform generator to the resistor terminations of the special resistor junction box. Attach a BNC tee to the third connector of the junction box, and connect one end of the tee to the UUT and the other to the oscilloscope.

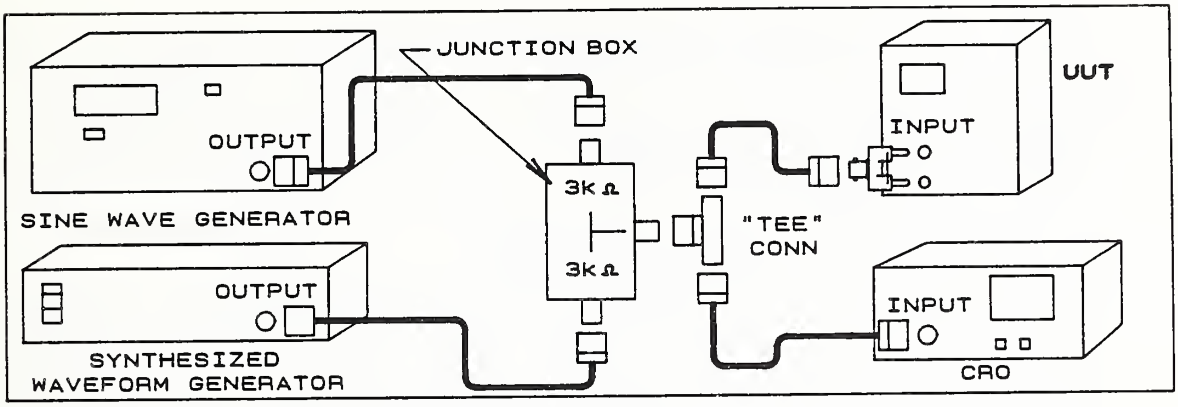


Fig. 10.1a Set-Up for Type-of-Response Test

To set up the Wavetek Model 275, push the front-panel controls in the following sequence:

1. Power

2. STAT Check Display as indicated in Wavetek Instruction Manual, page 2-4.

3. OUT-ON, 1, EXEC Display reads "OUTPUT ON(1)" (This command connects the signal to the output terminal)

Steps 1 to 3 set up the Wavetek Function Generator to its default values of 1 kHz and 5 V.

The next three steps will set up the Hewlett-Packard Model 3325A Synthesizer to approximately 3 kHz and 1.5 V rms.

4. Turn on power switch

5. FREQ, 3, kHz

6. AMPTD, 1.5, V rms.

This should produce an image of a distorted sine wave on the oscilloscope. Since the frequency setting of the Wavetek Model 275 may not be exactly 1 kHz, a fine adjustment of the frequency of the Hewlett-Packard Model 3325A Synthesizer may be necessary. To adjust the frequency, proceed as follows:

7. FREQ, Left arrow in the "Modify" field. (This turns on additional digits on the display).

8. Push left arrow repeatedly until the zero to left of the decimal point is blinking.

9. Push the "up" or the "down" arrow until the pattern on the oscilloscope is almost stationary.

   If the adjustment is too fine, use the "left" arrow once more, then use the "up" or "down" arrows.

   If the adjustment is too coarse, use the "right" arrow instead of the "left" arrow and proceed as before.

   If the frequency fine adjustment has been done correctly, the image on the oscilloscope screen should vary slowly from one waveform, shown in figure 10.1b, to the other and back again. The time for the pattern to return to its original shape should take approximately 10 seconds.

10. While the waveform pattern is changing slowly, observe the output reading of the digital voltmeter-under-test (UUT), and enter into the data sheet the highest and lowest readings obtained. The difference between the two readings should be within ±3%.

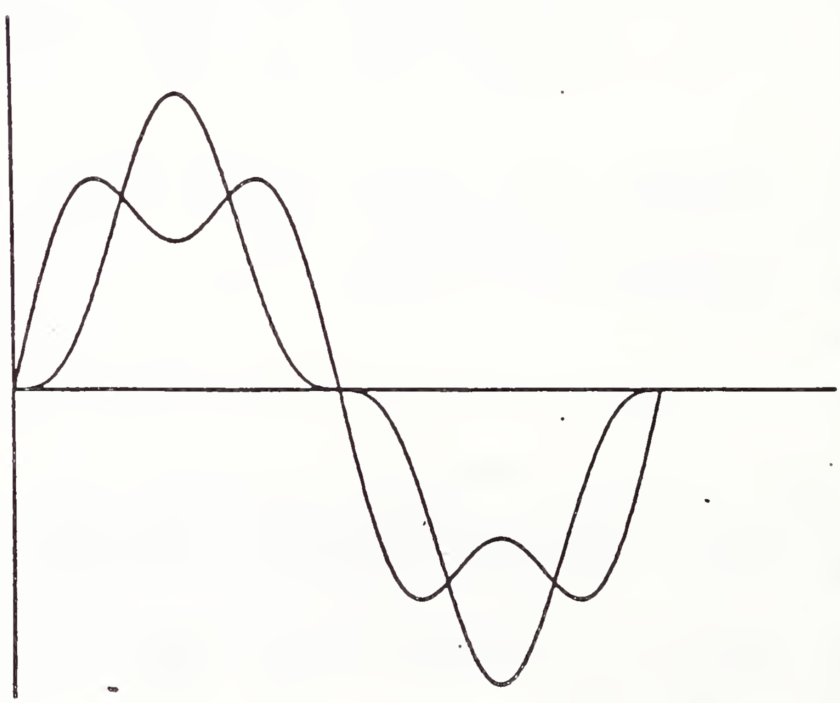


Fig. 10.1b Waveforms for Type of Response Test

Table 10.1 Type-of-Response Test

High Reading (Volts)	Low Reading (Volts)	Difference (Volts)	Uncertainty	Specification Limits
			±1 lsd*	± 3%

* least significant digit on display

10.1.1 DC Coupling

Specification:

Meter shall have the capability of being dc coupled, for measuring ac signals with dc components.

This test checks whether the digital voltmeter under test (UUT) correctly combines dc signals and ac signals. The Hewlett-Packard Model 3325A Function Generator (or equivalent) is used as signal source. This signal generator provides means for adding a dc offset (maximum 443 mV).

Equipment:

Items	Model
Function Generator	Hewlett-Packard 3325A or equivalent
DC millivoltmeter	Fluke 8506A or equivalent
Oscilloscope	Tektronix 465 or equivalent
Cable with BNC connectors	
50-ohm BNC adapter	
BNC tee connector	
BNC to dual banana adapter	

Procedure:

1. Connect the output of the Hewlett-Packard Model 3325A Function Generator to the digital voltmeter under test (UUT) using a 50-ohm BNC adapter at the voltmeter input terminal and also to the input of the dc millivoltmeter. Set the UUT to its "ac+dc" mode, and set the millivoltmeter to its 1-volt dc range.

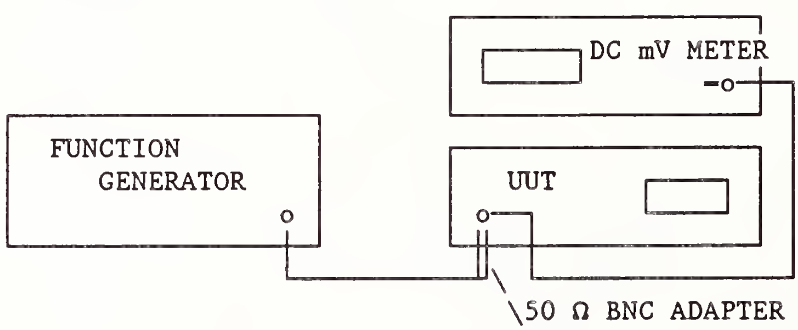


Fig. 10.1.1 Set-Up for testing DC Coupling

2. Set the frequency to 1 kHz.

3. Set the amplitude to 30 mV rms.

4. Set the dc offset to 0.00 V.

6. Read the meter and record the ac reading on the data sheet.

7. Set the dc offset to 0.040 V.

8. Read the UUT and record the ac+dc reading on the data sheet, Table 10.1.1.

9. Read the dc millivoltmeter and record the dc reading on the data sheet.

10. Compute what the meter should read using formula below:

$$\text{reading(ac+dc)} = \sqrt{\{(\text{ac rdg in mV})^2 + (\text{dc reading})^2\}}$$

Table 10.1.1 DC Coupling Test

AC Reading (mV) [Step 6]	AC+DC Reading (mV) [Step 8]	DC Reading (mV) [Step 9]	Computed Reading (mV) [Step 10]	Uncertainty (mV)	Specification
				0.08	± 6%

10.2 Frequency Range

Specification:

Frequency response shall be at least 10 Hz to 20 MHz.

Compliance with the frequency range specifications is implicit if the digital voltmeter-under-test (UUT) passes the tests for accuracy (see 10.6). A special test is therefore not necessary.

10.3 Voltage Range

Specification:

Shall be from 100 micro-volts rms or less, to 300 volts rms or greater except where limited by the volt-hertz product of para. 10.12.

The limits of the voltage range of the digital voltmeter under test (UUT) are determined as part of the Accuracy test (see 10.6).

10.3.1 Selectable Ranges

Specification:

Meter shall provide no less than seven selectable ranges, with the lowest full scale range no greater than 2 millivolts rms, and the greatest full scale range at least 300 volts rms.

Procedure:

1. Consult the manufacturer's literature concerning the number and upper limits of the selectable ranges available.

Table 10.3.1 Selectable Ranges

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Number of ranges	________	N/A	7		
Lowest range	________	N/A		2	mV
Highest range	________	N/A	300		V

10.3.2 Ranging

Specification:

Shall be auto-ranging, also shall have the capability of manually setting the range. Shall provide at least 10% over-range, or 10% under-range when manually auto-ranged.

This test determines whether in the automatic mode sufficient hysteresis has been provided so that the instrument will not hunt between ranges when the input voltage is near the range transition voltage.

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Power amplifier	Fluke 5205A or equivalent
Cable with BNC connectors	3 feet or less, each.
Dual banana plug to BNC adapter	

Procedure:

1. Connect the ac voltage calibrator (Fluke Model 5200) to the digital voltmeter under test (UUT) using a dual banana plug-to-BNC adapter and a cable with BNC connectors. Use the set-up shown in Fig. 10.3.2b for tests greater than 120 volts.

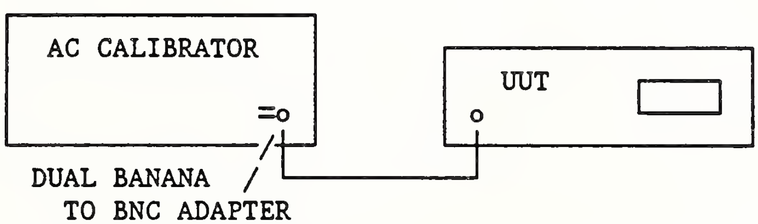


Fig. 10.3.2a Set-Up for Voltage Range Test

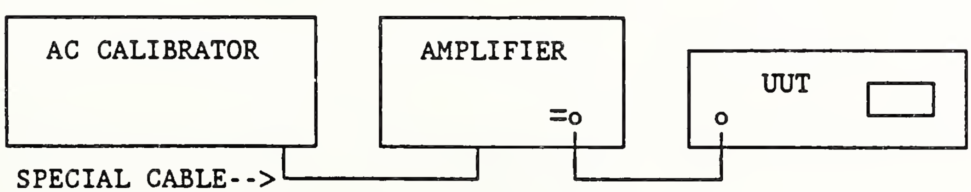


Fig. 10.3.2b Set-Up for Voltage Range Test for voltages above 100 volts

2. Set the amplitude to zero, and set the frequency of the calibrator to 1 kHz.

3. Set the UUT to autoranging.

4. Increase the voltage of the calibrator so that a reading on the lowest range is obtained.

5. Slowly increase the voltage further until the UUT switches to the next higher range. Note, but do not record the approximate transition voltage.

6. Starting from somewhat below the approximate transition voltage, again increase the voltage, but more slowly than before, until the meter changes range. Observe the indicated voltage at each step and record the voltage on the data sheet corresponding to the step <u>just before</u> the meter changes to the next higher range. The changing of the range occurs when the analog voltage indicator changes from near full-scale deflection downscale to zero or near zero.

   If the transition voltage cannot be determined exactly on the first try, repeat step 6, allowing the meter to settle a little longer after each step increase of the input voltage.

7. Starting from somewhat above the transition voltage, decrease the input voltage, using a procedure similar to that of step 6, until the meter shifts to a lower range. Record on the data sheet the indicated voltage <u>after</u> the downshift has occurred.

8. Repeat steps 6 and 7 for each range of the meter.

Table 10.3.2 Ranging

Transition Up-Range	Transition Down-Range	Difference	Uncertainty	Specification Limits
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%
			N/A	± 10%

10.3.3 Voltage Resolution

Specification:

Display resolution in voltage mode shall be at least as specified herein:

READING	RESOLUTION
for readings below 1.999 mV	1 microvolt
2.00 mV to 19.99 mV	10 microvolts
20.00 mV to 199.9 mV	100 microvolts
200 mV to 1999 mV	1 millivolt
2.00 V to 19.99 V	10 millivolts
20.0 V to 199.9 V	100 millivolts
200 V to 300 V	1 volt

Test Points:

Table 10.3.3.1

T.P.No.	Test Voltage	Voltage Increment	Frequency
1.	1.998 mV rms	0.001 mV rms	10.00 kHz
2.	19.98 mV rms	0.010 mV rms	10.00 kHz
3.	199.8 mV rms	0.100 mV rms	10.00 kHz
4.	1.998 V rms	0.001 V rms	10.00 kHz
5.	19.98 V rms	0.010 V rms	10.00 kHz
6.	199.8 V rms	0.100 V rms	10.00 kHz
7.	298 V rms	1.000 V rms	10.00 kHz

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Power amplifier	Fluke 5205A or equivalent
Cable with BNC connectors	3 feet or less, each.
Dual banana plug to BNC adapter	

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

1. Connect the ac voltage calibrator (Fluke Model 5200) to the digital voltmeter under test (UUT) using a dual banana plug-to-BNC adapter and a cable with BNC connectors.

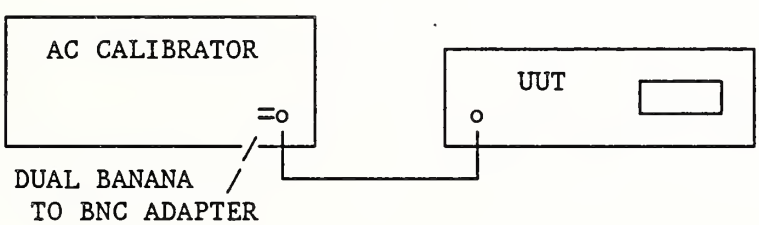


Fig. 10.3.3a Set-Up for Voltage Resolution Test

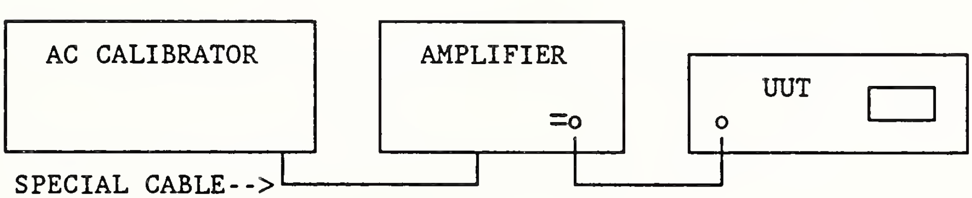


Fig. 10.3.3b Set-Up for the Resolution Test for voltages above 100 volts.

2. Set the output amplitude on the ac calibrator to approximately 1.99 mV.

3. Set the signal frequency to 10 kHz.

4. Using the values given in Table 10.3.3.1, repeat the procedure in step 5 to step 9 below for Test Points 1. to 7.

5. Set the meter to "Auto-Range."

6. Adjust the signal amplitude until the meter reads the value given for Test Point voltage.

7. Set meter to "Manual" range (or "Range Hold").

8. Increase the signal voltage by a step of exactly the incremental voltage given in Table 10.3.3.1.

9. Note and enter the meter reading on the data sheet Table 10.3.3.2.

10. Calculate the differences between the value of the meter reading obtained in step 9 and the Test Point Voltage. (This establishes the resolution on the range selected). <u>Note the units of the Test Point Voltage and the specification limits</u>.

Table 10.3.3.2 Voltage Resolution

Test Point	Meter Rdg.	Difference	Uncertainty	Specification Limits
1.998 mV			±0.01 μV	1 μV
19.98 mV			±0.1 μV	10 μV
199.8 mV			±1.0 μV	100 μV
1.998 V			±0.01 mV	1 mV
19.98 V			±0.1 mV	10 mV
199.8 V			±1.0 mV	100 mV
298 V			±0.01 V	1 V

10.4 Display Type and Units

Specification:

Shall have a digital display with 3 1/2 digits, or more, in the voltage mode. Shall also have analog peak and null indicator. Analog peak and null indicator shall show changes in voltage equal to, or greater than 5% of full scale of range in use. The digital display shall have annunciators for volts, millivolts, decibels relative, dBm, and polarity.

Procedure:

1. Check digital voltmeter under test (UUT) by visual inspection.

Table 10.4 Display Type and Resolution

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Number of digits	________	N/A	3 1/2		
Peak and null indic.	________	N/A	Yes		
Show changes ≥ 5% of FS	________	N/A	Yes		
Proper annunciators	________	N/A	Yes		

10.5 Decibel Measurements

Specification:

Meter shall have a minimum span of 130 dB and comply with the requirements herein.

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Power amplifier	Fluke 5205A or equivalent
Cable with BNC connectors	3 feet or less, each.
Dual banana plug to BNC adapter	

Procedure:

The following test indicates the range of the voltage to decibel conversion capability of the digital voltmeter under test (UUT).

1. Short the input to the meter.

2. Set the meter into the decibel (dB) mode.

3. Set the meter to auto-ranging, note the decibel (dB) reading, and enter the value into the data sheet, Table 10.5.

4. Remove the short from the input and connect the meter to the ac voltage standard and amplifier with the frequency set to 1 kHz, as shown in figure 10.5.

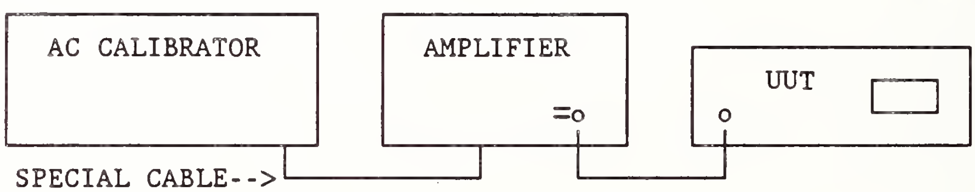


Fig. 10.5 Set-Up for the Decibel Test.

5. Set the output from the ac voltage standard to 300 V.

6. Note the decibel reading with the voltage applied, and enter the value into the data sheet, Table 10.5.

7. Subtract the value obtained in step 3 from the value obtained in step 6, and enter this difference on line 3 of the data sheet, Table 10.5.

Table 10.5 Decibel Measurement

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Reading with input shorted	____________	N/A	****	****	dB
Reading with 300 V applied	____________	N/A	****	****	dB
dB range	____________	N/A	130		dB

10.5.1 Decibel Display and Resolution

Specification:

Meter shall have at least 4-digit display with polarity indicator when in the decibel mode, decibel resolution shall be at least 0.01 dB.

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Cable with BNC connectors	3 feet or less, each.
Dual banana plug to BNC adapter	

Procedure:

The number of digits in the display of the digital voltmeter under test (UUT) are determined by inspection.

1. Set the meter to the auto-ranging mode and to the decibel display mode.

2. Connect the ac voltage standard to the meter as shown in figure 10.5.1, and set the voltage to 1.00 volt.

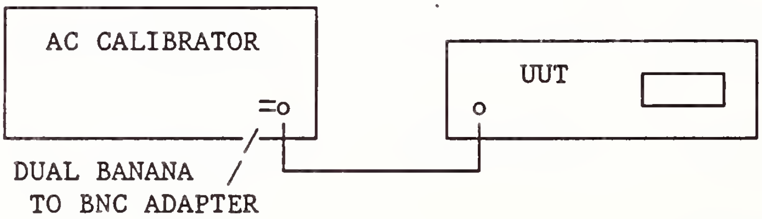


Fig. 10.5.1 Set-Up for Decibel Resolution Test

3. Adjust the voltage up or down until the maximum number of digits are displayed.

4. Check the number of digits and the presence of a polarity indicator and enter the appropriate answers in the data sheet, Table 10.5.1.

Table 10.5.1 Decibel Measurements

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Number of digits	____________	N/A	4		
Polarity indicator	____________	N/A	Yes		
Resolution	____________	N/A	0.01		dB

10.5.2 dBm Reference Impedance

Specification:

In dB mode, reference impedance shall be selectable, with a minimum of five selection: 50 ohms, 75 ohms, 124 ohms, 135 ohms, and 600 ohms.

Procedure:

1. The number and values of the reference impedances are to be determined by inspection.

Table 10.5.2 dBm Reference Impedance

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Number of ref. levels	____________	N/A	5		
Levels comply	____________	N/A	Yes		

10.6 Accuracy

Specification:

Shall be at least as specified below over the operating temperature range from 18 to 28 degrees Celsius, for ac-coupled measurements. AC + DC measurement accuracy shall be within twice the tolerance for ac measurements.

Procedure:

Note: Because of the wide frequency and voltage ranges covered by the digital voltmeter under test (UUT), accuracy tests are carried out using three different methods.

From 10 Hz to 99.9 kHz, for voltages above 1 millivolt, test signals are obtained from a calibrated ac voltage standard, while at frequencies from 100 kHz to 20 MHz an uncalibrated signal source is used, and the voltage applied to the meter is measured using thermal converters.

For measurements at a voltage level of 100 microvolts, regardless of the signal frequency, a micropotentiometer is used.

The procedures that make use of the ac voltage calibrator have been automated with a Hewlett-Packard Model 9836 computer as the controller for the calibrator. Readings of the digital voltmeter under test (UUT) are read visually and entered via the computer keyboard. The computer terminal provides the necessary prompts to carry out the calibration.

For tests at frequencies at or above 100 kHz, a Hewlett-Packard Model 3325A Function Generator and a power amplifier (ENI Model A300-40PA) are used as a signal source. For output voltages from 1.0 to 50.0 volts rms, the output of the amplifier is connected directly to the input of the meter, and for voltages above 50 volts a special step-up (output) transformer (ENI Model AM5-5B) is used.

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

PRELIMINARY DC CALIBRATION OF THE MICROPOTENTIOMETER

RF-DC transfer difference from dc to 100 MHz at a voltage level of 100 microvolts

Specification:

Shall be within 0.2% of dc input level.

Test Point: 100 μV rms at dc

Equipment:

Items	Model
DC calibrator	Fluke 5440B or equivalent
10-mA Micropotentiometer	Ballantine 440-10
0.01 ohm standard resistor	Ballantine 440-02
DC millivoltmeter	Fluke 8506A or equivalent (2 required)
Thermal converter output cable attached)	Special cable with dual Banana plug

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

WARNING:	Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Attach the 0.01 ohm standard resistor to the output port of the micropotentiometer housing.

2. Connect the equipment as shown in figure 10.6.1. Attach a BNC (female) to type N (male) adapter to the input connector of the micropotentiometer. Attach a dual banana plug (male) to type N (female) adapter to a type N - N (male-male) adapter, and connect the adapters to the output connector (standard resistor) of the micropotentiometer. Connect the combination to the input of one of the millivoltmeters.

3. Connect the output of the thermal converter to the other dc

millivoltmeter using the attached thermal converter output cable. Set the millivoltmeter to the 1-volt range.

4. Set the dc calibrator to an amplitude of approximately 0.15 volts, and then fine-adjust the calibrator voltage until the micropotentiometer output reads 100 microvolts. NOTE WARNING! Wait for about one minute until the voltage reading settles, and then read and record on the data sheet the output voltage of the thermoelement of the micropotentiometer on the other millivoltmeter.

   Note: To achieve the required accuracy, the dc millivoltmeter must be used in the averaging mode.

5. Reverse the polarity of the dc supplied by the calibrator and repeat step 4. Then proceed to step 6.

6. Calculate the average of the two thermoelement output voltages by adding the two numerical values recorded on the data sheet, ignoring the sign, and dividing the sum by two.

7. Disconnect the dc voltage calibrator immediately after making the measurement to prevent possible damage to the thermoelement. Carefully disassemble the setup so that the micropotentiometer and its associated resistor can be used to make ac measurements. Note warning!

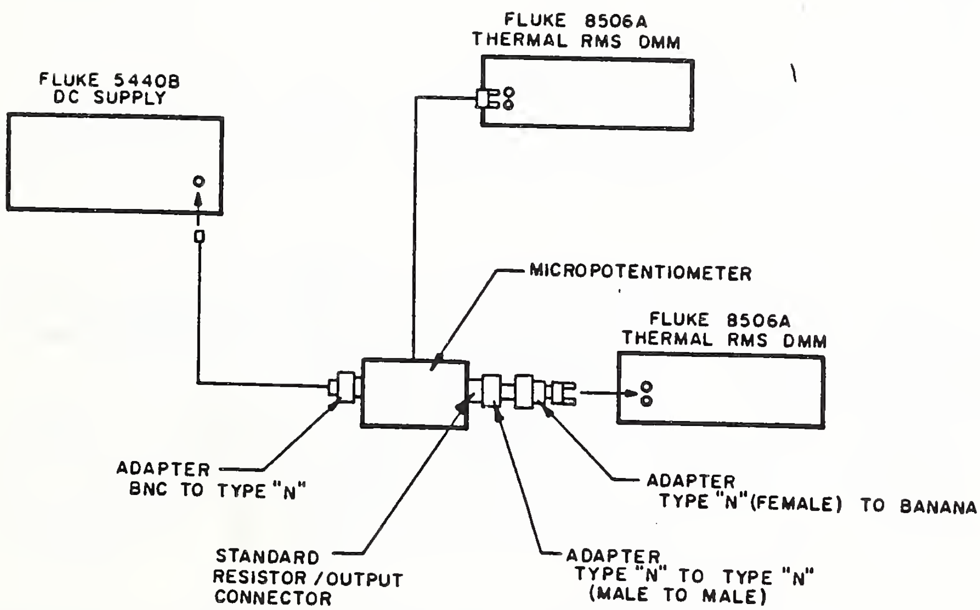


Fig. 10.6.1 Set-Up for Micropotentiometer DC Calibration

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Accuracy for frequencies from 10 Hz to 49.99 Hz for all input levels from 100 microvolts to 300 volts

Specification:

Shall be within ± 5% of true input level.

Test Point: 100 μV rms at 10.0 Hz

Equipment:

Items	Model
Function generator	Hewlett-Packard 3325A or equivalent
10-mA Micropotentiometer	Ballantine 440-10
0.01 ohm standard resistor	Ballantine 440-02
DC millivoltmeter	Fluke 8506A or equivalent
Thermal converter output cable	Attached to micropotentiometer, free end dual Banana plug

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> WARNING: Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Attach the 0.01 ohm standard resistor to the output port of the micropotentiometer housing.

2. Connect the equipment as shown in figure 10.6.2. Attach a BNC (female) to type N (male) adapter to the input connector of the micropotentiometer. Attach a BNC (male) to type N (female) adapter to a type N - N (male-male) adapter, and connect the adapters to the output connector (standard resistor) of the micropotentiometer. Connect the combination to the input of the UUT.

3. Connect the output of the thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range.

4. Set the function generator to a frequency of 10.0 Hz, and set the amplitude to 0.4 millivolts. This will prevent applying an overvoltage to the thermoelement.

5. Connect the output of the function generator to the input of the micropotentiometer using any shielded cable (e.g. RG 58-U) with BNC connectors.

6. Slowly increase the output voltage of the function generator, while watching the reading of the dc millivoltmeter, until the reading reaches the voltage determined during the dc calibration of the micropotentiometer. An ac voltage of 100 μV is then being applied to the UUT.

7. Consult the manufacturer's instructions for operation of the UUT in the 100-μV range, and make the prescribed adjustments such as setting the averaging time constant, switching a filter into the circuit, etc.

8. When the reading of the UUT has settled, note and record it on the data sheet.

9. Disconnect the function generator immediately after making the measurement to prevent possible damage to the thermoelement. Note warning!

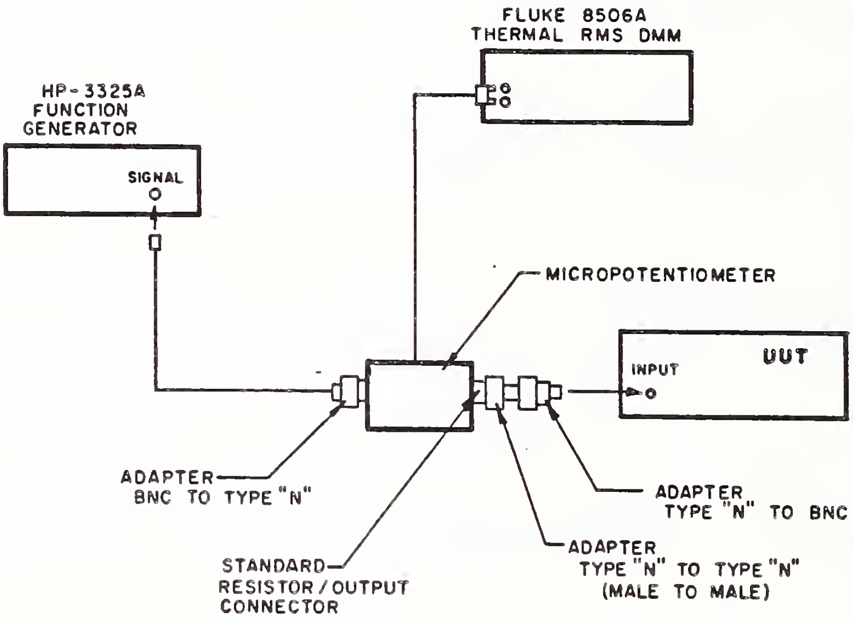


Fig. 10.6.2 Set-Up for 100 μV AC Measurements

Accuracy for frequencies from 100 Hz to 99.9 kHz for all input levels from 100 microvolts to 1 millivolt

Specification:

Shall be within ± 5% of true input level.

Test Point: 100 μV rms at 10.0 kHz

Equipment:

Items	Model
Function generator	Hewlett-Packard 3325A or equivalent
10-mA Micropotentiometer	Ballantine 440-10
0.01 ohm standard resistor	Ballantine 440-02
DC millivoltmeter	Fluke 8506A or equivalent
Thermal converter output cable	Attached to micropotentiometer, free end dual Banana plug

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> WARNING: Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Attach the 0.01 ohm standard resistor to the output port of the micropotentiometer housing.

2. Connect the equipment as shown in figure 10.6.2. Attach a BNC (female) to type N (male) adapter to the input connector of the micropotentiometer. Attach a BNC (male) to type N (female) adapter to a type N - N (male-male) adapter, and connect the adapters to the output connector (standard resistor) of the micropotentiometer. Connect the combination to the input of the UUT.

3. Connect the output of the thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range.

4. Set the function generator to a frequency of 10.0 kHz, and set the amplitude to 0.4 millivolts. This will prevent applying an overvoltage to the thermoelement.

5. Connect the output of the function generator to the input of the micropotentiometer using any shielded cable (e.g. RG 58-U) with BNC connectors.

6. Slowly increase the output voltage of the function generator, while watching the reading of the dc millivoltmeter, until the reading reaches the voltage determined during the dc calibration of the micropotentiometer. An ac voltage of 100 μV is then being applied to the UUT.

7. Consult the manufacturer's instructions for operation of the UUT in the 100-μV range, and make the prescribed adjustments such as setting the averaging time constant, switching a filter into the circuit, etc.

8. When the reading of the UUT has settled, note and record it on the data sheet.

9. Disconnect the function generator immediately after making the measurement to prevent possible damage to the thermoelement. Note warning!

Accuracy for frequencies from 100 kHz to 999.9 kHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Specification:

Shall be within ± 5% of true input level.

Test Point: 100 μV rms at 999.9 kHz

Equipment:

Items	Model
AC calibrator	Fluke 5200A or equivalent
Function generator	Hewlett-Packard 3325A or equivalent
10-mA Micropotentiometer	Ballantine 440-10
0.01 ohm standard resistor	Ballantine 440-02
DC millivoltmeter	Fluke 8506A or equivalent
Thermal converter output cable	Attached to micropotentiometer, free end dual Banana plug

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> WARNING: Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Attach the 0.01 ohm standard resistor to the output port of the micropotentiometer housing.

2. Connect the equipment as shown in figure 10.6.2. Attach a BNC (female) to type N (male) adapter to the input connector of the micropotentiometer. Attach a BNC (male) to type N (female) adapter to a type N - N (male-male) adapter, and connect the adapters to the output connector (standard resistor) of the micropotentiometer. Connect the combination to the input of the UUT.

3. Connect the output of the thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range.

4. Set the function generator to a frequency of 999.9 kHz, and set the amplitude to 0.4 millivolts. This will prevent applying an overvoltage to the thermoelement.

5. Connect the output of the function generator to the input of the micropotentiometer using any shielded cable (e.g. RG 58-U) with BNC connectors.

6. Slowly increase the output voltage of the function generator, while watching the reading of the dc millivoltmeter, until the reading reaches the voltage determined during the dc calibration of the micropotentiometer. An ac voltage of 100 μV is then being applied to the UUT.

7. Consult the manufacturer's instructions for operation of the UUT in the 100-μV range, and make the prescribed adjustments such as setting the averaging time constant, switching a filter into the circuit, etc.

8. When the reading of the UUT has settled, note and record it on the data sheet.

9. Disconnect the function generator immediately after making the measurement to prevent possible damage to the thermoelement. Note warning!

Accuracy for frequencies from 1 MHz to 9.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Specification:

Shall be within ± 10% of true input level.

Test Point: 100 μV rms at 9.99 MHz

Equipment:

Items	Model
Function generator	Hewlett-Packard 3325A or equivalent
10-mA Micropotentiometer	Ballantine 440-10
0.01 ohm standard resistor	Ballantine 440-02
DC millivoltmeter	Fluke 8506A or equivalent
Thermal converter output cable	Attached to micropotentiometer, free end dual Banana plug

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> **WARNING:** Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Attach the 0.01 ohm standard resistor to the output port of the micropotentiometer housing.

2. Connect the equipment as shown in figure 10.6.2. Attach a BNC (female) to type N (male) adapter to the input connector of the micropotentiometer. Attach a BNC (male) to type N (female) adapter to a type N - N (male-male) adapter, and connect the adapters to the output connector (standard resistor) of the micropotentiometer. Connect the combination to the input of the UUT.

3. Connect the output of the thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range.

4. Set the function generator to a frequency of 9.99 MHz, and set the amplitude to 0.4 millivolts. This will prevent applying an overvoltage to the thermoelement.

5. Connect the output of the function generator to the input of the micropotentiometer using any shielded cable (e.g. RG 58-U) with BNC connectors.

6. Slowly increase the output voltage of the function generator, while watching the reading of the dc millivoltmeter, until the reading reaches the voltage determined during the dc calibration of the micropotentiometer. An ac voltage of 100 μV is then being applied to the UUT.

7. Consult the manufacturer's instructions for operation of the UUT in the 100-μV range, and make the prescribed adjustments such as setting the averaging time constant, switching a filter into the circuit, etc.

8. When the reading of the UUT has settled, note and record it on the data sheet.

9. Disconnect the function generator immediately after making the measurement to prevent possible damage to the thermoelement. Note warning!

Accuracy for frequencies from 10 MHz to 19.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Specification:

Shall be within ± 15% of true input level.

Test Point: 100 μV rms at 19.99 MHz

Equipment:

Items	Model
AC calibrator	Fluke 5200A or equivalent
Function generator	Hewlett-Packard 3325A or equivalent
10-mA Micropotentiometer	Ballantine 440-10
0.01 ohm standard resistor	Ballantine 440-02
DC millivoltmeter	Fluke 8506A or equivalent
Thermal converter output cable	Attached to micropotentiometer, free end dual Banana plug

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> WARNING: Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Attach the 0.01 ohm standard resistor to the output port of the micropotentiometer housing.

2. Connect the equipment as shown in figure 10.6.2. Attach a BNC (female) to type N (male) adapter to the input connector of the micropotentiometer. Attach a BNC (male) to type N (female) adapter to a type N - N (male-male) adapter, and connect the adapters to the output connector (standard resistor) of the micropotentiometer. Connect the combination to the input of the UUT.

3. Connect the output of the thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range.

4. Set the function generator to a frequency of 19.99 MHz, and set the amplitude to 0.4 millivolts. This will prevent applying an overvoltage to the thermoelement.

5. Connect the output of the function generator to the input of the micropotentiometer using any shielded cable (e.g. RG 58/U) with BNC connectors.

6. Slowly increase the output voltage of the function generator, while watching the reading of the dc millivoltmeter, until the reading reaches the voltage determined during the dc calibration of the micropotentiometer. An ac voltage of 100 μV is then being applied to the UUT.

7. Consult the manufacturer's instructions for operation of the UUT in the 100-μV range, and make the prescribed adjustments such as setting the averaging time constant, switching a filter into the circuit, etc.

8. When the reading of the UUT has settled, note and record it on the data sheet.

9. Disconnect the function generator immediately after making the measurement to prevent possible damage to the thermoelement. Note warning!

Accuracy for frequencies from 10 Hz to 49.99 Hz for all input levels from 100 microvolts to 300.0 volts and for frequencies from 50 Hz to 99.99 kHz for all input levels from 1 millivolt to 300 volts (200 volts 20 kHz to 99.99 kHz).

Specification:

Shall be within ± 3% of true input level.

Test Points:

1.0	mV	rms	at	10.00	Hz
300.0	V	rms	at	10.00	Hz
1.0	mV	rms	at	50.00	Hz
300.0	V	rms	at	50.00	Hz
1.0	mV	rms	at	10.0	kHz
10.0	mV	rms	at	10.00	kHz
100.0	mV	rms	at	10.00	kHz
1.0	V	rms	at	10.00	kHz
10.0	V	rms	at	10.00	kHz
300.0	V	rms	at	10.00	kHz
1.0	mV	rms	at	99.99	kHz
200.0	V	rms	at	99.99	kHz

Equipment:

Items	Model
AC calibrator	Fluke 5200A or equivalent
Power amplifier	Fluke 5205A or equivalent
Instrument Controller (IEEE-488 Bus)	Hewlett-Packard 9836 or equivalent
IEEE-488 cable	
Dual banana to BNC adapter	
Cable with BNC connectors	

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> **WARNING:** This procedure uses lethal voltages during the test Care should be taken to avoid injury or shock.

1. Link the instrument controller (computer) to the calibrator and the power amplifier using the IEEE-488 cable. Also, connect the power amplifier to the calibrator with the special purpose cable supplied by the manufacturer.

   For tests with voltages between 1 volt and 100 volts, use the equipment as shown in figure 10.6.3. Connect the calibrator to the to the input of the UUT directly using the cable with BNC connectors and the dual-banana adapter.

   For tests with voltages above 100 volts, connect the UUT to the power amplifier using the cable attached to the power amplifier and an adapter to make the connection as shown in figure 10.6.4. (The program will provide the necessary prompts.)

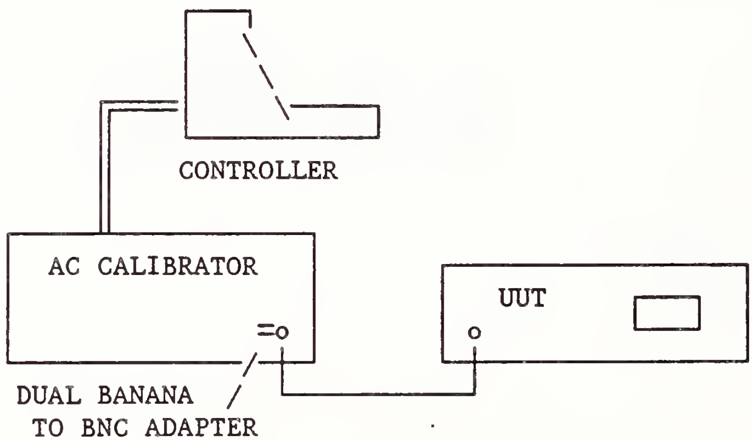


Fig. 10.6.3 Set-Up for the Accuracy Test with the Calibrator

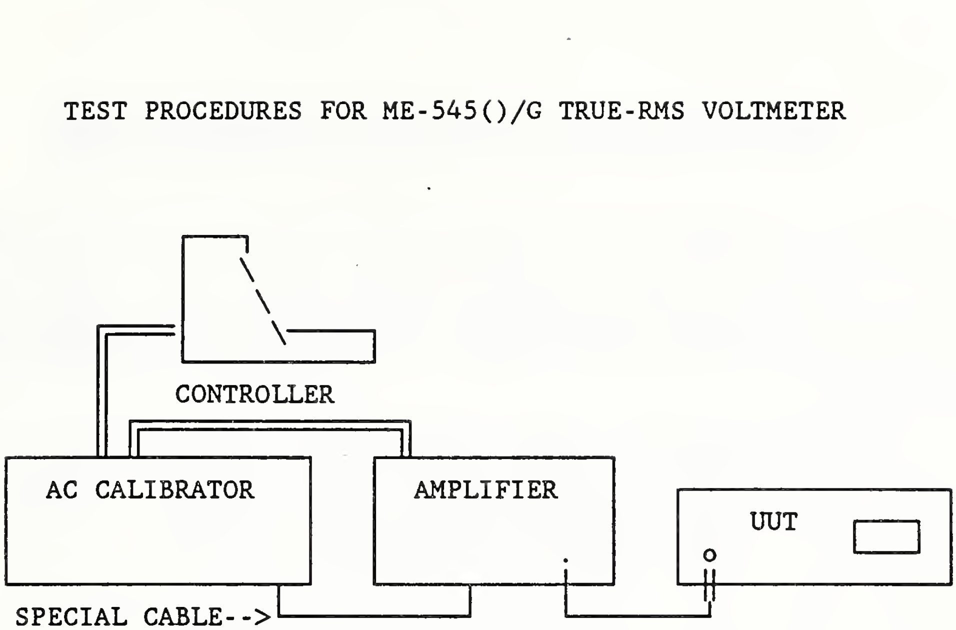


Fig. 10.6.4 Set-Up for the Accuracy Test with the Calibrator and Amplifier

2. Insert the 5 1/4 in. floppy disk labelled "TMDE4A" into the right-hand disk drive of the computer (controller). The program requires that HP-Basic 2.1 and AP 2.1 (or later versions) are first loaded into the computer.

3. Type LOAD "MENU" on the computer keyboard.

4. Press EXECUTE.

5. Press RUN and follow directions shown on the computer display.

6. Enter the results of the measurement shown on the printout into the data sheet, Table 10.6b.

Accuracy for frequencies from 100 kHz to 999.9 kHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Specification:

Shall be within ± 5% of true input level.

Test Point: 100.0 V rms at 999.9 kHz

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Function Generator	Hewlett-Packard 3325A or equivalent
Power Amplifier	ENI A300-40PA (modified)
28-volt dc power supply	Kepco JQE 25-10M or equivalent
Output Transformer	ENI AM-5B Serial No. 103
100-volt thermal converter	Ballantine 1394A-100 (modified)
DC millivoltmeter	Fluke 8506A or equivalent
Oscilloscope	Tektronix 465 or equivalent
Thermal converter output cable	Type MS connector MS3102A-10SL-3P (3-pin male) to dual Banana plug
Cable with BNC connectors	
RG 214/U cable with type "N" connectors (3 required)	3 feet or less, each.
Type "N" tee (2 required)	
BNC (male) to "N" (female) (4 required)	
Dual banana to "N" adapter	
Coaxial relay	Hewlett-Packard 8761A
Relay control box	Special part

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

WARNING:	Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Connect the equipment as shown in figure 10.6.5. Attach the BNC (male) to N (female) adapter to a type "N" (male) to "N" (male) adapter and then to a type "N" tee, and connect the combination to the input of the UUT.

2. Attach the coaxial relay to the thermal converter and port 1 of the coaxial relay to the type "N" tee.

3. Attach a BNC (male) to "N" (female) adapter to both input and output terminals of the output transformer.

4. Make sure the amplifier power supply is turned off. Then use a RG 214/U cable to connect the output of the power amplifier to the input of the transformer and another RG 214/U cable to connect the transformer to the tee leading to the UUT and thermal converter.

5. Make sure that the output voltage from the ac calibrator is zero. Then connect the output of the ac calibrator to port 2 of the coaxial switch using the dual banana to "N" adapter and a RG 214/U cable.

6. Connect the output of the 100-volt thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range. Set the coaxial switch to "Port 2" by momentarily depressing button No. 2 on the switch control box.

7. Set the frequency of the ac calibrator to 1 kHz, and bring the output voltage up slowly to 100 volts rms while observing the dc millivoltmeter reading and making sure the reading does not exceed 8 millivolts.

8. With the ac calibrator set to 100.0 V and when the reading on the dc

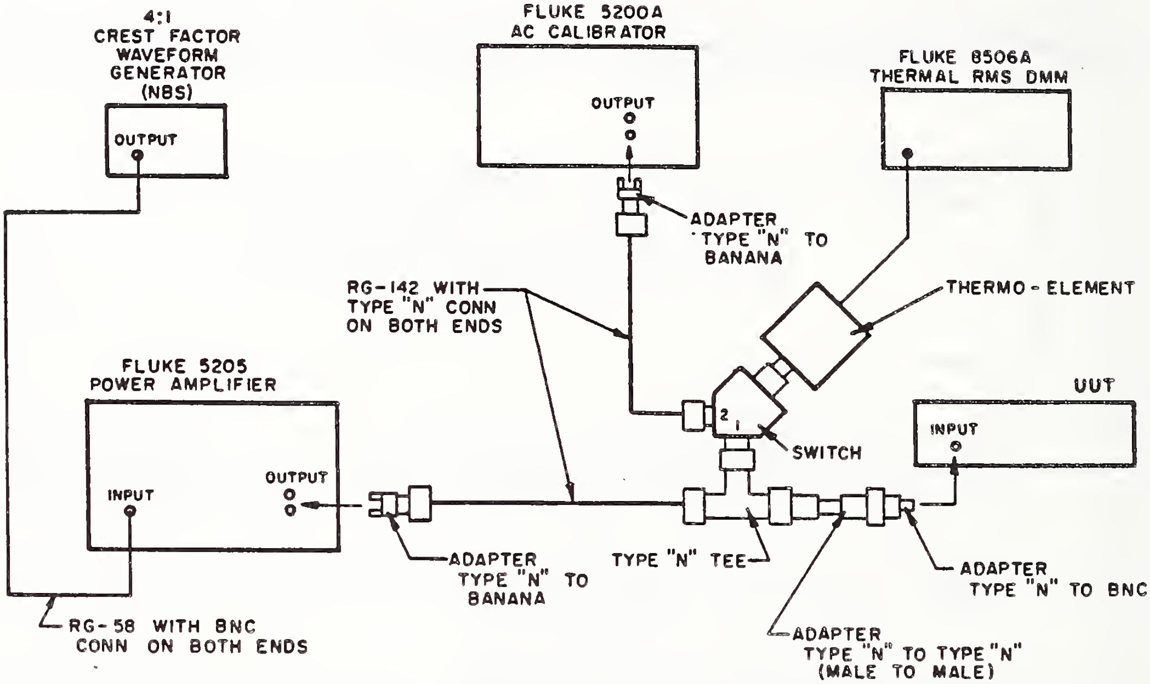


Fig. 10.6.5 Set-Up for the 100-volt Accuracy Test using a Thermal Converter

millivoltmeter has settled (about 5 to 10 minutes after setting frequency and amplitude; step 7), note and record the millivoltmeter reading on the data sheet, Table 10.6.c.

9. Turn on the power supply to the rf power amplifier and adjust it to 28 volts dc. The quiescent current should be approximately 6.5 amperes. Note warning!

WARNING:	**Do not turn on the rf power amplifier if the cooling fan is not operating. Do not obstruct air flow to the heat sink. After switching off the power supply, leave fan on until the heat sink is at room temperature.**

11. Set the frequency of the function generator to 999.9 kHz and the amplitude to 1 mV rms. Increase the output voltage until the UUT reads approximately 100.0 V rms.

12. Set the increment control on the function generator so that the least significant digit can be incremented (0.001 mV).

13. Set the coaxial switch to "Port 1" and, using the increment or decrement control (up or down arrows) of the function generator, slowly adjust the output voltage until the dc millivoltmeter reading settles to the same voltage as that obtained when using the 1 kHz signal from the ac calibrator. The dc voltage reading will take 20 to 30 seconds to settle, and it may not be possible to get exactly the same reading as before because of limited resolution in the adjustment of the function generator. Generally, the dc millivolt readings should agree within ± 0.002 mV.

14. When the millivoltmeter reading agrees within the tolerance with the reading obtained when measuring the 1-kHz reference signal, note and record on the data sheet, Table 10.6c, the reading on the UUT (including the units) as well as the millivoltmeter reading.

15. Set the coaxial switch back to "Port 2," and check whether the reading has changed. If the reading has changed by more than 0.002 mV, repeat steps 11 to 13. If it has not changed, the test is completed.

16. Set the function generator voltage to 0.4 millivolts (it cannot be set to zero) to power down the equipment, and set the ac calibrator to zero output. Turn off the power amplifier.

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Accuracy for frequencies from 1 MHz to 9.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Specification:

Shall be within ± 10% of true input level.

Test Point: 10.00 V rms at 9.99 MHz

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Function Generator	Hewlett-Packard 3325A or equivalent
Power Amplifier	ENI A300-40PA (modified)
28-volt dc power supply	Kepco JQE 25-10M or equivalent
10-volt thermal converter	Ballantine 1394A-10 or equivalent
DC millivoltmeter	Fluke 8506A or equivalent
Oscilloscope	Tektronix 465 or equivalent
Thermal converter output cable	Type MS connector MS3102A-10SL-3P (3-pin male) to dual Banana plug
Cable with BNC connectors	
RG 214/U cable with type "N" connectors (3 required)	3 feet or less, each.
Type "N" tee (2 required)	
50-ohm "N" adapter	Special part
BNC (male) to "N" (female) (2 required)	
Dual banana to "N" adapter	
Coaxial relay	Hewlett-Packard 8761A
Relay control box	Special part

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

WARNING:	Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Connect the equipment as shown in figure 10.6.6. Attach the BNC (male) to N (female) adapter to the 50-ohm "N-N" adapter, then to a type "N" tee, and connect the combination to the input of the UUT.

2. Attach the coaxial relay to the thermal converter and port 1 of the coaxial relay to the type "N" tee.

3. Attach a BNC (male) to "N" (female) adapter to a type "N" tee, and connect the combination to one of the inputs of the oscilloscope.

4. Make sure the amplifier power supply is turned off. Then use a RG 214/U cable to connect the output of the power amplifier to the tee at the oscilloscope and another RG 214/U cable to connect the oscilloscope to the tee leading to the UUT and thermal converter.

5. Make sure that the output voltage from the ac calibrator is zero. Then connect the output of the ac calibrator to port 2 of the coaxial switch using a dual banana to "N" adapter and a RG 214/U cable.

6. Connect the output of the thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range. Set the coaxial switch to "Port 2" by momentarily depressing button No. 2 on the switch control box.

7. Set the frequency of the ac calibrator to 1 kHz, and bring the output voltage up slowly to 10 volts rms while observing the dc millivoltmeter reading and making sure the reading does not exceed 8 millivolts.

8. Turn on the oscilloscope and set it to display a 10-volt, 10-MHz signal (5 volts/div; 0.2 microsecond/div, 10x magnification, dc coupled).

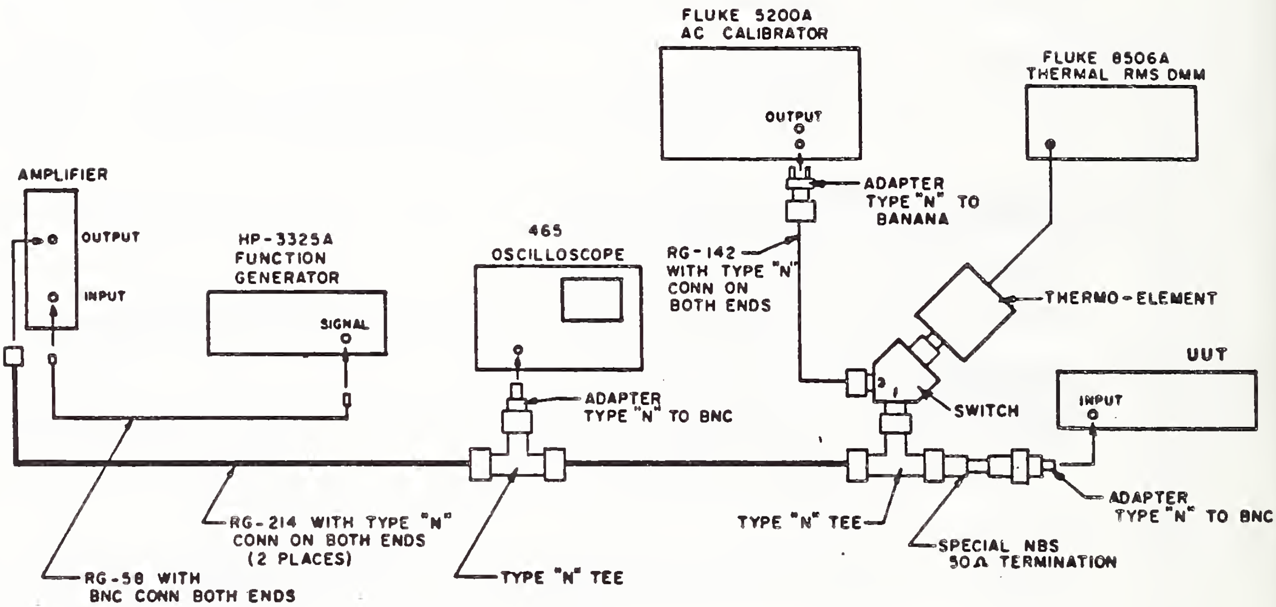


Fig. 10.6.6 Set-Up for Low-Voltage Accuracy Test using a Thermal Converter

9. Turn on the power supply to the rf power amplifier and adjust it to 28 volts dc. The quiescent current should be approximately 6.5 amperes. Note warning!

> **WARNING:** Do not turn on the rf power amplifier if the cooling fan is not operating. Do not obstruct air flow to the heat sink. After switching off the power supply, leave fan on until the heat sink is at room temperature.

10. Set the frequency of the function generator to 9.99 MHz and the amplitude to 1 mV rms. Increase the output voltage until the UUT reads approximately 10.0 V rms.

11. Observe the amplifier output waveform on the oscilloscope for parasitic oscillations, clipping, or other distortion. If distortion or oscillation is observed, shut off the amplifier immediately and investigate the cause.

12. Set the increment control on the function generator so that the least significant digit can be incremented (0.001 mV).

13. With the ac calibrator set to 10.000 V, and when the reading on the dc millivoltmeter has settled (about 5 to 10 minutes after setting frequency and amplitude; step 7), note and record the millivoltmeter reading on the data sheet.

14. Set the coaxial switch to "Port 1" and, using the increment or decrement control (up or down arrows) of the function generator, slowly adjust the output voltage until the dc millivoltmeter reading settles to the same voltage as that obtained when using the 1 kHz signal from the ac calibrator. The dc voltage reading will take 20 to 30 seconds to settle, and it may not be possible to get exactly the same reading as before because of limited resolution in the adjustment of the function generator. Generally, the dc millivolt readings should agree within ± 0.002 mV.

15. When the millivoltmeter reading agrees within the tolerance with the reading obtained when measuring the 1-kHz reference signal, note and record on the data sheet, Table 10.6c, the reading on the UUT (including the units) as well as the millivoltmeter reading.

16. Set the coaxial switch back to "Port 2," and check whether the reading has changed. If the reading is unchanged, the test is completed. If the reading has changed by more than 0.002 mV, repeat steps 11 to 16 and revise the reading on the data sheet, Table 10.6c.

17. Set the function generator voltage to 0.4 millivolts (it cannot be set to zero) to power down the equipment, and set the ac calibrator to zero output.

Accuracy for frequencies from 10 MHz to 19.99 MHz for all input levels from 100 microvolts to 1 x 10^8 volt-hertz.

Specification:

Shall be within ± 15% of true input level.

Test Point: 5.00 V rms at 19.99 MHz

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Function Generator	Hewlett-Packard 3325A or equivalent
Power Amplifier	ENI A300-40PA (modified)
28-volt dc power supply	Kepco JQE 25-10M or equivalent
5-volt thermal converter	Ballantine 1394A-5 (modified)
DC millivoltmeter	Fluke 8506A or equivalent
Oscilloscope	Tektronix 465 or equivalent
Thermal converter output cable	Type MS connector MS3102A-10SL-3P (3-pin male) to dual Banana plug
Cable with BNC connectors	
RG 214/U cable with type "N" connectors (3 required)	3 feet or less, each.
Type "N" tee (2 required)	
50-ohm "N" adapter	Special part
BNC (male) to "N" (female) (2 required)	
Dual banana to "N" adapter	
Coaxial relay	Hewlett-Packard 8761A
Relay control box	Special part

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

> WARNING: Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Connect the equipment as shown in figure 10.6.6. Attach the BNC (male) to N (female) adapter to the 50-ohm "N-N" adapter, then to a type "N" tee, and connect the combination to the input of the UUT.

2. Attach the coaxial relay to the thermal converter and port 1 of the coaxial relay to the type "N" tee.

3. Attach a BNC (male) to "N" (female) adapter to a type "N" tee, and connect the combination to one of the inputs of the oscilloscope.

4. Make sure the amplifier power supply is turned off. Then use a RG 214/U cable to connect the output of the power amplifier to the tee at the oscilloscope and another RG 214/U cable to connect the oscilloscope to the tee leading to the UUT and thermal converter.

5. Make sure that the output voltage from the ac calibrator is zero. Then connect the output of the ac calibrator to port 2 of the coaxial switch using a dual banana to "N" adapter and a RG 214/U cable.

6. Connect the output of the 5-volt thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range. (10 mV will then be displayed as 0.010000 V). Set the coaxial switch to "Port 2" by momentarily depressing button No. 2 on the switch control box.

7. Set the frequency of the ac calibrator to 1 kHz, and bring the output voltage up slowly to 5 volts rms while observing the dc millivoltmeter reading and making sure the reading does not exceed 8 millivolts.

8. Turn on the oscilloscope and set it to display a 5-volt, 20-MHz signal (2 volts/div; 0.1 microsecond/div, 10x magnification, dc coupled).

9. Turn on the power supply to the rf power amplifier and adjust it to 28 volts dc. The quiescent current should be approximately 6.5 amperes. Note warning!

WARNING:	Do not turn on the rf power amplifier if the cooling fan is not operating. Do not obstruct air flow to the heat sink. After switching off the power supply, leave fan on until the heat sink is at room temperature.

10. Set the frequency of the function generator to 19.99 MHz and the amplitude to 1 mV rms. Increase the output voltage until the UUT reads approximately 5.0 V rms.

11. Observe the amplifier output waveform on the oscilloscope for parasitic oscillations, clipping, or other distortion. If distortion or oscillation is observed, shut off the amplifier immediately and investigate the cause.

12. Set the increment control on the function generator so that the least significant digit can be incremented (0.001 mV).

13. With the ac calibrator set to 5.000 V, and when the reading on the dc millivoltmeter has settled (about 5 to 10 minutes after setting frequency and amplitude; step 7), note and record the millivoltmeter reading on the data sheet, Table 10.6c.

14. Set the coaxial switch to "Port 1" and, using the increment or decrement control (up or down arrows) of the function generator, slowly adjust the output voltage until the dc millivoltmeter reading settles to the same voltage as that obtained when using the 1 kHz signal from the ac calibrator. The dc voltage reading will take 20 to 30 seconds to settle, and it may not be possible to get exactly the same reading as before because of limited resolution in the adjustment of the function generator. Generally, the dc millivolt readings should agree within ± 0.002 mV.

15. When the millivoltmeter reading agrees within the tolerance with the reading obtained when measuring the 1-kHz reference signal, note and record on the data sheet the reading on the UUT (including the units) as well as the millivoltmeter reading.

16. Set the coaxial switch back to "Port 2," and check whether the reading has changed. If the reading is unchanged, the test is completed. If the reading has changed by more than 0.002 mV, repeat steps 11 to 16 and revise the reading on the data sheet, Table 10.6c.

17. Set the function generator voltage to 0.4 millivolts (it cannot be set to zero) to power down the equipment, and set the ac calibrator to zero output.

Table 10.6a Accuracy Test, Data Sheet, Micropotentiometer Measurements.

Test Point	Measurement Data Num. Value	Units	Estimated Uncertainty Measurement	Specification Limits Min.	Max.	Calibr. mV Value
+100 μV dc			± 0.8 μV	****************		**
-100 μV dc			± 0.8 μV	****************		
100 μV 10.00 Hz			± 3 μV	95 μV	105 μV	
100 μV 10.00 kHz			± 3 μV	95 μV	105 μV	
100 μV 999.9 kHz			± 3 μV	95 μV	105 μV	
100 μV 9.99 MHz			± 3 μV	90 μV	110 μV	
100 μV 19.99 MHz			± 3 μV	85 μV	115 μV	

TEST PROCEDURES FOR ME-545()/G TRUE-RMS VOLTMETER

Table 10.6b Accuracy Test, Data Sheet, Calibrator.

Test Point	Measurement Data Num. Value	Measurement Data Units	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.
1.00 mV 10.00 Hz			±0.0002 mV	1.05 mV	0.95 mV
300.0 V 10.00 Hz			±0.06 V	315 V	285 V
1.00 mV 50.00 Hz			±0.0002 mV	1.03 mV	0.97 mV
300.0 V 50.00 Hz			±0.06 V	309 V	291 V
1.00 mV 10.0 kHz			±0.0002 mV	1.03 mV	0.97 mV
10.0 mV 10.0 kHz			±0.002 mV	10.3 mV	9.7 mV
100.0 mV 10.0 kHz			±0.02 mV	103 mV	97 mV
1.00 V 10.0 kHz			±0.0002 V	1.03 V	0.97 V
10.0 V 10.0 kHz			±0.002 V	10.3 V	9.7 V
300.0 V 10.0 kHz			±0.06 V	309 V	291 V
1.00 mV 99.9 kHz			±0.0002 mV	1.03 mV	0.97 mV
200.0 V 99.9 kHz			±0.04 V	206 V	194 V

Table 10.6c Accuracy Test, Data Sheet, Thermal Converter.

Test Point	Measurement Data Num. Value	Measurement Data Units	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Millivolt-meter Reading
100.0 V 1 kHz	***********	***	(± 0.1%)	***********		
100.0 V 999.9 kHz			± 0.2 V	95 V	105 V	
10.00 V 1 kHz	***********	***	(± 0.1%)	***********		
10.00 V 9.99 MHz			± 0.03 V	9 V	11 V	
5.00 V 1 kHz	***********	***	(± 0.1%)	***********		
5.00 V 19.99 MHz			± 0.02 V	4.25 V	5.75 V	

10.7 Response Time

Shall be 3 seconds or less to rated accuracy.

Specification:

Shall be within ± 3% of true input level.

Test Points:

100.0 mV rms	at	1.00 kHz
1.0 V rms	at	1.00 kHz
10.0 V rms	at	1.00 kHz
100.0 V rms	at	1.00 kHz

Equipment:

Items	Model
AC calibrator	Fluke 5101B or equivalent
Instrument Controller (IEEE-488 Bus)	Hewlett-Packard 9836 or equivalent
IEEE-488 cable	
Dual banana to BNC adapter	
Cable with BNC connectors	

> **WARNING:** This procedure uses lethal voltages during the test Care should be taken to avoid injury or shock.

1. Connect the calibrator to the to the input of the UUT using the cable with BNC connectors and the dual-banana adapter, as shown in figure 10.7.1. Link the instrument controller (computer) to the calibrator using the IEEE-488 cable.

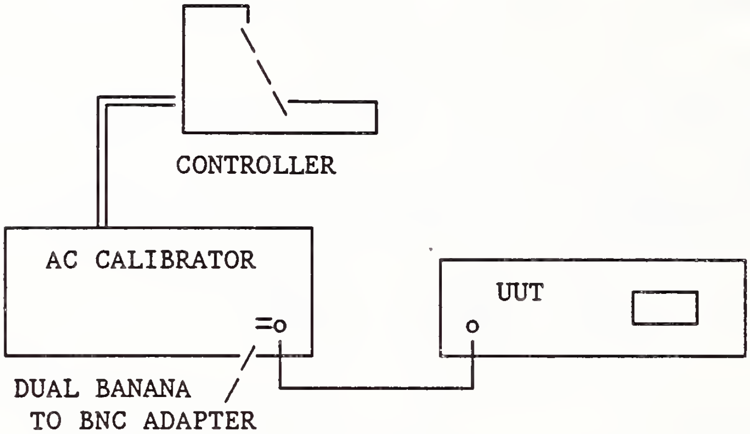


Fig. 10.7.1 Set-Up for Response Time Test

2. Insert the 5 1/4 in. floppy disk labelled "TMDE4A" into the right-hand disk drive of the computer (controller). The program requires that HP-Basic 2.1 and AP 2.1 (or later versions) are first loaded into the computer.

3. Type LOAD "MENU" on the keyboard of the computer.

4. Press EXECUTE.

5. Press RUN and follow directions shown on the computer display.

6. Record the results shown on the printout into the data sheet, Table 10.7

Table 10.7 Response Time, Data Sheet, (3 Seconds)

Test Point	Measurement Data		Estimated Measurement Uncertainty	Specification Limits	
	Num. Value	Units		Min.	Max.
100.0 mV 1.00 kHz			± 0.2 s*	103 mV	97 mV
1.00 V 1.00 kHz			± 0.2 s*	1.03 V	0.97 V
10.0 V 1.00 kHz			± 0.2 s*	10.3 V	9.7 V
100.0 V 1.00 kHz			± 0.2 s*	103 V	97 V

* Estimate in the uncertainty of the time interval is based on spread of results obtained by a skilled observer.

10.8 Crest Factor

Specification:

Meter shall handle crest factors of 4:1 for all input levels below 100 volts, increasing for downscale measurements.

Test Point: 90.0 V rms at 60 kHz (nominal)

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent
Power Amplifier	Fluke 5205 or equivalent
100-volt thermal converter	Ballantine 1394A-100 (modified)
DC millivoltmeter	Fluke 8506A or equivalent
Thermal converter output cable	Type MS connector MS3102A-10SL-3P (3-pin male) to dual Banana plug
Cable with BNC connectors (2 required)	
RG 142/U cable with type "N" connectors (2 required)	3 feet or less, each.
Type "N" tee	
BNC (male) to "N" (female)	
Dual banana to "N" adapters (2 required)	
"N" to "N" adapter (male)	
Coaxial relay	Hewlett-Packard 8761A
Relay control box	Special part (NBS design)
4:1 Crest Factor Waveform Generator	Special part (NBS design)

Procedure:

It is important to read the entire procedure before beginning the test. All equipment should be warmed up following the manufacturers' specification before any measurements are made.

WARNING:	Thermoelements are easily damaged by even moderate over-voltage. Do not leave connected except when actually carrying out test.

1. Connect the equipment as shown in figure 10.8. Attach the BNC (male) to N (female) adapter to a type "N" (male) to "N" (male) adapter and then to a type "N" tee, and connect the combination to the input of the UUT.

2. Attach the coaxial relay to the thermal converter and port 1 of the coaxial relay to the type "N" tee.

3. Attach dual banana plug to "N" adapters to one end of each of the two RG-142 cables. Connect the other end of one of the cables to the "tee", and connect the free end of the other cable to port 2 of the coaxial relay.

4. Make sure that the output voltage from the power amplifier is zero, then plug the cable from the "tee" into the output terminal of the power amplifier.

5. Connect the output of the 100-volt thermal converter to the dc millivoltmeter using a thermal converter output cable. Set the millivoltmeter to the 1-volt range. Set the coaxial switch to "Port 1" by momentarily depressing button No. 1 on the switch control box.

6. Make sure that the output voltage from the ac calibrator is zero. Then connect the output of the ac calibrator to port 2 of the coaxial switch using the dual banana to "N" adapter and a RG 142/U cable.

7. Set the instrument under test to the manual range mode. Then, set the UUT to a range that has a full scale value of 100 volts rms. If the UUT does not have a manual range setting with a full scale value of 100 volts rms, see the note on page 65.

8. Connect the special crest factor waveform generator to the input of the power amplifier, and observe the millivoltmeter reading. The reading should not exceed 8 millivolts. When the reading has settled, record the UUT reading and the millivoltmeter reading on the first line of the data sheet, Table 10.8.

9. Set the coaxial switch to "Port 2" by momentarily depressing button No. 2 on the switch control box.

10. Set the frequency of the ac calibrator to 60 kHz, and bring the output voltage up slowly while observing the dc millivoltmeter reading and making sure the reading does not exceed 8 millivolts. When the millivoltmeter reading approaches the reading determined in step 8, wait and let the reading settle.

11. Adjust the calibrator voltage until the dc millivoltmeter reading settles to the same voltage as that obtained when using the crest factor generator and amplifier (step 8). The dc voltage reading may take 20 to 30 seconds to settle, and it may not be possible to get exactly the same reading as before because of limited resolution in the adjustment of the calibrator. Generally, the dc millivolt readings should agree within $\pm$ 0.002 mV.

12. When the millivoltmeter reading has settled and agrees to within the tolerance with the reading obtained in step 8, enter the calibrator voltage and the new millivoltmeter reading in the second line of the data sheet, Table 10.8.

13. Set the coaxial switch back to "Port 1," and check whether the millivoltmeter reading has changed. If the reading has changed by more than 0.002 mV, repeat steps 11 to 13. If it has not changed, the test is completed. The test is successful if the difference between the UUT UUT reading and the calibrator voltage does not exceed the stated tolerance.

Note:

Although the crest factor test can be performed with the UUT in the autorange mode, operation in this mode does not insure that the applied voltage will be near the full-scale value. The test is more meaningful if the rms amplitude of the crest factor signal applied to the UUT is at, or just below, the full-scale voltage of the measuring range.

If the UUT does not have a range with a full-scale value of 100 volts rms, set the meter to its next lower range and reduce the output voltage of the crest-factor waveform generator so that the rms output from the power amplifier is about 10% below the nominal value of the range selected. To reduce the output voltage of the crest-factor waveform generator, an attenuator is inserted between the output terminals of the waveform generator and the input terminals of the power amplifier. In its simplest form, the attenuator can be constructed using two resistors with resistances of the order of 1 kΩ to 10 kΩ. Adjustment and verification of the desired output voltage level can be obtained using the Fluke 8506 Digital Multimeter.

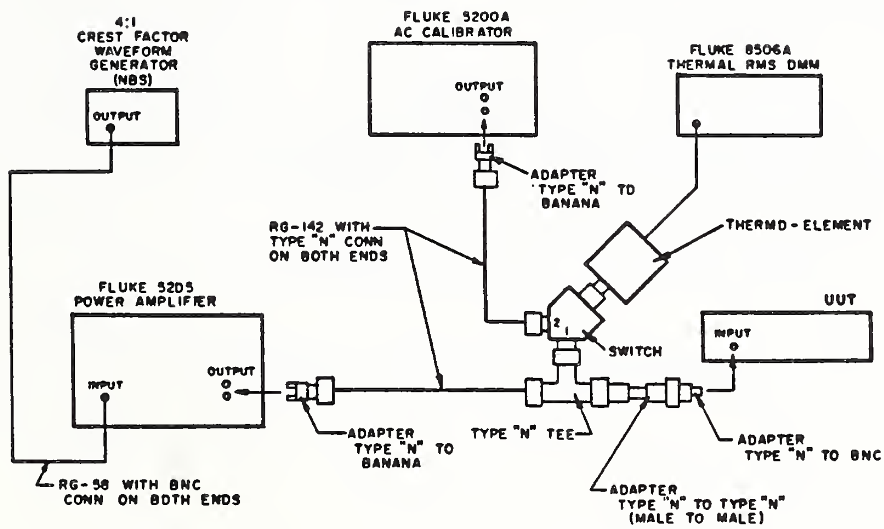


Fig. 10.8 Set-Up for the Crest Factor Test

Table 10.8 Crest Factor.

Test Point	Calibrator Voltage		U U T	Estim. Meas. Uncert.	Specification Limits	Millivolt-meter Reading
	Num. Value	Units	Reading		Min. Max.	
90.0 V* 60 kHz	**********	***			±3% of Calibrator volts	
60 kHz			**********	±0.1%	***********	

* See Note if attenuator is used.

10.9 Input Connector

Specification:

Input connector of meter shall be selectable by a front panel switch, allowing the outer connector to be floating from chassis ground or to be connected to chassis ground. Connector type shall be BNC type female.

Procedure:

1. The existance of the input connector is to be determined by inspection.

2. Connect an ohmmeter between the BNC outer shell and a grounded point on the chassis.

3. Switch the front panel switch to the grounded position. Read and record the resistance.

4. Switch the front panel switch to the ungrounded position. Read and record the resistance.

Table 10.9 Input Connector

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Connector of BNC type	____________	N/A	Yes		
Resistance grounded	____________	N/A			ohms
Resistance floating	____________	N/A			ohms

10.11 AC Common Mode Rejection

Specification:

Shall be greater than 60 dB up to 400 Hz.

Equipment:

Items	Model
AC Calibrator	Fluke 5200A or equivalent

Procedure:

1. Connect the equipment as shown below.

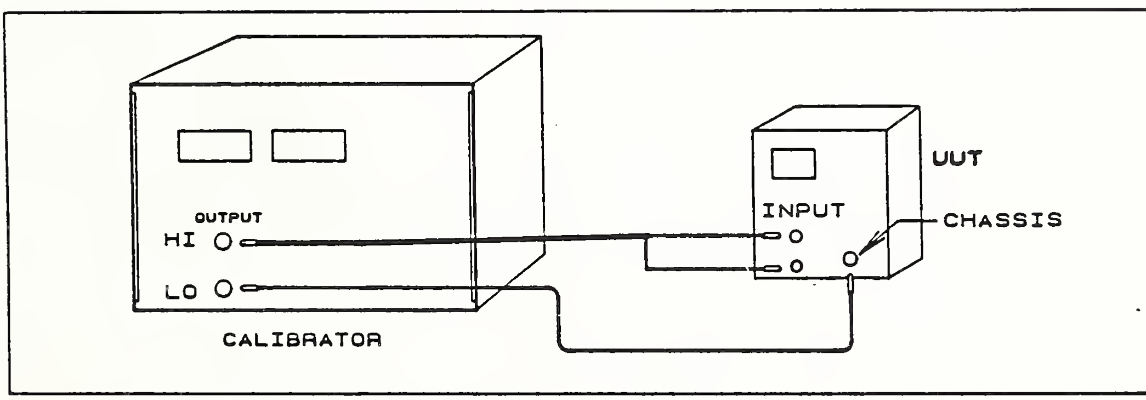


Fig. 10.11.1 Test setup for measuring the common mode rejection.

2. Initially, set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: MANUAL - most sensitive range

3. Set the output level of the calibrator to 0.100 mV rms and 400 Hz.

4. Set the calibrator to OPERATE position. Read and record the value displayed on the UUT as V_1.

   NOTE: If the UUT indicates underrange, enter zero for V_1.

5. Set the output level of the calibrator to 0.420 V rms and 400 Hz. Set the calibrator to OPERATE and record the value displayed by the UUT on the data sheet as V_2.

   NOTE: If the UUT indicates an overrrange, set the range switch to its next highest position and repeat steps 4 and 5.

6. Calculate the common mode rejection (CMR) according to the formula

$$CMR = 20 \log_{10} \frac{(V_2^2 - V_1^2)^{1/2}}{0.42}$$

and record this value on the data sheet, Table 10.11.

NOTE: Assure that the units in the above equation are consistent.

Table 10.11 Common Mode Rejection

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
V_1		N/A			V
V_2		N/A			V
CMR		± 0.5	60		dB

10.12 Maximum Input Protection

Specification:

Shall be at least 420 volts peak (300 volts RMS) on all ranges, and shall be at least 1 x 10^8 volt-hertz on all ranges above 1 volt.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Wall Clock	Commercial item

Procedure:

WARNING:	This procedure uses lethal voltages during the test. Care should be taken to avoid injury or shock.

1. Connect the equipment as shown below.

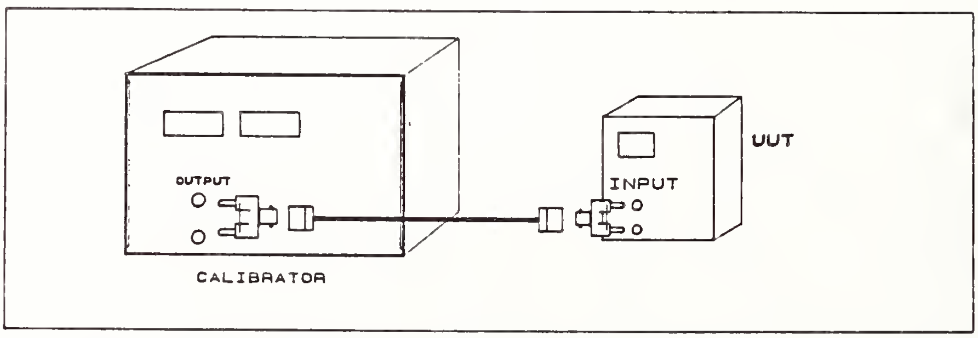


Fig. 10.12 Test setup for measuring maximum input protection.

2. Set the UUT controls as follows:

Function: AC VOLTAGE
Range Mode: MANUAL

3. Apply 300 volts ac at 1 kHz from the meter calibrator to the input of the UUT. Note the time on the wall clock.

4. After 2 minutes has elapsed, note any evidence of smoking, arcing, or

10.13 Input Impedance

Specification:

Input impedance shall be 1 megohm or greater, shunted by 50 picofarads capacitance or less.

Equipment:

Items	Model
Digital LCR meter	Hewlett-Packard 4262A or equivalent
Isolation Transformer	Topaz 91002-22 or equivalent
Three-wire-female to two-wire-male adapter	Order by description

Procedure:

1. Connect the equipment as shown below.

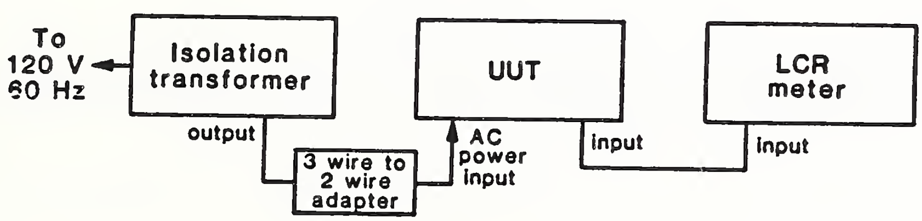


Fig. 10.13 Test setup for measuring input impedance.

> Note: This procedure requires that the chassis of the UUT be ungrounded with respect to earth ground. Assure that adequate safety precautions are observed.

2. Set the UUT controls as follows:

Function: AC VOLTAGE
Range Mode: AUTORANGE

3. Set the controls on the LCR meter as follows:

DC Bias	OFF
Circuit Mode	PRL
Function	C
Test Signal	1 kHz
LCR Range	AUTO
DQ Range	AUTO
Trigger	INT

4. Disconnect the cable to the input of the UUT.

5. Read and record on the data sheet the value of the cable capacitance as indicated by the LCR meter.

6. Reconnect the cable to the input of the UUT.

7. Read and record on the data sheet the value of the sum of the cable and input capacitance as indicated by the LCR meter.

8. Subtract the value of the capacitance obtained in step 5 from the value of the capacitance obtained in step 7. Record this difference on the data sheet.

9. Press the R/ESR button on the LCR meter.

10. Read and record on the data sheet the value of the input resistance indicated on the LCR display.

Table 10.13 Input Impedance

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Cable Cap.		± 0.2			pF
Cable + Input		± 0.2			pF
Input Cap.		± 0.2	0	50	pF
Input Resist.		± 0.004	1		MΩ

10.14 DC Output

Specification:

The meter shall have rear panel dc output. Output connector shall be BNC type female or dual banana female.

Procedure:

1. The existance of the dc output connector is to be determined by inspection.

Table 10.14 DC Output

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Connector on rear pnl.	________	N/A	Yes		
Connector proper type	________	N/A	Yes		

APPENDIX C

SOFTWARE FOR THE AUTOMATIC TESTS FOR THE ME-545()/G TRUE-RMS VOLTMETER

```
10    !*************** MENU **********************
20    !
30    !  MAIN PROGRAM TO TEST ME-545()/G TRUE RMS VOLTMETER.
40    ! VOL=TMDE4A. PROGRAM NAME = MENU. KJL.
50    ! VERSION 1.0
60    !
70    !
80    Printer=701
90    CLEAR 7
100   OUTPUT 2;"SCRATCH KEY"&CHR$(255)&CHR$(88);    ! CLEAR SOFTKEYS
110   OFF KEY
120   PRINTER IS CRT
130   PRINT CHR$(12)                              ! Roll the screen to clear
140   PRINT "*********************** MAIN MENU **************************"
150   PRINT
160   PRINT "PROGRAM SELECTIONS FOR TESTS OF ME-545()/G TRUE RMS VOLTMETER"
170 Timedate:PRINT
180   PRINT
190   BEEP
200   DIM Yes_no$[1],Date$[15],Time$[10]
210   PRINT "DATE : ";DATE$(TIMEDATE)
220   PRINT "TIME : ";TIME$(TIMEDATE)
221   Yes_no$=""
230   INPUT "ARE DATE AND TIME CORRECT? (Y/N)!",Yes_no$
231   IF Yes_no$="" THEN 180
240   IF Yes_no$="Y" OR Yes_no$="y" THEN Headings
250   BEEP
260   INPUT "ENTER DATE AS 25 JUN 1986",Date$
270   BEEP
280   INPUT "ENTER TIME AS 16:09:21",Time$
290   SET TIMEDATE DATE(Date$)+TIME(Time$)
300   GOTO Timedate
310   !
320   !*********************************************************************
330   !
340 Headings:   !
350   BEEP
351   Yes_no$=""
360   INPUT "DO YOU WANT A PRINTED TEST HEADING? (Y/N).",Yes_no$
361   IF Yes_no$="" THEN 350
370   IF Yes_no$="N" OR Yes_no$="n" THEN Ok
380   BEEP
390   INPUT "OPERATOR NAME",Name$
400   BEEP
410   INPUT "MANUFACTURER NAME",Mfg$
420   BEEP
430   INPUT "MODEL NUMBER",Model$
440   BEEP
450   INPUT "METER SERIAL NUMBER",Sernumber$
460   PRINT
470   PRINT CHR$(12)
480   BEEP
490   PRINT "**************** ME-545()/G TRUE RMS VOLTMETER ACCEPTANCE TESTS *****************"
500   OUTPUT Printer;CHR$(12)       ! FORM FEED FOR EXTERNAL PRINTER
510   OUTPUT Printer;"*************** ME-545-()/G TRUE RMS VOLTMETER ACCEPTANCE TESTS**************"
520   PRINT
530   OUTPUT Printer;CHR$(10)     ! LINE FEED FOR EXTERNAL PRINTER
540   OUTPUT Printer;CHR$(10)     ! LINE FEED FOR EXTERNAL PRINTER
550   PRINT "OPERATOR: ";Name$
560   OUTPUT Printer;"     OPERATOR: ";Name$
570   PRINT "MANUFACTURER: ";Mfg$
580   OUTPUT Printer;"     MANUFACTURER: ";Mfg$
590   PRINT "MODEL: ";Model$
600   OUTPUT Printer;"     MODEL: ";Model$
610   PRINT "SERIAL NUMBER: ";Sernumber$
620   OUTPUT Printer;"     SERIAL NUMBER: ";Sernumber$
630   PRINT
```

```
640   PRINT DATE$(TIMEDATE)&" "&TIME$(TIMEDATE)
650   OUTPUT Printer;"     "&DATE$(TIMEDATE)&" "&TIME$(TIMEDATE)
660   PRINT
670   OUTPUT Printer;CHR$(10)     ! LINE FEED FOR EXTERNAL PRINTER
680   PRINTER IS CRT
690   PRINT "PAUSED. PRESS <CONTINUE> WHEN READY."
700   PAUSE
710   !
720   !*******************************************************************
730   !
740 Ok:PRINT CHR$(12)
750   !
760   !
770   BEEP
780   PRINT "     Run the test for :"
790   PRINT
800   PRINT
810   PRINT "                  1. AC VOLTAGE  (5200A/5205A)   "
820   PRINT
830   PRINT "                  2. RESPONSE TIME     (5101B)   "
840   PRINT
850   PRINT
860   PRINT "     ENTER THE NUMBER OF CHOICE                     "
870   INPUT Choice
880   !
890   PRINT
900   PRINT "              WAIT -- Loading program number ";Choice
910   IF Choice<0 THEN PRINT "          Improper Choice"
920   IF Choice<0 THEN WAIT 2.0
930   IF Choice<0 THEN GOTO Ok
940   IF Choice=1 THEN LOAD "VOLTS"
950   IF Choice=2 THEN LOAD "RESP"
960   IF Choice=0 THEN Ok
970   IF Choice>2 THEN PRINT "           Improper choice"
980   IF Choice>2 THEN WAIT 2.0
990   IF Choice>2 THEN GOTO Ok
1000  END
10    !*************** RESP **********************
20    !
30    !
40    !  Program to test AC response time for meters in the voltage mode.
50    !
60    ! PROGRAM = RESP. VOL=TMDE4A. VERSION 1.1
70    ! KJL.
80    !
90    !
100   !
110 Start:Addr=702
120   DIM Pass$[1]
130   Printer=701
140   PRINTER IS CRT
150   PRINT CHR$(12)                         ! Roll the screen to clear it
160   BEEP
170   PRINT "    Enter the type of test desired:"
180   PRINT "  "
190   PRINT "           (1)  AC VOLTAGE RESPONSE TIME"
200   PRINT "           (2)  RETURN TO MAIN MENU."
210   PRINT
220   PRINT "    Enter 1 or 2"
230   INPUT Choice
240   IF Choice=1 THEN 330
250   IF Choice=2 THEN LOAD "MENU"
260   PRINT
270   PRINT "  IMPROPER  CHOICE  !!            Try Again "
280   BEEP
290   WAIT 2.0
300   GOTO Start
```

```
310   !
320  !
330  ! ------------------  Start of the AC Voltage Section  ---------------
340  !
350   OUTPUT Addr;"CC"
360   PRINT CHR$(12)                          ! Roll Screen to Clear
370  !
380   Time=3.0   ! RESPONSE TIME INTERVAL IN SECONDS
390   Numberoftests=4                         ! Number of tests to be performed
400  !
410   RESTORE 420   ! DATA=VOLTAGES @1 kHz. TO BE USED IN THE TEST
420   DATA     0.10,    1.0,    10.0,      100.
430  !
440   FOR N=1 TO Numberoftests                ! Loop each test
450     READ D(N)                             ! Read output level
460   NEXT N
470  !
480   BEEP 3000,.6
490   PRINT "*********** ENSURE THAT METER IS SET TO RESPOND TO AC VOLTAGE **********"
500   PRINT
510   PRINT
520   PRINT "     CONNECT METER TO FLUKE 5101B CALIBRATOR!!!!!"
530   PRINT
540   PRINT
550   PRINT "    At the sound of the tone, mentally note the voltage reading on the meter."
560   PRINT
570   PRINT "    This test will consist of";Numberoftests;"tests."
580   PRINT
590   PRINT "********** PRESS <CONTINUE> WHEN READY! **********"
600   PRINT
610   PAUSE
620   PRINT CHR$(12)
630   FOR Test=1 TO Numberoftests
640     IF Test=1 THEN OUTPUT Printer;"                    AC VOLTAGE RESPONSE TIME TESTS"
650 Ac_volts:OUTPUT Addr;D(Test);"V"
660     OUTPUT Addr;","
670     OUTPUT Addr;"1000H,"      ! TEST FREQUENCY = 1 kHZ.
680     PRINT CHR$(12)
690     PRINT
700     PRINT "------------------ Test ";Test;" of ";Numberoftests;"----------------------------"
710     PRINT
720     BEEP
730     PRINT "      PROGRAMMED VOLTAGE WILL BE =";D(Test);"volts"
740     PRINT
750     PRINT "            PRESS <ENTER> WHEN READY"
760     PRINT
770     PRINT "             WATCH THE METER NOW!!!"
780     INPUT A$
790     PRINT
800     PRINT "                    AC VOLTAGE TESTS"
810     OUTPUT Addr;"N"
820     WAIT Time
830 Enter_acvolts:BEEP 3000,.15
840     PRINT
841     Meter_reading$=""
850     PRINT "ENTER THE OBSERVED READING AT THE TIME OF THE TONE"
860     INPUT Meter_reading$
861     IF Meter_reading$="" THEN Enter_acvolts
870     PRINT
880     PRINT "             READING ENTERED = ";Meter_reading$
890     PRINT
900     BEEP
901     Yes_no$=""
910     PRINT "IS THE READING ENTERED CORRECTLY? (Y/N)"
920     INPUT Yes_no$
921     IF Yes_no$="" THEN 900
930     IF Yes_no$="N" OR Yes_no$="n" THEN Enter_acvolts
```

```
940      OUTPUT Addr;"CC"
950      PRINT
960      BEEP
961      Yes_no$=""
970      PRINT "DO YOU WISH TO RE-TEST THIS VOLTAGE? (Y/N)"
980      INPUT Yes_no$
981      IF Yes_no$="" THEN 960
990      IF Yes_no$="Y" OR Yes_no$="y" THEN Ac_volts
1000     GOSUB Record
1010  NEXT Test
1020  OUTPUT Addr;"CC"
1030  PRINT
1040  BEEP 500,.4
1050  PRINT "ALL";Numberoftests;"TESTS COMPLETED!"
1060  PRINT
1070  PRINTER IS Printer
1080  PRINT
1090  PRINT TAB(25),"ALL";Numberoftests;"TESTS COMPLETED!"
1100  PRINT
1110  PRINT TAB(10),"TIME INTERVAL = ";Time;" seconds"
1120  PRINT
1130  PRINT TAB(10),"TEST FREQUENCY = 1 kHz."
1140  PRINT
1150  PRINTER IS CRT
1160  PRINT "WAIT 5 SECONDS"
1170  WAIT 5
1180  GOTO Start
1190  !
1200 ! *******PRINT ROUTINE HERE**************
1210 !
1220 Record: !
1230  PRINTER IS CRT
1240  PRINT
1250  PRINT "ENTERED READING =",Meter_reading$
1260  ! BEEP 400,.4
1270  ! PRINT "WAIT 2 SECONDS"
1280  PRINTER IS Printer
1290  PRINT
1300  PRINT TAB(10),"PROGRAMMED VOLTAGE = ";D(Test),"   METER READING = ";Meter_reading$
1310  PRINTER IS CRT
1320  RETURN
1330  END
10    !*************** VOLTS ********************
20    !
30    ! PRG=VOLTS. FRI 05 SEPT 86. KJL.
40    ! VERSION 2.1.   DISC VOLUME = TMDE4A.
50    !
60    !
70 Start:CLEAR 7
80    !
90    GOSUB Initialize
100   ! -----------------------------------------------------------
110   !         Test  Data Definition Section
120   ! -----------------------------------------------------------
130   !
140   !
150   !  AC Voltage Test Data
160   !
170   Test_points=12
180   Actest_length=7                          ! Number of AC Voltage Tests
190   !
200   !     Voltage !# Freqs !------- Frequencies ---------------------------!
210   DATA  0.001,    4, 10,  50,   10000.,  99900.
220   DATA  0.010,    4,  0,   0,   10000.,  0
230   DATA  0.100,    4,  0,   0,   10000.,  0
240   DATA  1.000,    4,  0,   0,   10000.,  0
250   DATA  10.00,    4,  0,   0,   10000.,  0
```

```
260   DATA 200.00,   4,  0,   0,       0.,  99900.
270   DATA 300.00,   4, 10,  50.,  10000.,  0
280   !
290   !
300   FOR N=1 TO Actest_length              !  Loop each Vac Test
310     READ Vac(N,1)                       !  Read the Voltage into Vac(*)
320     READ Vac(N,2)                       !  Read the number of frequency pts.
330     FOR M=1 TO Vac(N,2)                 !  Loop the frequency points
340       READ Vac(N,M+2)                   !  Read the frequency points
350     NEXT M
360   NEXT N
370   PRINT
380   PRINT
390   PRINT
400   ! -------------------------------------------------------------------
410   !               End of Test Data Definition Section
420   ! -------------------------------------------------------------------
430   !
440   ! --------------------------------------------------------------------
450   !                  Start of ac test sequence
460   ! --------------------------------------------------------------------
470 Restart:CLEAR 7
480   BEEP
490   PRINT
500   PRINT "SET METER TO RESPOND TO AC VOLTAGE!"
510   PRINT
520   PRINT "PRESS <CONTINUE> WHEN READY!"
530   PRINT
540   PAUSE
550   !
560   Test=1   ! COUNTER SET FOR FIRST TEST AT FIRST RFEQUENCY
570   FOR Freqnum=1 TO 4                         ! Loop up to 4 freqs / voltage
580     FOR T=1 TO Actest_length                 ! Loop voltages
590       OUTPUT 2;Clear$;
600       Volts=Vac(T,1)
610       Freq=Vac(T,Freqnum+2)
620       IF Freq=0 THEN 1070
630       BEEP
640       PRINT "AC test number";Test;"of";Test_points   ! Displays test sequence
650       PRINT "PROGRAMMED FREQUENCY = ",Freq
660       PRINT "PROGRAMMED   VOLTAGE = ",Volts
670       GOSUB Volt_hertz! Volts*Freq<=1E8
680       GOSUB Volts
690       GOSUB Entry
700       GOSUB Record
710       !
720 Next_test:Test=Test+1    ! ADVANCE COUNTER FOR NEXT VOLTAGE TEST AT THE SPECIFIED FREQ.
730 Next_voltage:NEXT T
740 Next_freq:NEXT Freqnum
750   CLEAR 7
760   OUTPUT 2;Clear$;
770   BEEP 550,.5
780   PRINTER IS Printer
790   PRINT
800   PRINT TAB(15),"ALL VOLTAGE TESTS AT ALL FREQUENCIES COMPLETED!"
810   PRINT
820   PRINTER IS CRT
830   PRINT
840   PRINT "ALL VOLTAGE TESTS AT ALL FREQUENCIES COMPLETED!"
850   PRINT
860   BEEP
870   Yes_no$=""
880   INPUT "DO YOU WISH TO REPEAT THE TEST? (Y/N)!",Yes_no$
890   IF Yes_no$="" THEN 860
900   IF Yes_no$="Y" OR Yes_no$="y" THEN GOTO Restart
910   PRINT
920   PRINT "WAIT 5 SECONDS!"
```

```
930   WAIT 5
940   LOAD "MENU"
950   ! ***********************************************************************
960   !              Start of Subroutines
970   ! ***********************************************************************
980 Volts:  !
990   Checkout=1
1000  !
1010  Addr=Addr+0                         ! Get HP address from IEEE address
1020  !
1030  !
1040  ! -----------------------------------------------------------------------
1050  !      ---   START OF THE AC VOLTAGE TEST
1060  ! -----------------------------------------------------------------------
1070  OUTPUT Addr;"*"                     ! Reset
1080  PRINT
1090  IF T=1 THEN PRINT TABXY(10,5),"CONNECT TEST METER TO  5200A CALIBRATOR!"
1100  IF T=1 THEN BEEP
1110  PRINT
1120  IF T=1 THEN PRINT TAB(10),"PRESS <CONTINUE> WHEN READY!"
1130  IF T=1 THEN PAUSE
1140  IF Freq=0 THEN Next_voltage
1150  PRINT
1160  WAIT .5
1170  V$=VAL$(Volts)
1180  OUTPUT Addr;V$                   ! Append the voltage value
1190  OUTPUT Addr;"V"                        ! Add the V
1200  WAIT .5
1210  F$=VAL$(Freq)
1220  OUTPUT Addr;F$                   ! Append the frequency
1230  OUTPUT Addr;"H"
1240  WAIT .5
1250  IF Volts>119.9999 THEN Highv
1260  OUTPUT Addr;"F0X0N"                         ! Go to operate condition
1270  !
1280  RETURN
1290  !
1300  !***********************************************************************
1310  !
1320 Entry:  !
1330  !
1340  !  This subroutine records the operator's entry of the UUT reading
1350  !  and checks for the validity of response.  In addition, it uses the
1360  !  numerical entry to determine the range the meter is set to, i.e.
1370  !  volts, millivolts, etc.
1380  !
1390  PRINT
1400  PRINT
1410  BEEP
1420  Meter_reading$=""
1430  PRINT "ENTER THE READING DISPLAYED ON THE TEST METER."
1440  PRINT
1450  INPUT Meter_reading$                ! The operator's entry of reading
1460  IF Meter_reading$="" THEN 1410
1470  Valid$=""                           ! Clear the flag for bad entry
1480 Convert:   ! Convert Meter_reading$ to Volts
1490  !
1500  Decade=-3
1510  FOR D=-6 TO +6                      ! Go through the ranges to determine
1520    Reading=VAL(Meter_reading$)*(10^D) !  the meter's range
1530    IF ABS(Reading/Volts-1)<.3 THEN Decade=D
1540  NEXT D
1550 Range_check:  !  Check to assure that a reasonable range has been entered
1560  !
1570  BEEP
1580  !
1590  IF Decade=-6 THEN PRINT "        Meter reading  = ";Meter_reading$;" microvolts"
```

```
1600  IF Decade=-5 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1610  IF Decade=-4 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1620  IF Decade=-3 THEN PRINT "        Meter reading  = ";Meter_reading$;" millivolts"
1630  IF Decade=-2 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1640  IF Decade=-1 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1650  IF Decade=0 THEN PRINT "         Meter reading  = ";Meter_reading$;" volts"
1660  IF Decade=+1 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1670  IF Decade=+2 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1680  IF Decade=+3 THEN PRINT "        Meter reading  = ";Meter_reading$;" kilovolts"
1690  IF Decade=+4 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1700  IF Decade=+5 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1710  IF Decade=+6 THEN PRINT "     Reading entered   = ";Meter_reading$;"  CHECK IT!"
1720  !
1730  !  If the operator's entry is more than 30 percent in error, question it.
1740  Error=ABS(((VAL(Meter_reading$)*(10^Decade))/Volts)-1)
1750  IF Error>.3 THEN
1760    BEEP 400,1.5
1770    WAIT .5
1780    BEEP 500,1
1790    PRINT
1800    PRINT "     ******* RECHECK THE READING! *******"
1810  END IF
1820  PRINT
1830  PRINT "ARE THE VALUE AND UNITS CORRECT?   Yes= <ENTER>;  No = <N>"
1840  INPUT Valid$                                 !  Check for valid entry
1850  IF Valid$="n" OR Valid$="N" THEN 1400        !  Re-enter data
1860  RETURN
1870  !
1880  !****************************************************************************
1890  !
1900 Record: !
1910  !
1920  IF Decade=-6 THEN Meter_reading$=Meter_reading$&" uV"
1930  IF Decade=-3 THEN Meter_reading$=Meter_reading$&" mV"
1940  IF Decade=0 THEN Meter_reading$=Meter_reading$&" V"
1950  IF Decade=3 THEN Meter_reading$=Meter_reading$&" kV"
1960  BEEP
1970  PRINT
1980  F$=VAL$(Freq)
1990  PRINT USING "3X,4A,3X,10A,3X,9A,3X,10A";"TEST","PROGRAMMED"," METER ","PROGRAMMED"
2000  PRINT USING "2X,6A,3X,7A,5X,9A,3X,10A";"NUMBER","VOLTAGE","READING","FREQUENCY"
2010  PRINT USING "2X,6A,3X,7A,5X,9A,3X,10A";"------","-------","-------","---------"
2020  PRINT USING "4X,2D,3X,5D.4D,3X,9A,4X,6A";Test,Volts,Meter_reading$,F$
2030  IF T=1 THEN Record1
2040  PRINTER IS Printer
2050  PRINT USING "16X,2D,10X,5D.4D,11X,9A";Test,Volts,Meter_reading$
2060 Return:PRINTER IS CRT
2070  OUTPUT 2;Clear$;     ! CLEARS SCREEN
2080  RETURN
2090  !
2100  !***********************************************************
2110  !
2120 Record1:     !
2130  !
2140  PRINTER IS Printer
2150  !PRINT CHR$(12)     ! FORM FEED
2160  PRINT
2170  IF Freq=0 THEN
2180    PRINT USING "32X,14A";"FREQUENCY = DC"
2190  ELSE
2200    PRINT
2210    PRINT USING "32X,12A,K,3A";"FREQUENCY = ",Freq," Hz."
2220  END IF
2230  PRINT
2240  PRINT USING "15X,4A,10X,10A,10X,9A";"TEST","PROGRAMMED"," METER "
2250  PRINT USING "14X,6A,10X,7A,12X,9A";"NUMBER","VOLTAGE","READING"
2260  PRINT USING "14X,6A,10X,7A,12X,9A";"------","-------","-------"
```

```
2270  PRINT USING "16X,2D,10X,5D.4D,11X,9A";Test,Volts,Meter_reading$
2280  BEEP
2290  PRINTER IS CRT
2300  GOTO Return
2310  !
2320  !*******************************************************************
2330  !
2340 Initialize:   !
2350  !
2360  Addr=703      ! IEEE-488 ADDRESS OF AC VOLTAGE CLIBRATOR
2370  Printer=701  ! IEEE-488 ADDRESS OF EXTERNAL PRINTER
2380  ASSIGN @Hpib TO 7
2390  REMOTE @Hpib
2400  LOAD KEY "ABORTKEYS"
2410  ON KEY 0 LABEL "TO    " GOSUB Abort
2420  ON KEY 1 LABEL "SAFELY  " GOSUB Abort
2430  ON KEY 2 LABEL "ABORT   " GOSUB Abort
2440  ON KEY 3 LABEL "THE     " GOSUB Abort
2450  ON KEY 4 LABEL "RUNNING " GOSUB Abort
2460  ON KEY 5 LABEL "PROGRAM " GOSUB Abort
2470  ON KEY 6 LABEL "PRESS   " GOSUB Abort
2480  ON KEY 7 LABEL "ANY     " GOSUB Abort
2490  ON KEY 8 LABEL "SOFT-   " GOSUB Abort
2500  ON KEY 9 LABEL "KEY     " GOSUB Abort
2510  PRINTER IS CRT
2520  DIM Clear$[2],Home$[2],Scratch_key$[13],Vac(50,9)
2530  DIM V$[20],H$[20],A$[3]
2540  Clear$=CHR$(255)&CHR$(75)      ! CLEAR THE CRT
2550  Home$=CHR$(255)&CHR$(84)       ! PLACE THE CURSOR IN THE UPPER LEFT TOP OF          THE SCREEN.
2560  Scratch_key$="SCRATCH KEY"&CHR$(255)&CHR$(88)  ! ERASE THE SOFT-KEYS
2570  GRAPHICS OFF
2580  CONTROL 2,1;0       ! PRINTALL OFF
2590  CONTROL 1,4;0       ! DISPLAY FUNCTIONS OFF
2600  OUTPUT 2;Clear$;
2610  RETURN
2620  !
2630  !*********************************************************
2640 Highv: !     OPERATE THE FLUKE 5205 POWER AMPLIFIER
2650  !
2660  BEEP 500,.4
2670  V$=V$&"V"
2680  F$=F$&"H"
2690  IF F$="0H" THEN Next_voltage
2700  IF V$>"120V" THEN 2730
2710  IF V$="120V" THEN 2730
2720  IF V$<"120V" THEN V$="120V"
2730  OUTPUT Addr;V$,H$,"FOX1S"
2740  PRINT
2750  BEEP 500,.4
2760  ! OUTPUT 2;Clear$;
2770  PRINT "CONNECT METER TO 5205A POWER AMPLIFIER!"
2780  PRINT
2790  PRINT "PRESS <CONTINUE> WHEN READY"
2800  PRINT
2810  PAUSE
2820  BEEP 500,.4
2830  PRINT "LETHAL VOLTAGE PRESENT!!!!!"
2840  PRINT
2850  DISP "LETHAL VOLTAGE PRESENT!!!!!!"
2860  IF Freq<30 THEN
2870    WAIT 5
2880    GOTO 2990
2890  END IF
2900  IF Freq<120 THEN
2910    WAIT 3
2920    GOTO 2990
2930  END IF
```

```
2940  IF Freq<1200 THEN
2950    WAIT 2
2960    GOTO 2990
2970  END IF
2980  WAIT .3
2990  OUTPUT Addr;V$,H$,"F0X1N"
3000  RETURN
3010  !
3020  !****************************************************
3030  !
3040 Volt_hertz:  !
3050  !
3060  IF Volts*Freq<=1.E+8 THEN
3070    RETURN
3080  ELSE
3090    PRINT
3100    BEEP 500,.4
3110    PRINT "VOLTAGE*FREQUENCY > 1E8"
3120    PRINT "CALCULATED PRODUCT =",Volts*Freq,"WAIT"
3130    BEEP
3140  END IF
3150  WAIT 5
3160  GOSUB Volts
3170  !
3180  !****************************************************
3190  !
3200 Abort:  !
3210         !
3220  CLEAR 7
3230  OUTPUT Addr;"*"
3240  OUTPUT 2;Clear$;
3250  PRINT
3260  BEEP 500,.4
3270  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3280  PRINT
3290  WAIT 3
3300  PRINTER IS Printer
3310  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3320  PRINT
3330  PRINTER IS CRT
3340  PRINT CHR$(12)      ! CLEAR SCREEN
3350  GOTO Restart
3360  !
3370  !********************************************************
3380  !
3390 Abort1:        !
3400  !
3410  CLEAR 7
3420  PRINT
3430  BEEP 500,.4
3440  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3450  PRINT
3460  WAIT 3
3470  PRINTER IS 701
3480  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3490  PRINT
3500  PRINTER IS CRT
3510  GOTO Start
3520  !
3530 !*****************************************************
3540  !
3550 End:  !
3560  !
3570  OUTPUT 2;Clear$;
3580  BEEP 500,.4
3590  OFF KEY
3600  PRINT
```

```
3610  PRINT "ALL AC VOLTAGE TESTS COMPLETED! WAIT."
3620  WAIT 5
3630  LOAD "MENU"
3640  BEEP 500,.4
3650  END
```

APPENDIX D

LIST OF SPECIAL PARTS

List of special parts

4:1 Crest Factor Waveform Generator

A circuit designed at NBS which generates a waveform for the crest-factor test with a fundamental of ≃ 31 kHz and significant harmonic components limited to ≃ 1 MHz. The circuit is shown in fig. D-1, and the spectrum generated is shown in fig. D-2. [Fabricated at NBS]

50-ohm "N" adapter

A modified set of commercial N-type male and female connectors attached to the ends of a short tube containing a disk-type, 50-ohm shunt resistor. [Fabricated at NBS]

Cable with dual Banana plug

A special cable supplied by the manufacturer (Fluke) with output and sensing leads for a voltage standard. [Manufactured by Fluke]

Relay control box

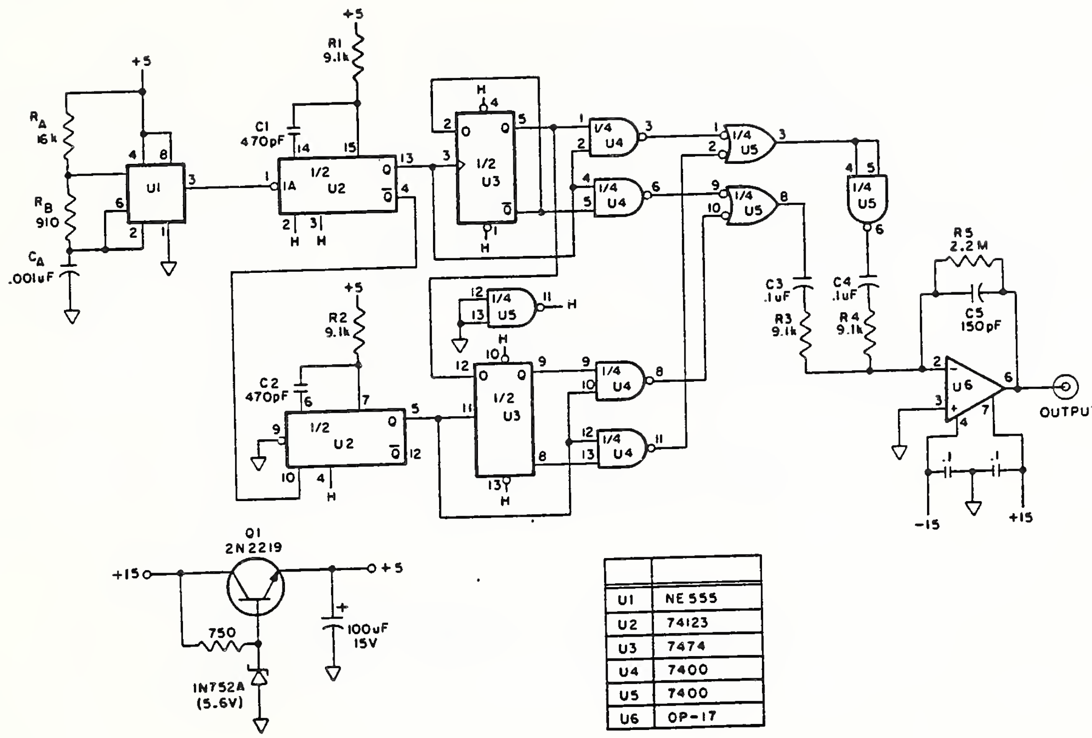
A metal enclosure containing a 9-volt battery and two double-pole, double-throw momentary push-button switches intended to control the operation of the Hewlett-Packard co-axial relay. The circuit is shown in fig. D-3. [Fabricated at NBS]

Resistor Junction Box

An enclosure containing two 3-kilohm tin-oxide resistors in series. The two ends of the resistor chain and the center tap are brought out to the center pins of three female BNC-type connectors. [Fabricated at NBS]

Step-up (output) transformer

A commercial signal transformer designed for use with the high-frequency amplifier to step up the output voltage. [ENI Model AM5-5B]



U1	NE555
U2	74123
U3	7474
U4	7400
U5	7400
U6	OP-17

Fig. D-1, Circuit Diagram of Crest Factor Test Signal Generator

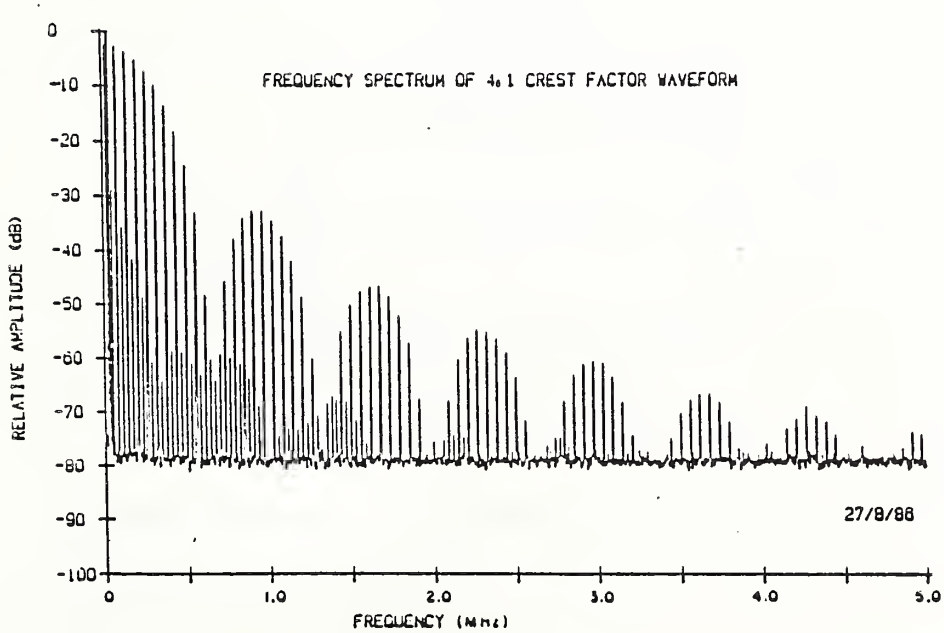


Fig. D-2, Frequency Spectrum of Crest Factor Test Signal

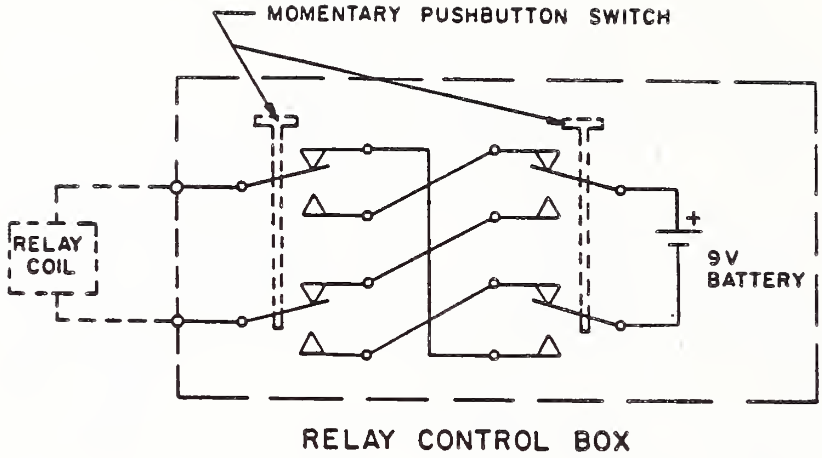


Fig. D-3, Circuit Diagram of Relay Control Box

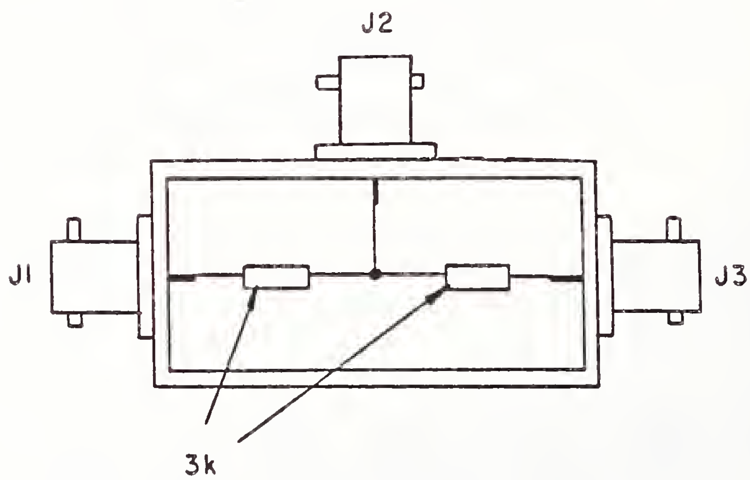


Fig. D-4, Resistor Junction Box, 3 kΩ, Assembly Drawing

APPENDIX E

EQUIPMENT LIST FOR RMS VOLTMETER TESTS

EQUIPMENT LIST for RMS VOLTMETER TESTS[3]

Function Generator	Hewlett-Packard 3325A or equival
Wall Clock, commercial item	

3 To describe the system discussed adequately, commercial equipment and parts are identified by the manufacturer's name and model number. In no case does such identification imply a recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

1. For an interesting discussion of analog meters, see Soisson, Harold E., *Electronic Measuring Systems*, McGraw-Hill Book Company, Inc., New York, 1961, pp. 182-188.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Electrical performance test procedures for a true rms voltmeter were developed by the National Bureau of Standards for the U.S. Army Communications-Electronics Command. The report provided detailed, step-by-step test procedures that are based on the specifications supplied by the Army for the purpose of evaluating the bid samples of this type of instrument. Examples are provided of the data sheets and tables for recording of interim data and the final results.

This report discusses the philosophy underlying each of the measurement procedures from a point of view of the basic metrology required to perform the measurements. In addition, the sources of measurement error are discussed.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Army specifications; rf voltmeter; test procedures; true rms voltmeter; voltmeter

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