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Electrical Performance Tests for Hand-Held Digital Multimeters

T. F. Leedy, K. J. Lentner, O. B. Laug, and B. A. Bell

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
(Formerly National Bureau of Standards)
Gaithersburg, MD 20899

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Final Report

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National Bureau of Standards became the National Institute of Standards and Technology on August 23, 1988, when the Omnibus Trade and Competitiveness Act was signed. NIST retains all NBS functions. Its new programs will encourage improved use of technology by U.S. industry.

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ELECTRICAL PERFORMANCE TEST FOR HAND-HELD DIGITAL MULTIMETERS

T.F. Leedy, K.J. Lentner, O.B. Laug, and B.A. Bell

Abstract

Electrical performance test procedures for battery-powered, hand-held digital multimeters were developed for the purpose of evaluating samples submitted by electronic instrument manufacturers in response to specifications issued by the U.S. Army Communications-Electronics Command. The detailed, step-by-step test procedures are based on the Army specifications and include sample data sheets and tables for the recording of interim data and final test results.

This report discusses the measurement principles and techniques underlying each of the procedures. In addition, the sources of measurement uncertainty are discussed.

Key Words: ammeter; digital multimeter; ohmmeter; test procedures; voltmeter.

1. INTRODUCTION

This report describes procedures that were developed by the National Institute of Standards and Technology (NIST) for the U.S. Army Communications-Electronics Command (CECOM) for testing the electrical performance of hand-held digital multimeters. The test procedures are based on performance specifications supplied by CECOM, and are intended for use by the Army in their Test Measurement and Diagnostic Equipment (TMDE) Modernization Program to evaluate bid samples of the candidate instruments. The report focuses only on the test procedures for electrical performance that can be conducted without access to the interior of the instruments under test. In addition, this report does not discuss in detail the electrical performance tests for the accessories that were specified by the Army; however, the tests for the accessories are included in the test procedures. For the most part, the Army performance specifications represent performance levels attainable by modern hand-held digital multimeters.

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 test procedures must be technically sound so as to provide an unbiased and objective evaluation of competitive instruments.

The test equipment chosen to perform these test procedures has been selected not only to satisfy the requirements of each individual test, but in the broader context of establishing a bid sample testing laboratory at CECOM.

Thus, some equipment used in the test procedures has higher accuracy or greater capability than is necessary to test these digital multimeters.

The remainder of this report is divided into three main sections: Section 2. gives a brief overview of the Army's TMDE Modernization Program. Section 3. contains general information on the applications and principles of commercial, hand-held, digital multimeters. Section 4. discusses the primary performance characteristics of these multimeters with emphasis on measurement techniques and includes a discussion of the sources of measurement uncertainties. The information in Section 4. also provides the theory and analysis to support the actual detailed test procedures given in Appendix B. The step-by-step test procedures are intended to be used by the Army for evaluating bid samples to assure conformity with the set of Army specifications given in Appendix A. Included in Appendix B are samples of appropriate data sheets and tables for recording interim and final results.

A computer program for testing these multimeters efficiently is provided in Appendix C. Appendix D shows the design and characteristics of specialized fixtures that are used in some of the test procedures, Appendix E contains the uncertainties of the signal sources and the specification limits for the digital hand-held multimeter, and Appendix F lists all the test equipment and accessories required for conducting the test procedures. Although the test procedures described in this report were specifically designed 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 standard for testing the performance of commercial hand-held digital multimeters.

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, and eliminate the proliferation of different types and models of such equipment in order to improve the efficiency of equipment maintenance. Specifically, the intent of the TMDE Modernization Program is to:

1. Introduce a minimum ensemble 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.

The acquisition of new TMDE items progresses through a two-step bid-sample-evaluation procedure. The first step begins with letter requests that are released to potential suppliers. The supplier has a period of 60 days to analyze the solicitation requirement and send bid samples to CECOM for testing. The samples are then evaluated for performance, useability, maintainability, workmanship, ease of calibration, military suitability, safety, and environmental capability. After bid sample testing, only the offerors of samples meeting the solicitation requirements are invited to submit bids. The second step occurs when the bids are received, evaluated, and the lowest responsive bidder awarded the contract.

Bid sample equipment evaluation requires an established set of test procedures which can objectively determine conformity with the specifications. Unlike some evaluations, such as safety and workmanship which are more general and widely applicable, test procedures for electrical performance are by necessity specification specific. That is, for each particular electrical performance attribute there must be a test procedure. Although some equipment manufacturers provide performance check procedures for purposes of incoming acceptance inspection, there is a lack of generic test methods applicable to various classes of equipment that can be directly and objectively used by the Army. The test procedures detailed in this report should fill this gap.

3. MULTIMETER OPERATING PRINCIPLES AND APPLICATIONS

Hand-held multimeters are one of the most common tools of the electronic engineer and technician. A decade ago, most multimeters were analog in nature and essentially consisted of an analog meter movement, together with a manual switching network used to implement the various functions and range capabilities of the meter. Generally, most analog multimeters were limited to the measurement of ac and dc voltage, current, and resistance with accuracies on the order of 2 to 5 percent. These analog meters were devices that used power from the circuit under test to provide for the movement of a meter pointer, except for the measurement of resistance. Older multimeters had relatively low input impedance voltage ranges, typically 20,000 Ω/V. Consequently, in some applications, the input impedance could affect the accuracy of the voltage measurements obtained since at least 50 μA was needed to provide a full-scale deflection of the meter on a voltage range. With the evolution of miniaturized, low-power electronic circuitry, the development of more sensitive and accurate multimeters was possible [1][1].

3.1. Basic Modern Digital Multimeter Design

The modern, battery-powered, hand-held digital multimeter can perform more functions than to its older analog counterpart. The usual basic measuring circuit of the digital multimeter is either a dual-slope integrating analog-to-digital (A/D) converter. The A/D converter is used in conjunction with automatic ranging circuitry; that is, the input range setting is automatically selected to provide the best measurement resolution possible for the A/D converter. To prevent hunting between ranges at the transition points, hysteresis is provided between the up-range and down-range transitions. Most digital multimeters also give a polarity indication and

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[1] Numbers in brackets refer to the literature citations listed at the end of this report.

automatically display the decimal point, as well as indicating the measurement units. Many digital multimeters also employ advanced logic circuitry, such as microprocessors, that enhance the ability of the meter to perform related measurements. For example, ac voltage measurements may be converted to decibels of power for various references impedances. Also, the computing power that is embodied in the microprocessor may be used to average readings and thus improve the accuracy of the meter. In addition, the microprocessor may store calibration tables, linearize the readings of the instrument, provide relative measurements between the present reading and a previously stored value, or actuate various displays such as "analog" bar-graph readouts.

While the digital processing power embedded in modern digital multimeters distinguishes them from their older analog counterparts, the analog circuitry which amplifies and conditions the input signals is also far superior to the simple resistance networks used in older units. The most notable feature is the high input impedance (typically 10 MΩ) afforded by high-performance, solid-state operational amplifiers. In addition to facilitating the measurement of voltages with far less loading effects than older analog designs, the high input impedance, coupled with protective devices, makes possible an overload protection capability that was previously unattainable. This input protection typically consists of a metal oxide varistor or zener diode circuit, possibly in combination with fuses or circuit breakers, which provides a voltage clamping action to prevent high voltages (or voltage transients) from reaching the solid-state circuitry. The major attribute of such clamping circuitry is its speed of operation and the ability to withstand high voltages without impairing the accuracy of the instrument. In addition, today's commercial hand-held digital multimeter is designed to withstand the vibrations and mechanical shocks that are encountered in field applications.

3.1.1. DC Voltage Measurements

The specific design of a digital multimeter is highly dependent on the manufacturer's technology of choice and prior design experience. Most modern digital multimeters use advanced dual-slope or quad-slope integrating A/D converters to change the analog signal input to the equivalent digital form necessary for processing and display. The dual-slope conversion technique, converts the dc input signal to an electrical pulse with a time duration proportional to the amplitude of the input signal. The time duration of the output of the comparator is then used to gate an accurate oscillator or clock pulse source into a high-resolution counter. The conversion of the dc input signal to an electrical pulse, is accomplished by the integration of a current that is proportional to the input voltage. The integration of the input voltage is performed by charging a high-quality capacitor for a predetermined time. Then, a reference input current, of opposite polarity, is switched to the integrator, and the capacitor is discharged at a known rate until a reference level is reached. An analog comparator and digital logic circuitry then provides a variable-length pulse that is of the same time duration as the discharge time.

Figure 1 shows the voltage output of the integrator of a dual-slope converter for two typical measurement cycles. The solid line represents a the voltage at the output of the integrator for a full-scale input voltage. The dotted line represents the output of the integrator for approximately one half the full-scale input voltage. The time for the second integration process (discharge time) is proportional to the average of the unknown signal over the predetermined integration time. The reference-integration time is then measured with an electronic counter (as described above), and the count, adjusted to provide a value in the appropriate measurement units, is displayed on an output indicator.

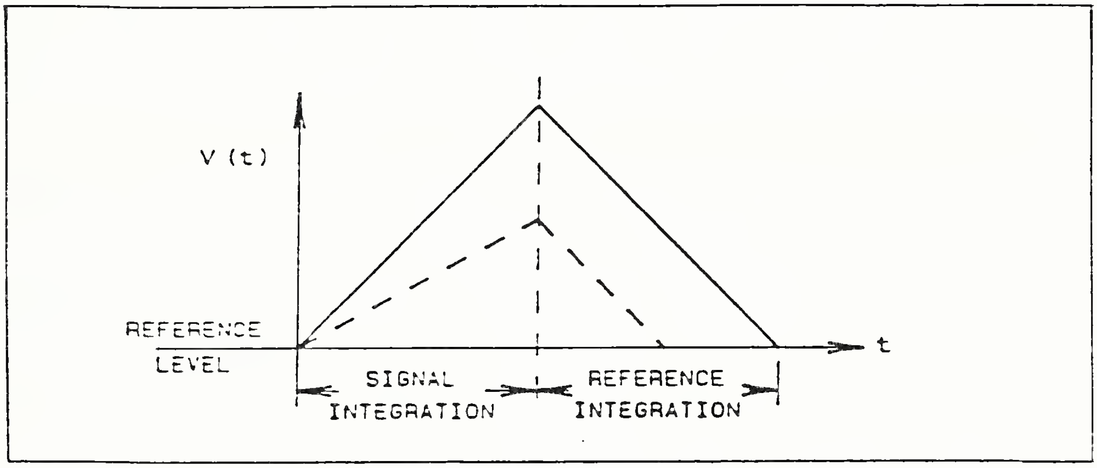

Figure 1 The output of the integrator of a dual-slope converter for one measurement cycle.

The dual-slope A/D conversion technique is widely used since the method does not require high-accuracy resistive divider networks to achieve very accurate measurements. The basis for accuracy is in the precision reference source which is used during the reference integration time. Besides the reference source, the other components are required to be stable only over the integration time in order for the dual-slope converter to achieve the specified accuracy. Generally, the most critical components reside in the attenuator network that provides the range switching function of the digital multimeter. However, the attenuator network must consist primarily of resistors with accurate ratios. Hence the attenuation stability depends on the maintenance of the ratio accuracy -- a condition that is readily achieved with low-temperature coefficient resistive materials and laser trimming of hybrid-circuit attenuators.

There are many variations on the basic, dual-slope A/D conversion technique. For example, additional circuitry may be added to provide compensation for zero offset during each measurement cycle. Additional circuitry may be used to provide more complicated measurement cycles such as used in quad-slope conversion techniques. Quad-slope converters remove many offset and residual inaccuracies by effectively shorting the input to the converter, measuring the offset voltage, and then subtracting the offset (in either an analog or digital manner) from the amplitude of the input signal being measured. Similar techniques may also be used to compensate for gain calibration errors and temperature errors.

3.1.2. AC Voltage Measurements

Several characteristics of ac signals may be measured to indicate magnitude. The most common measures are average value, peak-to-peak value, and the root-mean-square (rms) value. The rms value of an ac signal is generally the most meaningful since the rms value indicates the effective power of the measured ac waveform. In order to measure the rms value of ac signals, it is necessary to scale and convert the ac input voltage or current to a dc voltage level proportional to the rms value of the ac signal. The corresponding dc voltage is then fed to the A/D converter to be digitized and displayed.

The ac rms-to-dc conversion may be accomplished by several techniques. One typical way of obtaining the rms value of a waveform utilizes three circuit functions in series. In the first circuit, the input signal is multiplied by itself to obtain a voltage waveform that is the mathematical square of the input signal. The resultant signal is then time-averaged by the second circuit. The last circuit computes the square root of the time-averaged signal to obtain a dc voltage that is proportional to the rms value of the input. The analog circuitry can employ direct multiplication and division using variations of the Gilbert, or transconductance amplifier, multiplying circuit [2], or by using multipliers and dividers based on logarithmic amplifiers. Both the transconductance type and the logarithmic amplifier type multiplier are available as integrated circuits.

Greater accuracy can be obtained using thermal converters which compare the heat dissipated by the ac signal to that of an equivalent dc quantity. Thermal converters are normally used in precision digital multimeters of higher accuracy than encountered in hand-held digital multimeters. However, economical solid-state thermal converters are now commercially available, and these may be used in hand-held digital multimeters in the near future. The thermal converter employs a voltage ranging resistor in series with a low-resistance heating element to which a temperature sensor is attached. In the case of the solid-state units, the sensor is in the form of a transistor or diode [3]-[4]. For greater sensitivity two similar temperature sensors and heating elements are configured in the rms-to-dc converter circuit as a differentially connected pair. One heating element is energized with the unknown ac signal and the other with a measured dc signal driven by a feedback loop until the outputs of the two temperature sensors are equal. Another advantage of the thermal conversion technique is that it has a relatively wide bandwidth compared to transconductance or logarithmic multipliers. Thermal conversion techniques are also insensitive to waveform distortion, and can tolerate signals having large crest factors. A disadvantage of thermal converters is their relatively slow response time compared to that of solid state multipliers.

3.1.3. Resistance Measurements

In addition to voltage measurements, hand-held digital multimeters are usually capable of making resistance measurements. The resistance function is usually implemented by combining a constant current source circuit with the dc voltage measurement function. The constant current is passed through the unknown resistance, and the voltage is measured across the unknown resistance. Then, the value of the unknown resistance is determined from the measured voltage and the value of the constant current by using Ohm's law. Usually, range switching is implemented by selecting combinations of currents and dc voltage measurement ranges such that a wide spread of resistances may be accommodated. For example, a constant current of 10 mA in combination with a voltage range of 100 mV will provide a resistance measurement capability of 10 Ω, full scale. By changing the values of the current source and the voltage range to 1 μA and 10 V, respectively, full-scale resistance readings of 10 MΩ may be made.

With microprocessor capability, resistance functions of the modern digital multimeter may be modified to provide other functions as well. For example, the reciprocal of resistance, or conductance, may be calculated and displayed. The conductance is usually expressed in Siemens ($1\ S = (1\Omega)^{-1}$) or microsiemens ($1\ \mu S = (1\Omega)^{-6}$). Additionally, the processing capability of the digital multimeter may be used to activate a small speaker or piezoelectric "beeper" to indicate circuit continuity. The sound made by the meter allows the verification of electrical continuity between the test probes without requiring the operator to view the meter display. In the continuity mode the digital multimeter produces a sound when the resistance value is less than some threshold, typically about 100 Ω. The continuity function of a digital multimeter is very useful in situations such as checking cable assemblies, relay contacts, and other application where it is desired to quickly determine circuit continuity during circuit testing.

The resistance functions can also be used to test diodes and other semiconductor devices. A diode is a semiconductor device intended to conduct electrical current in the forward direction and to present a high resistance to the passage of current in the reverse direction. Thus, if a diode is placed across the test probes of a digital multimeter set to measure resistance a non-defective diode will present a relatively low electrical resistance if the positive probe is connected to the anode and the negative probe is connected to the cathode. This configuration biases the diode in the forward direction. Conversely, if the probes are interchanged, the diode will be reverse biased and a much higher electrical resistance (by several orders of magnitude) will be indicated than before. A diode damaged by overloading may be either shorted or open due to damage to the semiconductor junction region. Shorted diodes may be readily identified by the fact that there will not be a high reverse-to-forward resistance difference but rather a nearly equal resistance in both directions. Open diodes exhibit infinite resistance in both directions. Transistors can be considered as a pair of diodes and may be analyzed similarly for gross defects such as opens and shorts.

3.1.4. Current Measurements

AC and dc current measurements can be made with most hand-held digital multimeters. A current measurement is simply a measurement of the voltage drop produced across a known resistance of low value, commonly called a shunt resistor, internal to the meter. The accuracy of the current measurement is dependent upon the accuracy and stability of the shunt resistor as well as the basic accuracy of the voltage measurement. The ideal current measurement device will not introduce any voltage drop in the circuit under test. In practice, however, digital multimeters use different values of shunt resistors to provide various current measurement ranges. Typically, these resistors are on the order of 0.01 Ω to measure currents in the ampere range and up to 500 Ω for current measurements in the microampere range. The voltage drop across the shunt resistor is known as the voltage burden of the multimeter.

3.1.5. Other Design Features

Hand-held digital multimeters may also incorporate many other features to enhance their usefulness. For example, a frequency counter may be incorporated into the digital multimeter since much of the logic circuitry for counting pulses is already present in the A/D converter used for the measurement of voltage, current, and resistance. It is a reasonably simple modification to the counter circuitry to permit the counting of pulses from the test probes over a fixed length of time in order to obtain the frequency of the pulses.

Often it is desirable to make the measurement of a voltage and then have the multimeter "remember" the value of the measurement after the test probes have been removed from the voltage source. Modern hand-held digital multimeters may implement this memory function in several ways. The most straightforward method is to program the digital microprocessor to store the displayed voltage if the output of the A/D converter changes abruptly in a direction towards zero. This condition will be produced when a probe is removed from a voltage source causing a rapid decrease at the input of the digital multimeter. An alternative method of creating a memory function uses an analog track/hold circuit which changes state from the track to the hold mode when a rapid input voltage decrease occurs. This technique relies upon a capacitor holding a charge that is proportional to the voltage amplitude to be stored. The analog track/hold circuit is designed so that the charge on the capacitor changes very slowly over a period of several minutes. With either method, there is usually a manual method of resetting the memory function after the measurement has been read by the operator, so that the next measurement may be made. The reset operation usually involves pushing a button to either update the display in the case of the digital method, or to discharge the capacitor if the analog technique is used.

4. DIGITAL MULTIMETER PERFORMANCE MEASUREMENTS

4.1. Input Characteristics

The voltage input characteristics of a digital multimeter generally specified by manufacturers include the input impedance, the common-mode rejection ratio, the maximum input voltage, and the input over-voltage protection. These characteristics are specified to provide the user with information on the influence of the digital multimeter upon the circuit voltage being measured and the amount of abuse that the instrument will withstand.

Likewise, the current input characteristics of a digital multimeter may be of concern to the user. The accuracy of current measurements made with a digital multimeter may be adversely affected if the voltage drop across the meter is not small compared to the voltage compliance of the current source to be measured. For instance, if an external resistive branch circuit is powered from a 2 V source and the voltage drop across the digital multimeter (burden voltage) in the current mode is 2 mV, then the insertion of the meter into the branch circuit will reduce the current by $(0.002/2 \cdot 100)$ or 0.1%. To measure currents in low-voltage circuits, therefore, it is important to select a digital multimeter with an effective shunt resistance that is low enough to result in only a very small voltage drop across the meter. An exception to this rule is the measurement of current in a constant-current circuit where the effects of moderate voltage drops across the digital multimeter will not produce appreciable errors.

4.1.1. Input Impedance

The input characteristics of most hand-held digital multimeters are designed to minimize disturbing the circuit under test. Ideally, the input impedance should be an open circuit for ac and dc voltage measurements, and a short circuit for ac and dc current 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 uncertainty due to the changes in input impedance increases with frequency. DC measurement uncertainties are not adversely affected by the input capacitance.

<u>Measurement Technique</u>

There are numerous methods for measuring the input impedance of an instrument. Traditionally, impedance bridges are used to find the values of the input capacitance in parallel with the input resistance. Most bridges are manually balanced, have limited range, and do not measure resistance and capacitance directly. Instead, bridges will measure the value of the capacitance and the dissipation (D) or quality factor (Q) of the capacitor. From this information, the parallel resistance may be determined. A more convenient method for the measurement of input impedance is obtained using a self-balancing bridge. One class of self-balancing bridges are called LCR meters.

The measurement technique described in the test procedures given in Appendix B uses a commercial digital LCR meter to measure the input resistance and capacitance directly across the multimeter input terminals. Thus, the input resistance and capacitance of the digital multimeter may be directly determined without the need for additional equipment or calculations.

Sources of Measurement Uncertainty

The measurement uncertainties associated with using a direct-reading LCR meter are attributable to uncertainties associated with the accuracy of the LCR meter and the stray capacitance of the leads connecting the LCR meter to the multimeter under test. The insulation resistance of the leads is usually sufficiently large enough that the leads do not introduce a measurable uncertainty of input resistance. However, the leads may contribute some extraneous capacitance not attributable to the input capacitance of the digital multimeter. If the leads are separated by approximately 1 inch (25.4 mm), a set of test leads 3 feet long (0.91 m) contribute approximately 5 pf or less [5]. The capacitance introduced by the leads may be measured independently of the digital multimeter input capacitance by simply disconnecting the leads from the multimeter and noting the residual capacitance per the procedure provided. Other uncertainties in the measurement of input impedance arise from the basic calibration uncertainty of the LCR meter. For example, the uncertainty of the LCR meter used for making parallel resistance and capacitance measurements in the test procedure is specified by the manufacturer to be [6]

$$\text{Capacitance Uncertainty} = \pm(0.2\ \%\ \text{of reading} + 1\ \text{digit}),$$

and the uncertainty for parallel resistance measurements is

$$\text{Resistance Uncertainty} = \pm(0.3\ \%\ \text{of reading} + 2\ \text{digits}).$$

Therefore, the total measurement uncertainties associated with using the LCR meter, considering the ranges used and the number of digits displayed, are as follows:

$$\begin{aligned}\text{Capacitance Uncertainty} &= \pm((0.002 \cdot 100.0\ \text{pF}) + 0.1\ \text{pF}) \\ &= \pm\ 2.1\ \text{pF}\end{aligned}$$

$$\begin{aligned}\text{Resistance Uncertainty} &= \pm((0.003 \cdot 10.00\ \text{M}\Omega) + 0.02\ \text{M}\Omega) \\ &= \pm\ 0.050\ \text{M}\Omega = 50\ \text{k}\Omega.\end{aligned}$$

4.1.2. Common-mode Rejection

Common-mode rejection is the capability of the digital multimeter to measure a voltage drop across the input probes in the presence of a "common" or mutual ac or dc voltage at each probe with respect to ground. The capability of an instrument to reject a common-mode signal presented at both inputs simultaneously is an indication of the symmetry of the differential amplifiers used in the input circuitry of the instrument. In many measurement situations, such as the measurement of power-line voltage across the phases of a three-phase power supply, the common-mode rejection is important since both probes have large common-mode voltages above ground potential. The common-mode rejection is particularly important for meters that are grounded, such as those that are connected to the power line. For hand-held digital multimeters which are battery operated and not connected to the power line, this specification is less meaningful, especially for dc voltage measurements (although a procedure for dc common-mode rejection is presented for completeness.) However, measurement uncertainties may occur for ac voltage measurements due to common-mode errors associated with the capacitive coupling between the internal circuitry of the digital multimeter and ground. Common-mode errors associated with such capacitive coupling are highly dependent on the position of the digital multimeter with respect to a ground plane.

Measurement Technique

The common-mode rejection ratio specification applies to those instruments that have a differential voltage input.[7] Since such instruments ideally measure the potential difference between the two inputs, a measure of the common-mode rejection ratio may be obtained by connecting the two inputs together, applying a voltage between the leads and ground, and measuring the resultant output of the instrument. Ideally, if the instrument has infinite common-mode rejection capability, the output will be zero for any magnitude of applied common-mode input voltage. This general method for the measurement of common-mode rejection ratio is illustrated in figure 2.

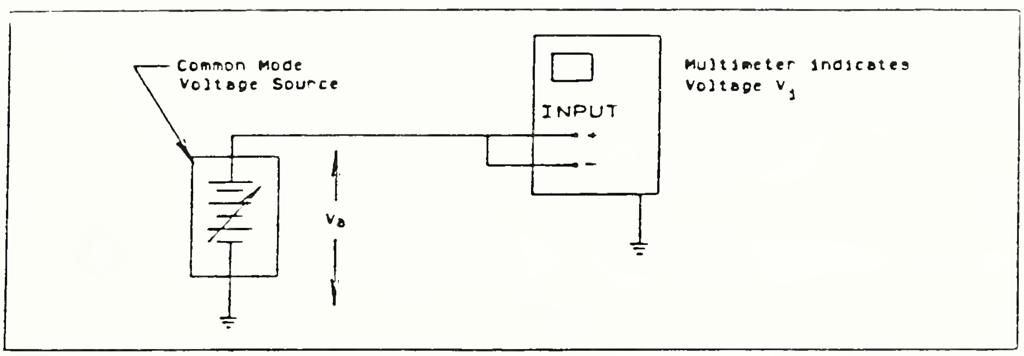

Figure 2 The general method for the measurement of common-mode rejection ratio of a grounded measurement instrument.

The common-mode rejection ratio is measured by applying a voltage, V_a, between the differential inputs of the instrument and ground, and reading the change in output indicated by the instrument. The change in output is $(V_i - V_o)$ where

V_i = the voltage indicated by the instrument under test when V_a is applied,

V_a = the applied common-mode voltage, and

V_o = the instrument indication with V_a set to zero.

The common-mode rejection ratio (CMRR), in decibels, is then calculated according to the formula

$$\mathrm{CMRR} = 20 \cdot \log_{10} \left[\frac{V_i - V_o}{V_a} \right] .$$

The value of V_o is measured since the instrument may not read zero with the inputs of the instrument shorted together and no common-mode voltage applied. In addition, there are often specifications placed upon the measurement conditions of the common-mode rejection ratio. These include the value of the applied voltage, V_a, and the value of a resistance to be placed in one of the measurement leads. A resistor placed in one lead of the instrument presents an unequal source impedance to the input circuitry. If the impedances of the inputs to the digital multimeter are not equal, the loading of the input circuitry may cause an apparent common-mode error. However, if the input impedance is much higher than the source impedance, the effect of unequal resistance at the input is negligible. There are limitations to the magnitude of common-mode voltage that may be applied to the input of an instrument. The common-mode voltage should not exceed the maximum input voltage that the instrument is designed to withstand.

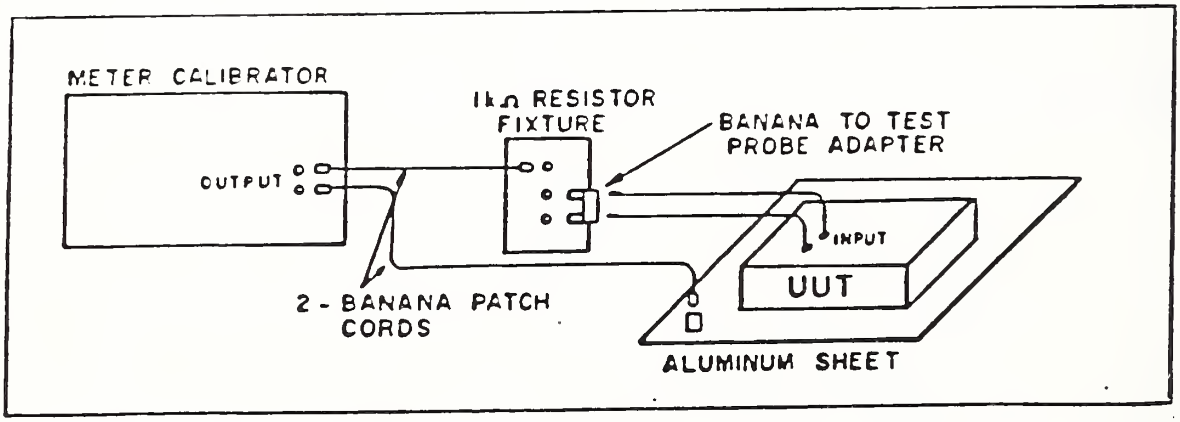

Figure 3 Test setup for measuring common-mode rejection ratio.

In the test procedure for ac common-mode rejection ratio developed for a battery-operated, hand-held digital multimeter, the instrument is placed upon a square metallic sheet which is considered to be the reference ground plane for the measurement. The input test probes are then connected together via a

1000 Ω resistor, as shown in the figure 3. The voltage output of the calibrator is set to zero and any residual offset voltage displayed by the meter is read and recorded as Vo. The common-mode voltage, V_a, is then set to be 100 V at 50 Hz. The voltage is applied from the ac calibrator between the metallic sheet and the input terminals of the meter. The voltage displayed on the digital multimeter is again read and recorded as V_i. The difference between the two voltage readings is the error caused by the common-mode voltage. The common-mode rejection ratio is then calculated as

$$CMRR = 20 \cdot \log_{10} \left(\frac{V_i - Vo}{100\ V} \right) .$$

This procedure may be repeated at other frequencies. The test procedures given in Appendix B measure the ac common-mode rejection ratio of the digital multimeter at 50, 60, and 400 Hz, the most commonly encountered power-line frequencies used in military equipment. A similar the same procedure is used to test the dc common-mode rejection ratio.

Sources of Measurement Uncertainty

There are several sources of error when measuring common-mode rejection. The uncertainties of the applied voltage provided by the calibrator, V_a, may be ignored since a small change in the applied voltage will not result in a significant change in common-mode rejection ratio. The major source of measurement uncertainty is the limited resolution and the relatively large inaccuracy of the digital multimeter in measuring the error, V_i, caused by the common-mode voltage. In this case, the accuracy of the digital multimeter is specified to be ±(0.5% + 3 counts) over the frequency range of 40 Hz to 1 kHz. Furthermore, the specification by the Army states that the digital multimeter shall exhibit at least a -60 dB CMRR. If we assume that the meter "just passes" the common-mode rejection ratio test, then the meter will indicate -60 dB, or a factor of 0.001 of the applied voltage, (100 V ac). This means that the meter will read 100 mV ac. The accuracy of the meter is ±1 mV for a 100 mV reading. Thus, the uncertainty of the common-mode rejection ratio test is found by calculating an example of the CMRR with the worst-case accuracy of the digital multimeter reading (100 mV ac):

$$\text{Uncertainty} = -60\ dB - \left((20 \cdot \log_{10} \frac{0.099\ V}{100\ V} \right)$$

$$= -60\ dB - (-60.087\ dB)$$
$$= -0.087\ dB.$$

A similar calculation may be performed for the dc common-mode rejection ratio. The specifications state that the dc CMRR shall be less than -80 dB. The required accuracy of the meter to measure the common-mode voltage of 10 mV dc is specified by the Army to be ±(0.1% + 1 count), or, ±0.1 mV for a 3

1/2-digit multimeter. Thus, the predicted uncertainty in measuring the CMRR should be the same numerical value as calculated for the ac case. In practice, it was found that due to noise and offsets, the dc CMRR could not be reproducibility measured to less than 0.5 dB.

4.1.3. Input Protection

The input protection of the hand-held digital multimeter is the ability of the unit to survive input voltage and current overloads without damage. This characteristic is important since the digital multimeter may be subjected to high voltages when the operator is not expecting such voltages and has the range switch set to a low-voltage range. Likewise, current ranges may be improperly set, or a short circuit in the external circuitry may cause an unexpectedly large input current through the digital multimeter. Another potentially destructive condition arises when a multimeter is used to measure resistance and the probes are accidentally connected across a large voltage. Modern digital multimeters are able to survive such abuse through several measures. The use of electrical protection devices such as metal-oxide varistors (MOV), spark gaps, and coordinated fusing makes the design of digital multimeters more robust relative to electrical overloads. In addition, microelectronic technology permits the design of high input-impedance measurement circuits which, in turn, permits a greater tolerance for high voltages at the input of the digital multimeter.

Any electrical measurement instrument will have a threshold input voltage above which the unit will be damaged. Caution should be exercised in the testing and use of electrical equipment not to exceed the maximum input signal levels recommended by the manufacturer. This caution is especially important if the instrument is to be used to measure voltages or currents from sources (such as power lines or large power supplies) that may provide high voltages from low source impedances. If the protective devices within the hand-held digital multimeter fail to operate properly, or if the power dissipation of the protective devices is exceeded, the external case or enclosure of the digital multimeter may rupture, causing a personnel hazard. In the tests used in the procedures in Appendix B, the source of power applied to the input is a current-limited meter calibrator which should not, under normal circumstances, cause a dangerous failure of the digital multimeter.

Measurement Technique

The best test for the ability of the input circuity to withstand an overload condition is simply to subject the meter under test to a worst-case overload voltage or current. Such tests may be destructive of the digital multimeter, and the evidence of test failure is damage to the meter which results in its inability to meet the specifications. The overload protection tests provided in Appendix B are based on the tests described in paragraph 6.13 of ANSI C39.6-1983 for Maximum Nondestructive Input Signal [8]. This specification states that the test shall "apply the maximum nondestructive input specified by the manufacturer to the instrument under test for all ranges of a given function for a period as specified by the manufacturer. For maximum continuous inputs, apply for at least five minutes." The input protection tests are applied to the digital multimeter for dc and ac voltage, resistance, and frequency counting modes. As an example, the dc voltage ranges of the digital multimeter are tested by the application of 1000 V dc to the meter on each of the six input ranges. The meter connections are then interchanged and the voltage reapplied to the meter with the opposite polarity. The meter is subjected to the maximum voltage for five minutes on each range. At the conclusion of the 1000 V dc test, a 1000 V peak (707 V (rms)) ac voltage is applied to the multimeter and the test is repeated. At the conclusion of the test, data are recorded to note the presence of any smoking, arcing, or charring of the digital multimeter during the application of maximum input voltage. Such indications are the only visual proof that damage has occurred to the digital multimeter. As an additional precaution, it may be advisable to perform any overload input protection tests at the beginning of acceptance testing of the digital multimeter. In this manner, it may be determined that the measurement integrity of the digital multimeter is not degraded because of latent defects.

The input protection tests for the ac voltage ranges are performed in a similar (but somewhat abbreviated) manner to those performed on the dc voltage ranges. The ac voltage input protection tests consist of applying the ac and dc voltages stated in the Army's specifications for voltage protection to the two lowest input voltage ranges available on the hand-held digital multimeter. The input protection tests for ac voltage apply the highest permissible voltages at the maximum frequencies allowed by the specifications.

The Army specification for the dc and ac current overload protection is given as a design specification. It states that the unit shall have a "2 A / 250 V fuse and a 3 A / 600 V fuse in series, or a single 2 A / 600 V fuse." Many meters have multiple fuses in series in order to protect the meter and the operator from serious damage if the meter is set for current but connected across a power line having negligible source impedance. For such a condition, multiple fuses may provide better coordination and cause less equipment damage than a single fuse. It should be noted that the test procedures given in Appendix B do not attempt to test the overload protection afforded by the fuses specified by the Army, but rather, to ascertain that the fuses are present in the equipment.

The input protection afforded by the digital multimeter to excessive voltage in the resistance and frequency counter modes is very similar to that described for the voltage-mode protection tests.

<u>Sources of Measurement Uncertainty</u>

The input protection tests are designed as pass/fail tests. Accordingly, there is no source of significant measurement error. The voltages used are provided by a high-accuracy meter calibrator and, thus, the uncertainty of the applied voltage is far less than other conditions of the test such as prior use, environmental conditions, etc.

4.2. DC Voltage / Current

The procedure for testing the accuracy of the dc voltage and current functions of a hand-held digital multimeter makes use of a programmable meter calibrator as a source of precision voltages and currents. The output of the calibrator is connected directly to the multimeter under test. Commercial meter calibration systems are available that provide stable dc voltages and currents of sufficient accuracy to verify the performance characteristics of a digital multimeter such as those specified by the Army in Appendix A. The sequence of voltages and currents necessary to implement the test procedures given in Appendix B are applied to the multimeter by the meter calibrator under computer control. The software that is necessary to perform the test procedures is given in Appendix C. The ability to control the output amplitude via computer greatly enhances the utility of the calibrator, helps prevent operator errors, and greatly conserves test time.

4.2.1. Range and Accuracy

The range and accuracy of hand-held digital multimeters are specified in several different ways depending upon the manufacturer. A common method used to specify the accuracy of hand-held digital multimeter is as follows:

$$\pm(\text{percent of reading + number of digits}).$$

For such accuracy statements to be meaningful, the number of full-scale counts displayed by the digital multimeter must be known. Thus, when comparing accuracy specifications, one digit on a 3 1/2- or 3 3/4-digit multimeter is equivalent to ten digits on a 4 1/2- or 4 3/4-digit multimeter.

A comment is in order at this point about the assumptions concerning the ranging and resolution characteristics of the digital multimeter specified by the Army and contained in the Notes of Appendix B. The procedures for testing the digital multimeter assume that the digital multimeter conforms to the usual definition of a 3 1/2-digit multimeter with 1999 discrete values displayed per range. (The Army specifications require a minimum of 3 1/2 digits of resolution to be displayed and thus permit more than 3 1/2 digits). Furthermore, it is assumed that the least-significant digit is always displayed except on the lowest ranges. If 3 1/2 digits were displayed on the lowest ranges, more resolution than is specified by the Army would be provided on these ranges. For example, a dc voltage measurement made on a 20 mV range, with a minimum specified resolution of 3 1/2 digits, or 1999 counts, would have the least-significant digit equal to 10μV. Thus, the resolution of the least-significant digit exceeds the requirements of the Army specifications. For purposes of testing, it is assumed that the resolution of such digital multimeters will not exceed the Army specifications. Using these assumptions, a series of test voltages and currents were formulated that are in a 1, 1.8, and 5 sequence. Such a sequence tests the digital multimeter at approximately 50 percent of the full-scale range, 90 percent of the full-scale range, and 25 percent of the (next higher) full-scale range, respectively.

Measurement Technique

The output of a dc calibrator is connected directly to the input of the digital multimeter, and preprogrammed calibration voltages are applied to the digital multimeter using a series of commands provided by the computer via the IEEE-488 bus. For each positive input value a corresponding negative input value is used as part of the set of test points.

Sources of Measurement Uncertainty

The uncertainty limits of the dc voltage and current test signals are given by the accuracy specifications of the meter calibrator used in the accuracy tests. The uncertainties associated with the dc voltages provided by the calibrator, for each value of dc voltage applied to the digital multimeter, are given in Table E-1. Table E-10 tabulates the dc current uncertainties in a similar manner. Other sources of measurement uncertainty may include thermoelectric voltage offsets introduced by the use of dissimilar metals to connect the digital multimeter to the meter calibrator. These uncertainties are temperature dependent and typically generate potentials on the order of 10 μV/°C. Such thermoelectric voltage offsets may, in practice, generate a few microvolts of dc potential that would change, add to, or subtract from, a dc voltage obtained from the calibrator. However, even on the lowest dc voltage measurement range, such thermoelectric voltages would contribute negligible uncertainties and are lower than could be measured with the most sensitive ranges provided by these types of digital multimeters.

4.2.2. Response Time

The determination of the dc voltage and current response time establishes whether a meter reading within the specified accuracy limits can be obtained in a given time interval. The response time for a digital multimeter should be "reasonable" since it would be annoying to have an instrument that responds very slowly especially if the instrument were to be used for the rapid checking of many test points in a production environment.

Measurement Technique

The measurement of response time for instruments having only a visual readout is necessarily subjective and dependent on operator reaction time to observe the rate at which the display changes. The measurement is carried out with a bus-controlled meter calibrator which applies a known dc voltage or current to the hand-held digital multimeter. 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 ac voltage or current accuracy limits applicable for the range of the input, the test is deemed successful. Generally, it is beneficial to repeat the test several times to check consistency of the result and to ensure that the operator does not contribute excessive random uncertainties to the outcome of the test.

Sources of Measurement Uncertainty

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

4.2.3. Burden Voltage

Current measurements have an uncertainty introduced by the small voltage drop (burden voltage) across the digital multimeter. The uncertainty results because insertion of the meter into the circuit changes the total circuit impedance and, therefore, the current to be measured. A current meter should, ideally, have a zero voltage drop. In practice, the voltage drop across the digital multimeter in the current mode is on the order of tens to hundreds of millivolts, depending on the range, sensitivity, and design of the meter.

Measurement Technique

A high-impedance precision millivoltmeter is connected across the input terminals of the digital multimeter, and a current from a calibrated current source is measured by the digital multimeter under test. The burden voltage, the voltage drop across the terminals of the digital multimeter, is then read on the millivoltmeter. The current applied to the multimeter should correspond to the maximum value specified for the particular range tested such that the maximum burden voltage is obtained.

Sources of Measurement Uncertainty

Since the burden voltage is generally directly proportional to the input current for a given range, the percentage uncertainties of the calibrated current source and those of the millivoltmeter are additive. Thermal offsets in the leads of the millivoltmeter may introduce an uncertainty in the measurement of dc burden voltage. The presence of thermal offsets may easily be checked by reducing the current through the digital multimeter to zero and assuring that the millivoltmeter also reads zero. For the magnitudes of the burden voltages specified for the digital multimeter, the thermal offsets should not be of concern.

4.3. AC Voltage / Current

The discussion in section 3.2.1 indicates that the measurement of ac voltage or current by a hand-held digital multimeter is usually done in two stages. The first stage converts the ac voltage or current to an equivalent dc voltage, and the second stage digitizes and displays the ac voltage. The accuracy of the ac to dc true-rms conversion circuitry is frequency dependent. In addition, the range resistor network which permits the digital multimeter to measure ac voltages, may be both frequency and amplitude dependent. Finally, the A/D converter that changes the dc voltage to a digital signal can also introduce amplitude uncertainties due to nonlinearities. Therefore, it is necessary to determine the performance of the ac ranges of the digital multimeter at various combinations of frequencies and voltage levels in order to completely characterize its performance. The procedures for assuring the accuracy of a digital multimeter at various combinations of input voltages and frequencies can be very lengthy. As a minimum, the tests should include voltages and frequencies that are at the extremes of the specifications -- the so-called "corner points" on a voltage-versus-frequency plot of the measurement capabilities of the meter.

4.3.1. Range and Accuracy

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

Measurement Technique

Over the frequency range from 20 Hz to 20 kHz, and for amplitudes from 1 mV to 1000 V, a commercial meter calibrator, together with a high-voltage amplifier, can be used to calibrate most hand-held digital multimeters directly. Other techniques may be necessary if the digital meter is specified to respond to ac voltages at frequencies or amplitudes beyond those normally generated by commercial meter calibration equipment [9]. For example, to test ac voltmeters with frequencies in excess of 1 MHz over the range of 1 V to 100 V (rms), one may use an uncalibrated test signal source in conjunction with a thermal voltage converter (TVC) connected in parallel with the voltmeter input. The source is then adjusted until it reaches the desired voltage, as indicated by the output of the TVC. The response of the converter may be calibrated by applying an accurate dc voltage, readily obtained from a meter calibrator, to the terminals of the TVC immediately after the unknown ac voltage has been applied. Ideally the output voltage of a TVC should be identical for both the dc voltage input and an equivalent (rms) ac voltage input. The measurement of ac voltages relative to known dc voltages is commonly referred to an ac/dc transfer measurement. Thermal converters may be obtained that demonstrate a relatively flat frequency response to approximately 100 MHz. Thermal converters permit the use of an uncalibrated ac voltage source, although the source must be sufficiently stable over the period of time necessary to measure the output of the converter.

For a wide range of frequencies and for voltages below 1 V (rms), a micropotentiometer may be used to provide reference voltages. A micropotentiometer is essentially a thermoelement used as an rms current measuring device. The current passes through the series connection of a special shunt resistor and the heater element of the thermal converter. The thermal converter is designed to have a very low ac-dc difference, and, thus the voltage drop across the shunt becomes a calibrated output voltage. Typically, a current of 10 mA and shunts in the range from 0.01 to 10.0 Ω are used providing output voltages from 100 μV to 100 mV.

Thermal converters and micropotentiometers are assigned an ac-dc difference by the manufacturer or by an independent calibration laboratory, based on intercomparisons with similar devices with known or computable ac-dc differences. The value of this ac-dc difference is usually stable over long periods of time. However, the nominal operating characteristic that links the current through a thermoelement heater with the output voltage of the temperature sensing device (thermocouple) is subject to drift. Therefore, before using these devices, it is advisable to obtain a calibration against a known dc or low-frequency ac reference standard.

The test procedures provided in Appendix B use a commercial meter calibrator to calibrate the digital multimeter directly. The voltage range and accuracy tests for the digital multimeter are very straightforward. Since many measurements must be made, an automated measurement method has been devised to assure that no test points are missed. The automated tests are especially helpful when a digital multimeter must be tested over a wide range of ac voltages and frequency combinations. A listing of the BASIC programs used to control the meter calibrator for testing the accuracy of the digital multimeter, as well as for other tests, is provided in Appendix C.

In general, the accuracy of the voltage and current readings of the digital multimeter are tested at three points per range. These points have values of 1.0, 1.8, and 5.0 times a multiplication factor which scales the voltage or current to the particular range to be tested. The selection of these test points were somewhat arbitrary and a departure from the traditional "1, 2, 5" sequence normally used with analog meters. The selection of 1.8 rather than 2.0 was to keep the digital multimeter from changing ranges if the uncertainty of the meter was too great on any given range. Since the minimum number of counts for a 3 1/2-digit meter is 1999, selecting a factor of 2.0 would have caused the meter to range between the displays of 1.980 and 2.02 for a one percent change in input or for a one percent inaccuracy. Since these two displays have different numbers of significant digits, the calculation of uncertainties exhibited by the digital multimeter is more complicated.

Sources of Measurement Uncertainty

The uncertainties encountered in the ac and dc voltage and current tests performed on the digital multimeter are few. The accuracy of the meter calibrator is provided by the manufacturer for each mode (ac, dc, and resistance) and voltage/frequency range. In these test procedures, it is assumed that the specified accuracy of the calibrator is the total uncertainty associated with applying ac and dc voltages to the digital multimeter. Uncertainties associated with other equipment, such as amplifiers, are also considered in determining the overall uncertainty. A set of summary tables for the accuracy of each of the voltage, current, and resistance tests performed is given in Appendix E for the equipment used in the test procedures given in Appendix B. Table E-2 shows, for example, in the first column, the set of applied ac voltages that are used to test the digital multimeter over the frequency range of 20 Hz to 30 Hz. The next four columns provide information on the characteristics of the source that provides the calibrated ac voltage. The range of the source is given in the second column, along with the components of the uncertainties of the measured output of the source: (1) the uncertainty of the offset of the output, (2) the uncertainty given as the percent of setting, and (3) the uncertainty given as the percent of range. The sixth column of the table gives the total estimated uncertainty of the source, in ac volts. Under Digital Multimeter Specifications there appears a tabulation of the following components of uncertainties: (1) the seventh column of the table gives the maximum reading of the meter, in volts, on the range appropriate for the applied ac voltage, (2) the next column provides the resolution of the meter on the range given in column seven (used to compute the uncertainty due to the number of counts) and, (3) the ninth column states the total estimated uncertainty of the meter, in volts. The 10th and 11th columns in the table are the minimum and maximum reading that may be displayed by the meter in order to meet the specifications given in Appendix A. The far right-hand column provides the ratio of the uncertainty of the meter divided by the uncertainty of the source. This "figure of merit" is an indicator of the appropriateness of using the equipment specified to test a meter on a given range and function. For example, if this number is unity, then the uncertainty of source equals the uncertainty of the meter; the higher the number, the greater confidence can be had that the uncertainties due to the calibration equipment will not cause an erroneous outcome of the test. Tables E-2 through E-6 tabulate the ac voltage uncertainties for one commercial model of an ac meter calibrator over various frequency ranges for both the calibrator and the digital multimeter. Tables E-1 and E-7 through E-9 provide similar information for another model of a commercial meter calibrator. Tables E-10 and E-11 contain the uncertainties associated with the dc and ac current measurements. The reader is cautioned to select the proper table depending on the frequency range and model meter calibrator used in the test.

There are other sources of uncertainty with electrical and electronic measuring instruments of any kind such as 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 voltages, ac measurements present more of a problem, particularly at higher frequencies because of capacitive and inductive couplings. At low audio frequencies inductive coupling predominates, while with increasing frequency capacitive coupling becomes more important. Any measuring circuit that produces a change in the reading when the operator comes near or touches part of the case or outside of the cable is liable to give an incorrect measurement result, even if the operator does not come near it. A rearrangement of the measuring circuit, and in particular of the ground connections and shielding, is then advisable. Careful circuit design, grounding, and shielding may be necessary to avoid these types of error, especially if the digital multimeter being tested greatly exceeds the performance of the multimeter described in Appendix A.

4.3.2. Frequency Response

In general, the frequency response of an instrument may be thought of as the frequency range over which the accuracy specifications apply. Determination of conformity with a frequency response specification then requires the selection of voltage (or current) and frequency combinations that verify the upper and lower specification limits. Thus, the measurement of frequency response is essentially a specialized ac voltage or current accuracy test. The test procedure described in Appendix B provides the accuracy of the digital multimeter at four frequencies. If a detailed frequency response is required, more frequency points may be selected.

Measurement Technique

The test method used to verify the frequency response of the digital multimeter is the same as that performed for the ac voltage or current accuracy tests. Since the tests for accuracy of the ac voltage ranges of the digital multimeter are performed over the specified frequency response, instruments that do not exhibit the required accuracy over their frequency range are considered to possess insufficient frequency response. Consequently, no separate "bandwidth" tests are performed. Passage of the accuracy tests is deemed sufficient to meet the frequency response specifications.

Sources of Measurement Uncertainty

The measurement uncertainties associated with the determination of sufficient frequency response of a digital multimeter are the same as those discussed in the previous section under the ac voltage and current tests.

4.3.3. True RMS Detection

The basis for true rms-detection testing is taken from ANSI C39.1 [10]. The test criteria are used to assess the ability of the true rms-responding digital multimeter to measure accurately non-sinusoidal waveforms generated by adding approximately 30 percent of the third harmonic to a fundamental signal at 1 kHz. A true rms-responding multimeter will provide an indication of the non-sinusoidal signal that is independent of the phase angle of the harmonic relative to the fundamental. Conversely, a digital multimeter that is average or peak responding will give indications that will vary with 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 is slowly swept over a 360° (in a time interval of the order of half a minute).

Measurement Technique

The true rms-detection test signal is generated by using two independent signal generators, each producing sine waves with stable frequencies. At least one of the signal generators should be a synthesized waveform generator with frequency adjustments in fractional-hertz increments. The choice of the fundamental frequency for this test is arbitrary; for best results it is convenient to chose a frequency in a range where the specified meter uncertainty is smallest for both the fundamental and the third harmonic. The harmonic component is generated at approximately 3.0001 times the fundamental frequency so that the phase of the third harmonic with respect to the fundamental sweeps through one cycle at a sufficiently slow rate that the maximum and minimum meter response can be read. The amplitude of the harmonic component should be set at about 30% of the fundamental in order to conform to the ANSI test specifications. To obtain good resolution, the amplitudes of the two signals should be chosen so that the meter indicates a value near full-scale on the range when the 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 (rms) 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 with a resistance network that acts as a summing junction for the inputs from the two generators, as shown in figure 4. The signal from the function generator is combined with the output from the arbitrary waveform generator by the two 3 kΩ resistors located in the junction box. The combined signal is then connected to the vertical input of a cathode-ray oscilloscope (CRO) and the hand-held multimeter or unit-under-test (UUT). Details of the construction of the resistance network is given in Appendix D.

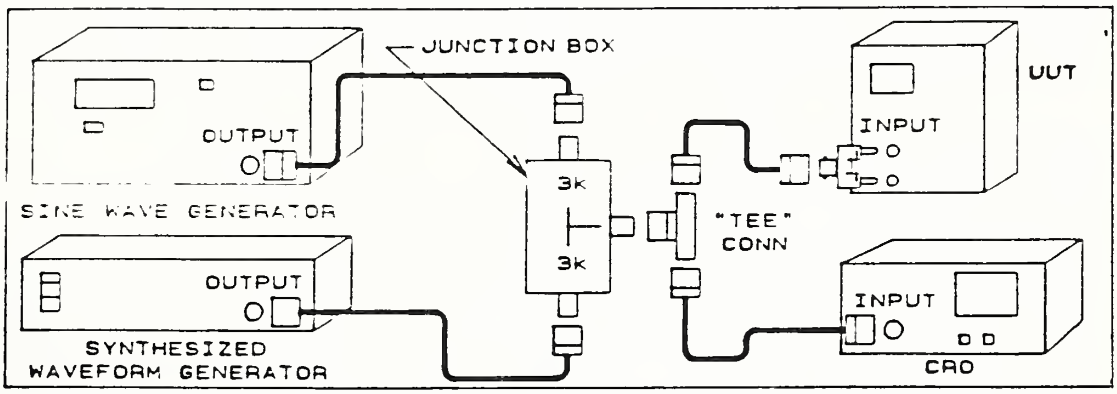

Figure 4 Test setup for true rms type of response test.

Sources of Measurement Uncertainty

A measurement of the true rms response is concerned only with the constancy of the indicated value within the tolerance of the digital multimeter for the range used. Calibrated ac voltage generators are not required for this test. However, the short-term stability of the voltage generators should exceed the resolution of the multimeter being tested so that small fluctuations in the amplitude of the generators are not confused with changes in response due to phase changes of the two sine waves. The signal frequencies need only be approximate for this test as long as the two generators are capable of producing sine wave of adequate frequency stability and resolution. Therefore, uncertainty statements for this test are not applicable.

4.3.4. Crest Factor

A crest factor signal test is an important performance measure for digital multimeters employing autoranging and true rms detection. Crest factor limitations introduce an uncertainty when measuring noise, spikes, or other random signals having a large dynamic range. Crest factor is defined as the ratio of the maximum value of a voltage waveform (the peak) to the effective or rms value. Most autoranging multimeters use the rms value of a signal to control the input attenuator networks or programmable amplifiers. The input signal processing circuitry must have sufficient dynamic range, particularly near the upper end of a range, to pass a signal with a given crest factor without clipping or distortion. Furthermore, the response of the rms detection system is sensitive to signals with high crest factors and, in fact, is one method of indicating true rms detection. However, as discussed in section 4.2.3, a different true rms-response test is performed in order to separate true rms response capability from possible crest factor limitations.

Typical true rms-responding multimeter 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 a particular crest factor. High crest factor signals have an inherently wide spectrum of harmonics above the fundamental. Thus, unless specified, the frequency and type of crest factor waveform could affect the test results.

Measurement technique

A crest factor measurement is performed by applying a test waveform with the specified crest factor to the multimeter under test and comparing the indication of the multimeter with the true rms value of the test waveform as determined by independent means. A worst case condition is ensured by setting the rms value of the test waveform near the full-scale of a given range. For an autoranging multimeter this requires a determination that the test waveform amplitude is close to the upper end of a given range.

Various types of test waveforms can be used to verify the crest factor performance of a digital multimeter. The 3:1 crest factor waveform used in the performance testing of audio distortion analyzers has limited application for wideband, true rms-responding multimeters [11]. The signal used to test the audio distortion analyzer contains a broad spectrum of harmonics which extend far beyond the fundamental and may exceed the specified frequency response of a digital multimeter, especially for high crest factor signals. Thus, it may be difficult to determine the uncertainty associated with a crest factor test when the test signals that contain significant harmonic energy beyond the frequency specification of the multimeter.

A rectangular pulse train can be used as a crest factor test waveform. Such a pulse waveform has the advantage that it may be generated by a commercial pulse generator. However, a pulse waveform also creates a spectrum of harmonics which could extend beyond the response of the multimeter. The crest factor tests presented in the test procedures given in Appendix B use a bipolar triangle waveform, as shown in figure 5. This waveform offers a good compromise between ease of generation and reduction of the higher order harmonics. Figure 6 shows a comparison of the voltage spectra calculated for two waveforms, both having a peak amplitude of unity and a crest factor of 4.0.

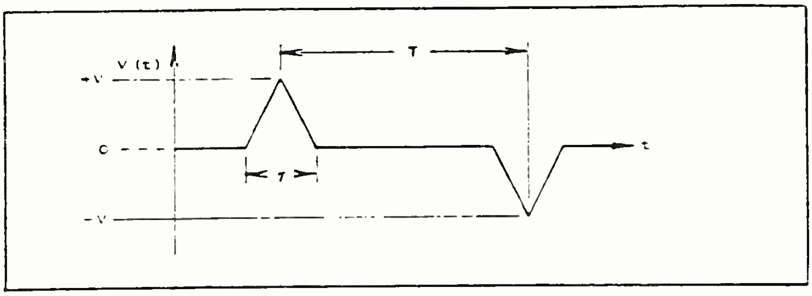

Figure 5 Crest factor test waveform

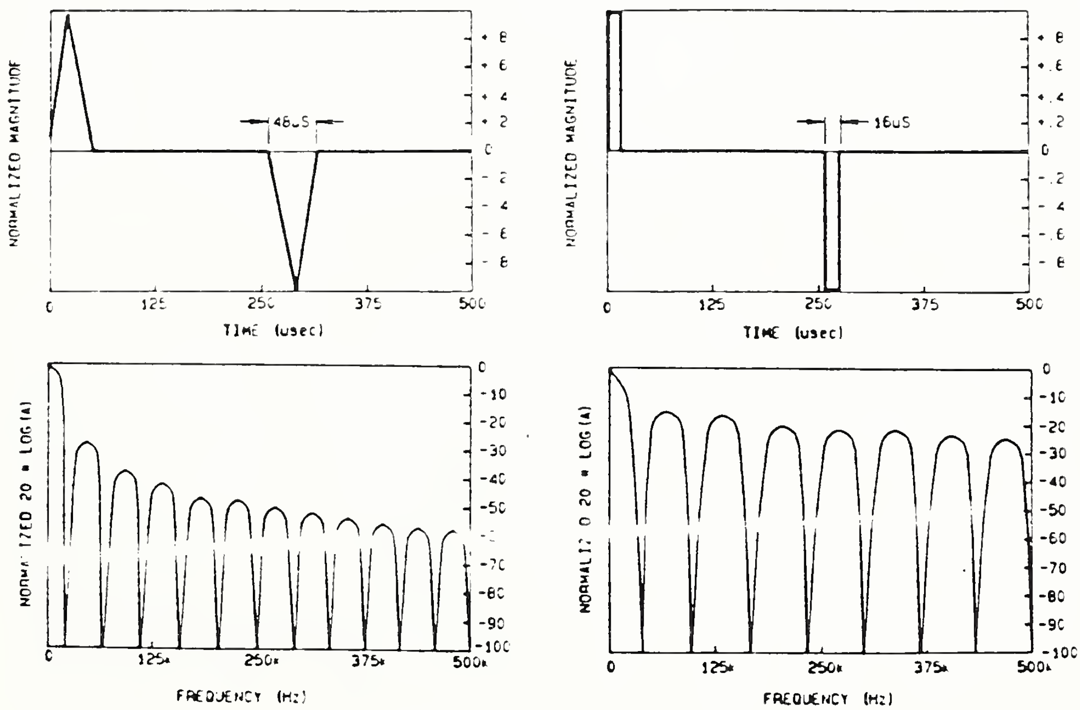

Figure 6 Pulse and triangle waveforms and their corresponding spectra

The bipolar pulse waveform has a duration of 16 μs and a period of 512 μs. The bipolar triangle waveform has a duration of 48 μs and also a period of 512 μs. It can be seen that the voltage amplitude of the triangle waveform decreases much more rapidly than that of the pulse waveform over the frequency range of 0 to 500 kHz. Thus, a triangle waveform is used for the crest factor test to minimize the voltages containing harmonic frequencies that exceed the frequency response of the digital multimeter.

The crest factor of this waveform is given by

$$CF = \left(\frac{3\ T}{\tau} \right)^{1/2}$$

where T and τ are defined in figure 5.

Thus, for the 3:1 crest factor specified by the Army for the digital multimeter, the ratio of T/τ becomes 3. The average of this test waveform is zero and, being bipolar and symmetrical, the waveform exercises the full peak-to-peak dynamic range of the multimeter under test. The bipolar triangle waveform is most easily generated by an arbitrary waveform generator or by a specially-designed function generator. The fundamental test frequency should be near the mid-band response of the digital multimeter and yet low enough in frequency to ensure that the significant harmonics are within the specified frequency band. A crest factor waveform generator fixture which produces the waveform of figure 5 was specifically designed for the crest factor test procedure given in Appendix B. The design was implemented using eight integrated circuits. The design provided for a selectable range of crest factors, various output voltage amplitudes, and two waveshapes. Essentially, the fixture consists of a clock circuit which determines the repetition rate of the triangle waveform, a read-only memory which contains information on the integral of the waveform to be generated, and a digital-to-analog converter to produce a current which is integrated by an operational amplifier to provide the required triangular waveform. The details of the circuit can be found in Appendix D. The circuit was designed to be implemented with a minimum of logic circuits. Normally, for a nominal 3:1 crest-factor waveform, the width of the triangle pulse τ, is set to 22 clock periods and the interval of the waveform, T, is 64 clock periods. By using 64 clock periods, it is not necessary to perform logic operations on the outputs of the binary circuits in order to drive the address lines of the read-only memory directly. For this ratio of clock periods, the actual value of the crest-factor of the waveform is 2.95. It is not expected that the difference between a crest factor of 2.95 and 3.00 will significantly affect the outcome of the crest-factor tests. If additional logic were incorporated into the generator, the triangle pulse could be obtained by using a pulse of 22 clock periods and an interval of 66 clock periods. This would yield a waveform with a crest factor of exactly 3.0. The waveform frequency is approximately 1 kHz for the measurement of crest factor, but the frequency may be easily changed by means of plug-in capacitors that change the basic clock frequency independently of the crest factor. The output amplitude of the crest-factor generator may be changed using a variable attenuator that connects directly to the crest-factor generator. In the test procedure the output of the crest-factor generator is boosted with a power amplifier to a nominal level of 190 V (rms). This amplified test waveform is then applied to both the digital multimeter under test and a high-accuracy digital multimeter with the capability of accurately measuring high crest-factor signals. Performing the crest factor test at high amplitudes, such as 190 volts, tends to emphasize a worst-case condition if any slew-rate limitations exist in the digital multimeter under test.

Sources of Measurement Uncertainty

The main source of uncertainty for this measurement is dependent on the accuracy with which the rms voltage measurement of the crest-factor signal can be determined. Thermal converters offer the most accurate means of determining the rms value of high crest factor waveforms. Thermal converters inherently respond to the rms value and are nearly independent of frequency over a wide range. A more convenient means of independently determining the true-rms voltage of the signal may be made using a high-accuracy, true-rms digital multimeter. The high-accuracy, true-rms digital voltmeter used in the procedures given in Appendix B is specified to handle input signals with up to an 8:1 crest factor (at full accuracy) with peaks less than two times full scale, and with the highest frequency components within a 10 MHz frequency response. The high-accuracy, true-rms digital voltmeter is operated on the 500 V ac (rms) range to measure the test voltage of 190 V ac (rms). Thus, the peak value is 570 V (peak-to-peak) for a 3:1 crest-factor signal, or less than two times the full scale amplitude of the high-accuracy, true-rms digital voltmeter. A conservative value for the uncertainty of the crest-factor measurement may be obtained by considering the accuracies specified by the manufacturer for the high-accuracy, true-rms digital voltmeter and the accuracy specifications by the Army for the digital multimeter under test. The manufacturer's specifications for the high-accuracy, true-rms digital voltmeter state that the 90-day accuracy, on the 500 V ac (rms) range and over a frequency range of 10 Hz to 100 kHz, is ±0.2 percent of the input voltage or less. The accuracy of the digital multimeter under test, in volts, is specified by the Army to be no less than

±(0.5 percent of input voltage reading + 3 counts)

at 1 kHz, the fundamental frequency of the 3:1 crest-factor waveform. The corresponding voltage accuracies for the high-accuracy, true-rms digital voltmeter and the hand-held digital multimeter are 0.38 V ac (rms) and 1.25 V ac (rms), respectively. Thus, the ratio of the uncertainty of the voltage measured by the digital multimeter to that measured by the high-accuracy, true-rms digital voltmeter exceeds three to one.

Ideally, the applied voltage should be as close as possible to the maximum input voltage permitted (750 V ac (rms)) to check for slew-rate limitations of the digital multimeter. However, a 750 V ac (rms) amplitude exceeds the peak capability of the power amplifier used to increase the amplitude of the 3:1 waveform. Instead, a voltage level of 190 V ac (rms) is used as a test voltage, which is well within the capability of the power amplifier.

4.3.5. Response Time

The determination of the response time establishes whether a reading obtained with a multimeter, within the specified accuracy limits, can be obtained in a given time interval. The response time for a digital multimeter should be "reasonable" since it would be annoying to have an instrument that responds very slowly, especially if the instrument were to be used for the rapid checking of many test points in a production environment.

Measurement Technique

The measurement of ac voltage and current response time for instruments having only a visual readout is necessarily subjective and dependent on operator reaction time. The measurement is carried out with a bus-controlled meter calibrator which applies a known ac voltage or current to the hand-held digital multimeter. After a programmed time delay, corresponding to the specified response time, the operator is signaled to read the multimeter. 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 consistency of the result and to ensure that the operator does not contribute excessive random uncertainties to the outcome of the test.

Sources of Measurement Uncertainty

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

4.3.6. Burden Voltage

Measurements of electrical currents, other than currents from a constant-current source, have an uncertainty introduced by the small voltage drop (burden voltage) across the multimeter. The uncertainty results because insertion of the multimeter in the circuit changes the total circuit impedance and, therefore, the current to be measured. A current meter should, ideally, have a zero voltage drop. In practice, the voltage drop across the digital multimeter in the current measurement mode is on the order of tens to hundreds of millivolts, depending on the range, sensitivity, and design of the meter.

Measurement Technique

A high-impedance precision millivoltmeter is connected across the input terminals of the digital multimeter, and a current from a calibrated current source is measured by the digital multimeter under test. The burden voltage -- the voltage drop across the terminals of the digital multimeter -- is then read on the millivoltmeter. The current applied to the multimeter should correspond to the maximum value specified for the particular range tested such that the maximum burden voltage is obtained. In the case of measuring burden voltages for ac currents, the frequency response of the millivoltmeter must be adequate to cover the range of the desired input frequencies to be measured.

Sources of Measurement Uncertainty

Since the burden voltage is generally directly proportional to the input current on a given range, the percentage uncertainties of the calibrated current source and those of the millivoltmeter are additive. If the common terminal of the multimeter is not at ground potential, ground-loop errors can arise if the multimeter and millivoltmeter inputs are not floating.

4.4. Resistance

Resistance measurement, like voltage and current measurement, is usually included in most digital multimeter capabilities. In addition to a resistance measurement capability, many newer digital multimeters have related functions such as continuity, conductance, and semiconductor junction tests. The digital multimeter provides a current to an external component connected to the test leads, and measures and displays a value which is a function of the resulting voltage across the test leads. The verification of the resistance accuracy consists of connecting each of a set of calibrated resistors to the input terminals of the digital multimeter. For convenience, the calibrated resistors in the IEEE-488 bus-controlled meter calibrator used for other tests can be used, provided that they have sufficient accuracy.

4.4.1. Range and Accuracy

The test points selected for the resistance accuracy tests given in Appendix B are determined by the standard resistors available internal to the meter calibrator. One resistance measurement per decade is performed. If a more rigorous test is desired, precision resistors with accuracies of 0.001 percent are commercially available. Use of these would permit the calibration of the digital multimeter at those resistance values not obtainable with the meter calibrator.

Measurement Technique

The input leads of the digital multimeter are connected directly to the resistance output of the calibrator in a two-terminal arrangement. The ability to control the standard resistance applied to the digital multimeter via computer control enhances the utility of the calibrator, helps prevent operator errors, and greatly conserves test time.

Sources of Measurement Uncertainty

The resistance values available for these tests have specified accuracies. For low resistance values lead and contact resistances constitute an additional source of uncertainty. An estimate of how much error the leads contribute can be obtained by shorting the leads and reading the indicated resistance value on the most sensitive range of the multimeter. The uncertainty limits of the resistance values available from the meter calibrator are given by the specifications of the meter calibrator used in the accuracy tests. The uncertainties associated with the resistance values provided by the calibrator, for each value of resistance applied to the digital multimeter, are given in Table E-12.

4.4.2. Response Time

The determination of the response time establishes whether a meter reading within the specified accuracy limits can be obtained in a given time interval. The response time for the resistance function of the digital multimeter is very similar to the technique described for previous response time measurements in sections 4.2.2. and 4.3.2.

Measurement Technique

The measurement of resistance response time for instruments having only a visual readout is necessarily subjective and dependent on operator reaction time. The measurement is carried out with a bus-controlled meter calibrator which applies a known resistance to the hand-held digital multimeter. After a programmed time delay corresponding to the specified response time, the operator is signaled to read the digital multimeter. If the reading falls within the accuracy limits of the input, the test is deemed successful. Generally, it is beneficial to repeat the test several times to check result consistency and to ensure that the operator does not contribute excessive random uncertainties to the outcome of the test.

Sources of Measurement Uncertainty

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

4.5. Frequency

Traditionally, hand-held digital multimeters have not included provision for the measurement of the frequency of an applied voltage. However, some newer models of hand-held digital multimeters have included this feature since the implementation of a frequency counter is made easier as a consequence of employing microcomputers within the digital multimeter. Usually, a multimeter measures the frequency of an ac voltage by applying the voltage from the test probes to a threshold detector, and feeding the resultant pulses to the counter that is associated with the integrating analog-to-digital converter incorporated in the instrument. The input attenuator allows the magnitude of the input voltage to be scaled automatically to suit the sensitivity of the threshold detector. Thus, the voltage sensitivity of the frequency counter may also be autoranging.

Currently, many digital multimeters have frequency measurement capability covering the range of approximately 10 Hz through 100 kHz. This is a useful range for many power-line and audio frequency measurements. The frequency measurement capability of a digital multimeter has an interesting side benefit. Since, in general, the ac voltage measurement accuracy of a digital multimeter depends on the frequency of the applied signal, an assessment of the voltage uncertainties depends on a knowledge of the applied frequency. A digital multimeter that incorporates a frequency counter can thus provide the user with a more confident statement of ac voltage measurement uncertainties.

4.5.1. Frequency Counter Range and Accuracy

The specifications for the digital multimeter, given in Appendix A, require that the digital frequency counter have a range from 50 Hz through 450 Hz.

Measurement Technique

Measurement of the range and accuracy of the frequency counter consists of applying an ac voltage to the input of the digital multimeter under test and, simultaneously, applying the same ac voltage to the input of a high-accuracy frequency counter. The high-accuracy counter employed achieves seven digits of resolution (one second acquisition time) at frequencies between 1 Hz and 100 MHz through the use of a reciprocal counting technique. This technique measures the period of the applied signal, and converts the period to the corresponding frequency prior to being displayed. The high-accuracy frequency counter can be used to allow a tradeoff between measurement time and resolution. Since the frequency may be precisely determined in one second by the high-accuracy counter, the long-term (on the order of hours or days) frequency stability requirements for the signal source need not be unusually stringent.

Sources of Measurement Uncertainty

The greatest single source of uncertainty in the determination of the frequency counter accuracy of the digital multimeter is the frequency stability of the ac calibrator during the period of time in which the frequency accuracy is being determined. The frequency instability of the calibrator employed in the test procedure of Appendix B is specified by the manufacturer to be ±0.05 percent of the nominal value for 24 hours. A conservative estimate of the instability of the source for a period of time of less than 24 hours may be obtained by assuming that the instantaneous frequency value has a variation that is normally distributed and that ±0.05 percent represents the 3-sigma value of the variation. From a table of the cumulative normal distribution [12], the stability of the source for a period of 2.4 hours may be calculated to be approximately (0.236) · (0.05), or approximately 0.01 percent. Since the test for frequency accuracy would take, at most, a few minutes, an instability of 0.01 percent, or better, is considered sufficient.

The uncertainties associated with the high-accuracy counter may be tabulated as follows:

$$\text{Accuracy} = \pm \text{Resolution} \pm (\text{time-base error}) \times \text{Frequency}$$

where:

The resolution is given by the manufacturer as ±0.00003 Hz for a one second gate time and for an input voltage of 1.0 V (rms). In actuality, the resolution would be slightly less than this value since the input voltage is approximately 3 V (rms).

The time-base uncertainty is composed of three components:

1. Aging rate: $<3 \times 10^{-7}$/month.
   The total time-base uncertainty (assuming a six-month calibration recall interval) contributed by the aging rate is estimated to be no greater than 1.8×10^{-6}.
2. Temperature: $\leq 5 \times 10^{-6}$, 0 to 50°C.
   The total time-base uncertainty (assuming an ambient temperature variation of ±10°C) is estimated to be no greater than 1×10^{-6}, and
3. Line Voltage: $\leq 1 \times 10^{-7}$ for ±10 percent variation.
   The total time-base uncertainty (assuming a ±10 percent variation in line voltage) is estimated to be no greater than 0.1×10^{-6}.

The total uncertainty of the high-accuracy counter is the sum of the resolution and the time base errors. Thus, the measurement uncertainty of the high-accuracy counter at 50 Hz is calculated to be ±0.0002 Hz or 0.0004 percent. The corresponding uncertainty at 450 Hz is calculated to be 0.0014 Hz or 0.0003 percent. These uncertainties may be neglected compared to the voltage source frequency instability of 0.01 percent.

4.5.2. Voltage Range

The input voltage range to the frequency counter of the digital multimeter given in Appendix A is specified to be "at least 50 volts (rms) to 450 volts (rms) across the full frequency range of the equipment." This is an unusual specification for a commercial frequency counter. Typically, electronic frequency counters are designed to respond to applied voltage amplitudes in the range of hundreds of millivolts to a few volts in order to measure low-level signals commonly encountered in solid-state equipment. Higher voltage levels are generally accommodated using probes connected to the input of the frequency counter with 10:1 or 100:1 division ratios.

Measurement Technique

The measurement technique to verify the performance of the frequency counter voltage range of the digital multimeter is very straightforward. The digital multimeter is connected to the output of an ac meter calibrator. In addition, a high-accuracy frequency counter is connected to the ac meter calibrator at a connector provided for the sensing of the frequency of the calibration voltage. The voltage level at the connector is nominally fixed at a level of 3 V ac (rms). The output voltage of the calibrator is set to 50 V ac (rms) at 50 Hz. Then, the reading on the two frequency counters are compared and the percent uncertainty is calculated. The test is then repeated at combinations of voltages and frequencies of 100, 200, 300, and 450 V ac (rms) and 200 and 450 Hz, respectively, for a total of 15 measurements. The criteria for passing the test is that the digital multimeter should meet the required specification for frequency accuracy at each of the 15 data points.

Sources of Measurement Uncertainty

The primary component of the measurement uncertainty in determining the frequency counter voltage range is the uncertainty of the applied frequency. The uncertainty of the applied frequency has been shown above to be approximately 0.01 percent.

5. Acknowledgments

The authors express gratitude to Robert Palm for the construction of many of the test fixtures, the preparation of the illustrations used in this report, and the verification of the Test Procedures given in Appendix B. In addition, the authors are also indebted to Jennifer Muse and Sandra Carlsen for help in the preparation of the manuscript.

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APPENDIX A

PERFORMANCE SPECIFICATION FOR
THE AN/PSM-51 DIGITAL MULTIMETER

(Supplied by CECOM)

AN/PSM-51 FINAL SPEC 26 AUG 86
9 Dec 86
New B.O SAMPLE SUBMISSION DATE

8.2 Electromagnetic Interference (EMI). EMI requirements shall be as specified in MIL-STD-461A, Notice 4 (EL) except as noted below. The equipment when tested as specified in Para. 8.2.1.

CEO 3	REO2	RSO3
CEO 5	REO2.1	RSO3.1

NOTE: The electric field strength and modulation characteristics for fields radiated at the unit under test (UUT) shall be as follows:

Frequency Range (Hz)	E-field (V/M)	Modulation
10 KHz - 2 MHz	1	AM, 50%, 1 KHz tone
2 MHz - 30 MHz	5	AM, 50%, 1 KHz tone
30 MHz - 76 MHz	10	FM, 8KHz Dev, 1 KHz tone
76 MHz - 400 MHz	10	AM, 50%, 1 KHz tone
400 MHz - 2.0 GHz	10	Pulse,0.1 msec, 800 PPS
2.0 GHz - 12.4 GHz	5	Pulse,0.1 msec, 800 PPS

8.2.1 EMI Testing. EMI testing shall be in accordance with MIL-STD-462, Notice 3 with the exceptions as noted in Paragraph 8.2 above.

9. RAM Requirements.

9.1 Reliability Requirements. The equipment shall comply with the Type II Reliability Requirements of MIL-T-28800C (Paras 3.10.2 and 4.5.8.1.2). The contractor shall demonstrate his equipment MTBT (θ_o), as stated in his bid data submission. The stated value shall be equal to or greater than a MTBF (θ_o) of 10,000 hours. Reliability Tests shall be performed on the first production lot only.

9.2 Calibration. Calibration interval shall meet or exceed 240 days with 85% of items still within tolerance at the end of the period.

9.3 Maintainability Requirements. The contractor shall demonstrate his equipment mean-time-to-repair (MTTR) (Ho in MIL-STD-471), as stated in his bid data submission. The stated value shall be less than or equal to MTTR (Ho) of 30 minutes. The maximum tolerable MTTR (H1 of MIL-STD-471) shall be 60 minutes. The MTTR shall include all the time required to troubleshoot, fault isolate, repair and test the equipment for any malfunction down to the lowest circuit card or module level of the equipement, but does not include calibration time. In concept, MTTR shall include all time required to troubleshoot, fault isolate, repair and test the equipment for any malfunction down to the lowest discrete component (resistor, switch, transistor, integrated circuit, nonrepairable assembly, and so forth) of the equipment, but does not include calibration time.

10. Performance. The following specifications apply to the equipment after five minutes warm-up.

10.1 DC Voltage. Shall meet the specified performance herein across the full voltage range (see para. 10.1.1).

10.1.1 <u>Range</u>. Shall be at least 20 millivolts to 1000 volts in no less than four ranges.

10.1.2 <u>Accuracy</u>. Shall be at least ± 0.1% + 1 count or better over the operating temperature range of 18° to 28° centigrade, up to 90% relative humidity.

10.1.3 <u>Input Impedance</u>. Shall be 10 megaohms or greater.

10.1.4 <u>Response Time</u>. Shall be 1 second or less to rated accuracy.

10.1.5 <u>Normal Mode Rejection Ratio</u>. Shall be at least 40 dB at 50, 60 and 400 Hz.

10.1.6 <u>Common Mode Rejection Ratio</u>. Shall be at least 80 dB with 1 Kiloohm unbalance in the low lead.

10.1.7 <u>Overload Protection</u>. Shall provide minimum of 1000 volts (DC or peak AC) protection on all ranges.

10.1.8 <u>Resolution</u>. Shall be 100 microvolts or less on lowest range and 1 volt or less on highest range.

10.2 <u>AC Voltage</u>. Shall meet the specified performance herein across the full voltage range (see para. 10.2.2).

10.2.1 <u>Detection</u>. Shall be true RMS Detection for signals with crest factors up to 3:1, or greater, across the full voltage range of the equipment.

10.2.2 <u>Range</u>. Shall be at least 20 millivolts RMS to 750 volts RMS in no less than four ranges.

10.2.3 <u>Frequency Response</u>. Shall be at least 20 Hz to 20 KHz.

10.2.4 <u>Accuracy</u>. Shall be at least as specified, or better, over the operating temperature range of 18° to 28° centigrade, up to 90% humidity.

Accuracy	Frequency
1.5% of input + 5 Counts	20 Hz to 40 Hz
0.5% of input + 3 Counts	40 Hz to 1 KHz
0.5% of input + 5 Counts	1 KHz to 10 KHz
1.0% of input + 40 Counts	10 KHz to 20 KHz

10.2.5 <u>Voltz-Hertz Product</u>. Shall be at least 1×10^7 or better.

10.2.6 Resolution. Shall be 100 microvolts or less on the lowest range; 1 volt or less on highest range.

10.2.7 Response Time. Shall be 5 seconds or less to rated accuracy.

10.2.8 Input Impedance. Shall be 2 Megaohm or greater shunted by 100 picofarads capacitance or less.

10.2.9 Common Mode Rejection Ratio (CMRR). CMRR shall be at least 60 dB at 50, 60 and 400 Hz and with 1000 Ohms unbalance in low lead.

10.2.10 Overload Protection. Shall provide a minimum of 1000 volts protection (DC or peak AC) or 750 volts RMS.

10.3 DC Current. Shall meet the specified performance herein across the full DC current range (see para 10.3.1).

10.3.1 Range. Shall be at least 2 milliamps to 2 amps in no less than three ranges.

10.3.2 Accuracy. Shall be at least as specified below or better over the operating temperature range of 18 to 28 degrees centigrade, up to 90% relative humidity.

Range	Accuracy
< 20 milliamps:	0.5% of the input + 1 count
>20 milliamps:	0.75% of the input + 1 count

10.3.3 Response Time. Less than 1 second to rated accuracy.

10.3.4 Overload Protection. 2A/250V fuse and 3A/600V fuse in series, or a single 2A/600V fuse.

10.3.5 Resolution. 10 microamperes or less on lowest range; 10 milliamperes or less on highest range.

10.3.6 Burden Voltage. Shall be as specified below:

Range	Burden Voltage
For current ≤ 0.6 mA	< 0.3 V
For current ≤ 2 mA	< 1 V
For current > 2 mA	< 1.9 V

10.4 AC Current. Shall meet the specified performance herein across the full AC current range (see para 10.4.1).

10.4.1 AC Current Range. Shall be at least 2 milliamps to 2 amps.

10.4.2 Detection. Shall be true RMS on signals with crest factors up to 3:1, or greater.

10.4.3 Frequency Response. Shall be at least 20 Hz to 1 KHz.

10.4.4 Accuracy. Accuracy shall be at least as specified below or better over the operating temperature range of 18 to 28 degrees centigrade, up to 90% relative humidity.

Accuracy	Frequency
2.0% of input + 5 counts	20 Hz to 40 Hz
1.5% of input + 5 counts	40 Hz to 1 KHz

10.4.5 Response Time. Shall be less than 5 seconds or less to rated accuracy.

10.4.6 Overload Protection. 2A/250V fuse and 3A/600V fuse in series, or a single 2A/600V fuse.

10.4.7 Resolution. Shall be 10 microamps or less on lowest range; 10 milliamps or less on highest range.

10.4.8 Burden Voltage. Shall be as specified below:

Range	Burden Voltage
For current ≤ 0.6 mA	< 0.3v
For current ≤ 2 mA	< 1 v
For current > 2 mA	< 1.9v

10.5 Resistance. Shall meet the specified performance contained herein across the full resistance range (see para 10.5.1).

10.5.1 Range. Shall be up to 20 Megaohms in no less than four ranges.

10.5.2 Accuracy. Shall be at least as specified below or better over the operating temperature range of 18 to 28 degrees centigrade, up to 90% relative humidity.

Range	Accuracy
For resistance < 1 Kiloohm	0.3% of input + 2 count
For resistance < 2 Megaohm	0.25% of input + 1 count
For resistance ≥ 2 Megaohm	1% of input + 1 count

10.5.3 Overload Protection. Shall provide a minimum of 750 Volts (DC + peak AC) protection on all ranges.

10.5.4 Resolution. On lowest range shall be less than 100 milliohms; highest range less than 10 Kiloohms.

10.5.5 Diode Test. Equipment shall check semi-conductor circuits, out of circuit, and shall make in circuit resistance measurements without turning on or damaging semi-conductors junctions.

10.5.6 Continuity. The equipment shall provide selection for an audible (beeper) indicating continuity. Minimum duration of continuity or open to be indicated in 200 milliseconds. Tone shall be audible for at least 100 milliseconds. Maximum open circuit voltage is 0.5 volts. There shall also be a visual indication of continuity.

10.5.7 Response Time. Shall be eight seconds or less to rated accuracy.

10.6 Frequency Counter. Shall meet the specified performance herein across the full frequency range (see 10.6.1).

10.6.1 Range. Shall be at least 50 Hz to 450 Hz

10.6.2 Accuracy. In the temperature range of 18 degrees centigrade to 28 degrees centigrade; up to 90% relative humidity, shall be at least 0.1% or better.

10.6.3 Voltage Range. Shall be at least 50 volts RMS to 450 volts RMS across the full frequency range of the equipment.

10.6.4 Overload Protection. Shall withstand at least an input voltage of 750V RMS or 1000V DC.

10.6.5 Resolution. Shall be at least 1 Hz.

10.7 Display. The display shall be a liquid crystal, with at least 3 1/2 digits, electronic digital display. It shall display voltage in units of volts and millivolts RMS; current in units of milliamps and amps, resistance in units of Ohms and Kiloohms and frequency in units of Kilohertz. The unit shall also have an analog bargraph display which has a 1 millivolt sensitivity on the lowest range.

10.8 Input Connector. The input shall be a recessed banana male or female connector. There shall be an input terminal for volts, Ohms measurement, and a separate terminal for current measurement and a common terminal; or an input terminal for volts, Ohms and low current measurement and a separate terminal for current measurements greater than 2 AMPs if that capability is internal to the instrument.

10.9 Ranging. The equipment in all modes of operation except frequency shall have both autoranging and manual ranging capabilities. Measurement of frequency shall be autoranging. In measuring, voltage, current and resistance in autoranging mode, input shall uprange when the input is greater than full scale. Instrument shall downrange when input is less than 10% of full range.

10.10 Temperature Coefficient. For temperatures outside the 18 degrees centigrade to 28 degrees centigrade range less than or equal to 0.1% of the specified accuracy (see paras. 10.1.2, 10.2.4, 10.3.2, 10.4.3, 10.5.2 and 10.6.2) shall be cumulatively added for every degree below 18 degrees centigrade and above 28 degrees centigrade.

10.11 Dimensions. The dimensions shall not exceed the following: 2.4 inches height, 5.8 inches width, and 8 inches in length.

10.12 10 AMP Current Shunt. A separate current shunt capable of extending the equipments upper current limit to 10 amps (AC or DC) across full frequency range for AC (see para 10.2.2) shall be supplied with each instrument.

10.12.1 Sensitivity. 10 MV/Amp.

10.12.1.1 Accuracy. ± 0.5% (does not include meter accuracy)

10.12.2 High Voltage Probe. A separate high voltage probe capable of extending the equipment upper voltage (AC and DC) across the frequency range of 20 Hz-1 KHz to at least a minimum of 5000 Volts shall be supplied with each equipment.

10.12.2.1 DC and AC Accuracy. (Does not include meter accuracy.) ≤ 5%

10.12.3 Clamp on AC. The equipment shall be capable of being used with an external clamp on AC current adapter which will extend the AC current measuring capability of the equipment to 300 amps (across the full frequency range, see para 10.13.3.3). This accessory must be available if requested by the procuring activity.

10.12.3.1 Current Range. 2 amps to 300 amps.

10.12.3.2 Accuracy. (Does not include meter accuracy.) ± 5%

10.12.3.3 Frequency Range. 45Hz-450 Hz.

10.12.3.4 Insulation. 5Kv

10.12.4 Temperature Probe. A separate temperature probe accessory must be available as an option to use with the multimeter. The measurement of temperatures may also be internal to the instrument. The following specs apply.

10.12.4.1 Temperature Range. -50°C to 150°C, (-58°F to 302°F).

10.12.4.2 Sensitivity. 1 mv per °C or °F.

10.12.4.3 Accuracy. (+15 degrees Centigrade to +35 degrees Centigrade ambient temperature operation; includes ± 0.1% + 1 count voltmeter accuracy) . ± 2 degrees Centigrade in the range of 0 degrees Centigrade to 100 degrees Centigrade, derated linearly to ± 4 degrees Centigrade at -50 degrees Centigrade and + 150 degrees Centigrade. Above + 35 degrees Centigrade and below + 15 degrees Centigrade ambient temperature, add 1 degree Centigrade to accuracies stated above.

10.12.4.4 Settling Time. 8 seconds maximum to settle within 2°C after a 50°C step change at sensor tip.

10.12.5 DC Clip on Milliammeter. An accessory shall be provided, on request, that will measure in conjunction with the multimeter DC current without interruption to the circuit under test. The following specifications apply.

10.12.5.1 Current Range. 1 milliamp - 10 amperes.

10.12.5.1.2 Probe Inductance. Less than 0.5 microhenries.

10.12.5.1.3 Probe Induced Voltages. Less than 15 millivolts peak.

10.12.5.1.4 Accuracy. Shall be at least ± 3% of input + 0.1 milliamps or better.

10.13 Zero Reference. The multimeter shall have the capability to set a zero reference on any measurement made by the multimeter.

10.14 Measurement Hold. The equipment shall have a measurement hold capability in which an audible beeper will indicate after a stable reading, i.e. a reading which is stable to within ± 40 counts, has been achieved. The instrument shall hold this reading on the display until a new measurement is needed.

B. QUALITY ASSURANCE PROVISIONS.

1. Responsibility for Inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inpsection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

APPENDIX B

TEST PROCEDURES FOR THE AN/PSM-51 DIGITAL MULTIMETER

<u>Note</u>:

The procedures described in this document are valid only if used with test equipment that is maintained within the normal Army calibration procedures. Certain commercial equipment is identified in this document. 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. Also, each specification description included with these procedures (in italics) have been copied with minor modifications from the specification paragraphs in Appendix A.

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NOTES

The following notes are to apprise the user of this document of some of the assumptions made in the preparation of the test procedures for a hand-held digital multimeter, called the unit-under-test (UUT).

1. Three specifications were deemed constructional specifications and not subject to electrical performance verification tests. These are:

   10.3.4 DC Current Overload Protection
   10.4.6 AC Current Overload Protection
   10.11 Dimensions

2. The accuracy statements of the hand-held digital multimeter are specified to be applicable for ambient temperatures of 18° to 28° C and for relative humidity to 90 percent. In this set of test procedures, all tests were designed to be conducted at a temperature and humidity level typically maintained in a laboratory environment. It is possible to conduct these tests over the specified temperature and humidity range with the addition of an appropriate environmental chamber.

3. Not all specifications contain a statement of accuracy. In such cases, the accept and reject criteria are based on an observation (such as smoking and arcing) rather than measurement data.

4. It is necessary to have a set of pass/fail criteria in order to assure that the hand-held digital multimeter conforms to the intent of the specifications given by the procuring activity. Hand-held digital multimeters may be constructed with a wide variety of features. For example, the number of counts, full-scale, that a digital meter exhibits may not necessarily be the same on each of the ranges. In addition, the span of the ranges may change in response to the direction of change of the input signal. In some hand-held digital multimeters, hysteresis is designed into the switching circuitry of the ranges to prevent "range chatter" or an oscillation between two contiguous ranges. Therefore, in order for the pass/fail criteria to be calculated, certain features and parameters were assumed. These are listed below:

The range of an instrument:	A specification that describes the range of the measurand (voltage, current, etc.) is taken to mean that the accuracy specifications for that measurand apply over the extent of the range given.
The number of ranges of an instrument:	A specification that describes the number of ranges of an instrument is taken to mean the number of internal amplification or attenuator settings that are designed into the instrument for

	the purpose of increasing the range, while maintaining a given measurement resolution.
Number of discrete counts full-scale:	The number of discrete counts on each scale are taken to be 2000 counts (from 0000 to 1999). The meter continuously displays a reading from 0000 to 1999 on all scales.
Range change intervals:	The instrument changes ranges at more than 1999 counts.
Least significant digit:	Always equals the least significant digit displayed.

The minimum resistance resolution on the lowest resistance range is assumed to be 0.1 Ω, regardless of the number of digits specified on the display. This assumption is reasonable for hand-held digital multimeters currently manufactured.

Using these criteria, the minimum and maximum permissible values are shown on each of the data sheets. Where the specification is given as a "one-sided" value (i.e., "not to exceed" or "minimum value"), the complementary field of the data sheet is left blank.

5. All electrical performance tests will be performed with the test probes and leads provided with the hand-held digital multimeter by the manufacturer. If no leads are provided, test leads will be used that conform to the physical configuration of Pomona Electronics, Inc. Model 5849-48-0 (black), or equivalent, for the "low" or common lead and Model 5049-48-2 (red), or equivalent, for the "high" lead. These types of leads have the following physical configuration and differ only in color:

    Insulated handle: molded construction with a probe tip and a 48-inch (1.22 m) length wire lead.

    Probe Tip Pin: 0.080 inch (0.20 cm) diameter by 0.5 inches (1.3 cm) long. The material of the probe tip is nickel plated brass. Note: a larger diameter probe tip may prevent the direct connection of the test probe to instruments specified in the test procedures.

    Wire: Number 18 American Wire Gauge, stranded, covered with a extra flexible polyvinyl insulation, 0.144 inch (0.366 cm) diameter jacket. The wire terminates in a retractable, sheathed banana plug.

To facilitate connection between the test probe and a banana connector, an adapter has been furnished.

5. Editorial, technical clarifications, and additions to the specifications have been indicated by enclosures in brackets [].

6. The test procedures reflect the specifications received from the U.S. Army Communications-Electronics Command (CECOM), dated August 26, 1986. The specifications have been reprinted exactly as presented to NBS by the Army and are reproduced in italics.

7. For many measurements, such as the voltage accuracy tests, it is necessary to generate a sequence of stimuli that are applied to the hand-held digital multimeter under test. The sequence chosen consisted of a power of ten times the multipliers 5, 10, and 18. In this manner, three measurement points would be obtained for each of the ranges of the hand-held digital multimeter. Since the hand-held digital multimeter was specified to be 3½ digits, the chosen sequence reduces the possibility of a range change occurring within each set of three measurements such as may be the case if a more conventional sequence of 1, 2, and 5 had been chosen.

10.1 DC Voltage

Specification:

Shall meet the specified performance herein across the full voltage range (see para. 10.1.1).

10.1.1 Range

Specification:

Shall be at least 20 millivolts to 1000 volts in no less than four ranges.

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the dc voltage range covers the limits specified.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.1.1 Range

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
DC Voltage Range Min.	______	N/A		20	mV dc
DC Voltage Range Max.	______	N/A	1000		V dc
Number of DC Voltage Ranges	______	N/A	4		units

10.1 DC Voltage

10.1.2 Accuracy

Specification:

Shall be at least ±0.1% + 1 count or better over the operating temperature range of 18° C to 28° C, up to 90% relative humidity.

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

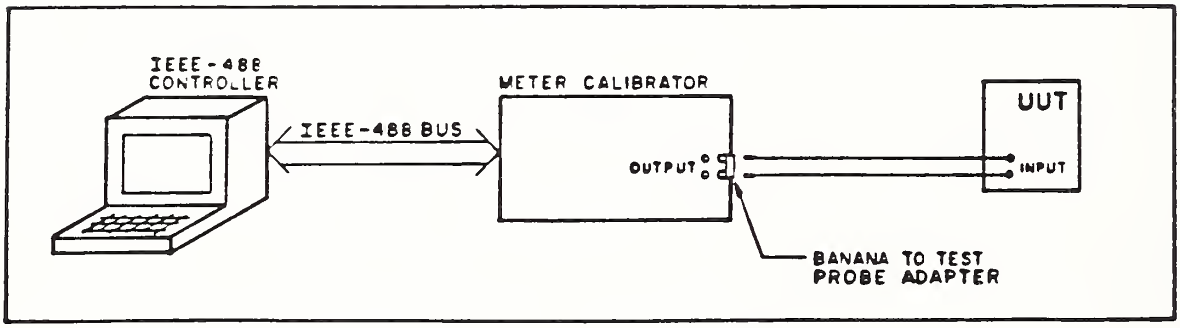

Figure 10.1.2 Test setup for measuring dc voltage accuracy.

2. Set the UUT controls as follows:

   Function: DC VOLTAGE
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "AC and DC VOLTAGE" from the menu provided by the 488 controller.

5. This program prompts the user to enter (1) name of the manufacturer of the UUT, (2) the model of the UUT, and (3) the serial number of the UUT. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the calibrator to apply a voltage to the UUT and then ask the operator to enter the reading displayed on the UUT into the 488 controller via the keyboard.

7. When the displayed value has been entered, press the key marked ENTER.

8. This process will test the UUT using the following sequence of dc voltages:

   5.0000 mV
   10.0000 mV
   18.0000 mV
   50.000 mV
   100.000 mV
   180.000 mV
   0.50000 V
   1.00000 V
   1.80000 V
   5.0000 V
   10.0000 V
   18.0000 V
   50.000 V
   100.000 V
   180.000 V
   500.00 V
   800.00 V

9. The program will then test the negative values of the voltage sequence.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.1.2a Accuracy - Positive

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Voltage 5.0 mV	____________	±0.00545	4.9	5.1	mV dc
10.0 mV	____________	±0.00570	9.9	10.1	mV dc
18.0 mV	____________	±0.00610	17.9	18.1	mV dc
50.0 mV	____________	±0.0095	49.8	50.2	mV dc
100.0 mV	____________	±0.012	99.8	100.2	mV dc
180.0 mV	____________	±0.016	179.7	180.3	mV dc
0.50 V	____________	±0.000050	0.498	0.502	V dc
1.0 V	____________	±0.000075	0.998	1.002	V dc
1.8 V	____________	±0.000115	1.797	1.803	V dc
5.0 V	____________	±0.000455	4.98	5.02	V dc
10.0 V	____________	±0.000705	9.98	10.02	V dc
18.0 V	____________	±0.001105	17.97	18.03	V dc
50.0 V	____________	±0.004505	49.8	50.2	V dc
100.0 V	____________	±0.007005	99.8	100.2	V dc

Table 10.1.2a Accuracy - Positive (continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Voltage 180.0 V	________	±0.011005	179.7	180.3	V dc
500.0 V	________	±0.036005	498	502	V dc
800.0 V	________	±0.51005	798	802	V dc

Table 10.1.2b Accuracy - Negative

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Voltage -5.0 mV	____________	±0.00545	-4.9	-5.1	mV dc
-10.0 mV	____________	±0.00570	-9.9	-10.1	mV dc
-18.0 mV	____________	±0.00610	-17.9	-18.1	mV dc
-50.0 mV	____________	±0.0095	-49.8	-50.2	mV dc
-100.0 mV	____________	±0.012	-99.8	-100.2	mV dc
-180.0 mV	____________	±0.016	-179.7	-180.3	mV dc
-0.50V	____________	±0.00005	-.498	-.502	V dc
-1.0 V	____________	±0.000075	-.998	-1.002	V dc
-1.8 V	____________	±0.000115	-1.797	-1.803	V dc
-5.0 V	____________	±0.000455	-4.98	-5.02	V dc
-10.0 V	____________	±0.000705	-9.98	-10.02	V dc
-18.0 V	____________	±0.001105	-17.97	-18.03	V dc
-50.0 V	____________	±0.004505	-49.8	-50.2	V dc
-100.0 V	____________	±0.007005	-99.8	-100.2	V dc

Table 10.1.2b Accuracy - Negative (continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Voltage -180.0 V	____________	±0.011005	-179.7	-180.3	V dc
-500.0 V	____________	±0.036005	-498	-502	V dc
-800.0 V	____________	±0.051005	-798	-802	V dc

10.1 DC Voltage

10.1.3 Input Impedance

Specification:

Shall be 10 MΩ or greater.

Equipment:

Items	Model
Digital LCR Meter	HP 4262A or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

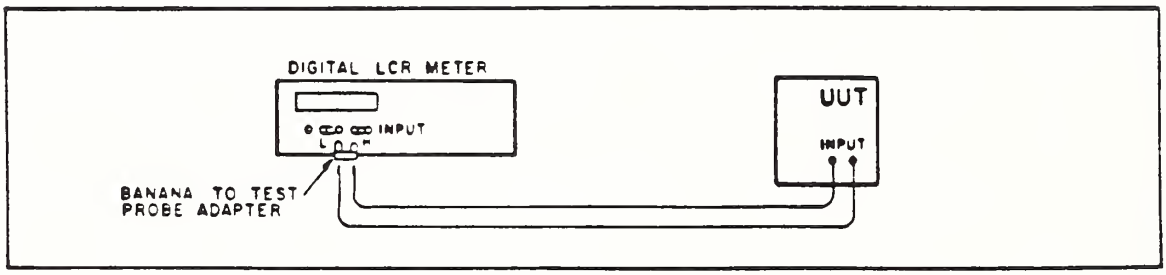

Figure 10.1.3 Test setup for measuring input impedance.

2. Set the UUT controls as follows:

Function:	DC 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. Place the LCR meter into the mode to read resistance by depressing the R/ESR button.

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

Table 10.1.3 Input Impedance (DC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
Input Resist.	______________	±0.04	10		MΩ

10.1 DC Voltage

10.1.4 Response Time

Specification:

Shall be 1 second or less to rated accuracy.

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

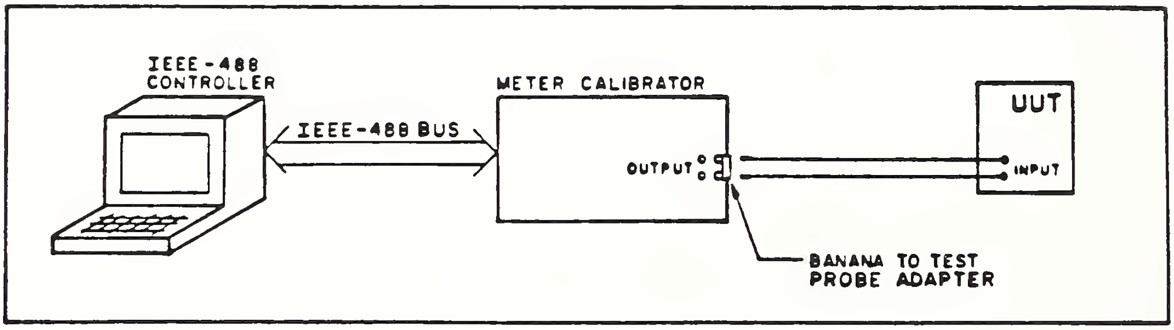

Figure 10.1.4 Test setup for measuring response time.

2. Set the UUT controls as follows:

   Function: DC VOLTAGE
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "RESPONSE TIMES" from the menu provided by the 488 controller.

5. This program prompts the user to enter (1) name of the manufacturer of the UUT, (2) the model of the UUT, and (3) the serial number of the UUT. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the operator to press the ENTER key. At the end of one second, a tone will be emitted from the controller.

7. At the time the tone is heard, the operator should mentally note the value of the voltage displayed on the UUT. Note: The operator may wish to practice this part of the procedure before recording the data.

8. Record the value of the observed voltage on the data sheet.

9. Steps 5 through 7 (inclusive) of this test will be repeated for voltage input changes of 0.005, 0.05, 0.5, 5.0, 50.0, and 500 V dc.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.1.4 Response Time (DC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC V Response 5.00 mV	____________	±0.00545	4.9	5.1	mV dc
50.0 mV	____________	±0.0095	49.8	50.2	mV dc
0.5 V	____________	±0.000050	0.498	0.502	V dc
5.0 V	____________	±0.000455	4.98	5.02	V dc
50.0 V	____________	±0.004505	49.8	50.2	V dc
500.0 V	____________	±0.036005	498	502	V dc

10.1 DC Voltage

10.1.5 Normal Mode Rejection Ratio

Specification:

Shall be at least 40 dB at 50, 60 and 400 Hz.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Capacitor	$0.1\mu F \pm 10\%$, 600 V, Film, See Appendix D, Item 5
BNC Male to Binding Post Adapter	Pomona 1269 or equivalent
BNC Female to Banana Adapter	Pomona 1452 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

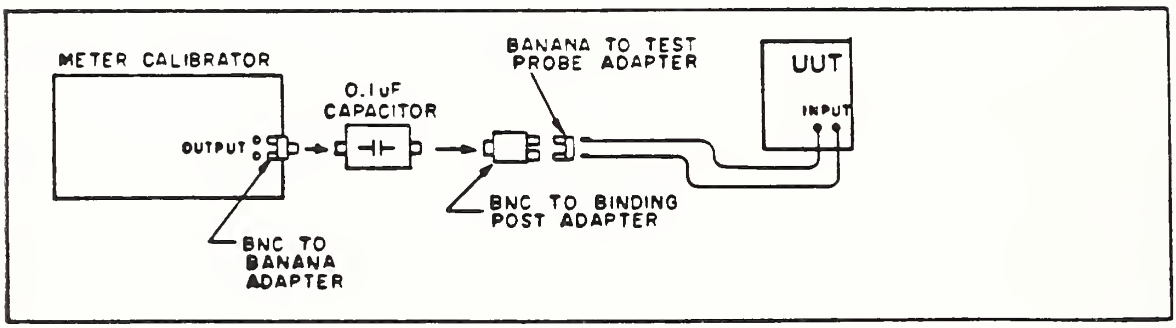

Figure 10.1.5 Test setup for measuring normal mode rejection ratio.

2. Initially, set the UUT controls as follows:

   Function: DC VOLTAGE
   Range Mode: AUTORANGE

3. Set the calibrator to apply zero voltage to the UUT. Read and record the dc voltage reading displayed on the UUT. This reading will be designated as V_0.

4. Set the calibrator to generate 100 V ac (rms) at 50 Hz.

5. Read and record the dc voltage reading displayed on the UUT. This reading will be designated as V_1.

6. Repeat steps 3 through 5 at frequencies of 60 and 400 Hz.

7. Calculate the normal mode rejection ratio according to the formula,

$$NMRR = 20 \cdot \log_{10} \frac{ABS\ (V_1 - V_0)}{\sqrt{2} \cdot 100}$$

for each of the frequencies (50 Hz, 60 Hz, and 400 Hz).
(Note: ABS in the equation above indicates the absolute value, in order to make the numerator always positive.)

8. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero output.

Table 10.1.5 Normal Mode Rejection Ratio (DC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
0 V ac reading 50 Hz	___________				V dc
100 V ac reading 50 Hz	___________				V dc
DC Rejection Ratio 50 Hz	___________	±0.015	-40		dB
0 V ac reading 60 Hz	___________				V dc
100 V ac reading 60 Hz	___________				V dc
DC Rejection Ration 60 Hz	___________	±0.015	-40		dB
0 V ac reading 400 Hz	___________				V dc
100 V ac reading 400 Hz	___________				V dc
DC Rejection Ratio 400 Hz	___________	±0.015	-40		dB

10.1 DC Voltage

10.1.6 Common Mode Rejection Ratio

Specification:

Shall be at least 80 dB with 1 kΩ unbalance in the low lead.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101A or equivalent
Resistor Fixture for CMRR Test, 1 kΩ	See Appendix D, Item 14
Aluminum Sheet	12" x 12" x 0.0625" thick with connection point attached. See Appendix D, Item 1
Banana Patch Cord, 2 ea.	Pomona Electronics B-12 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

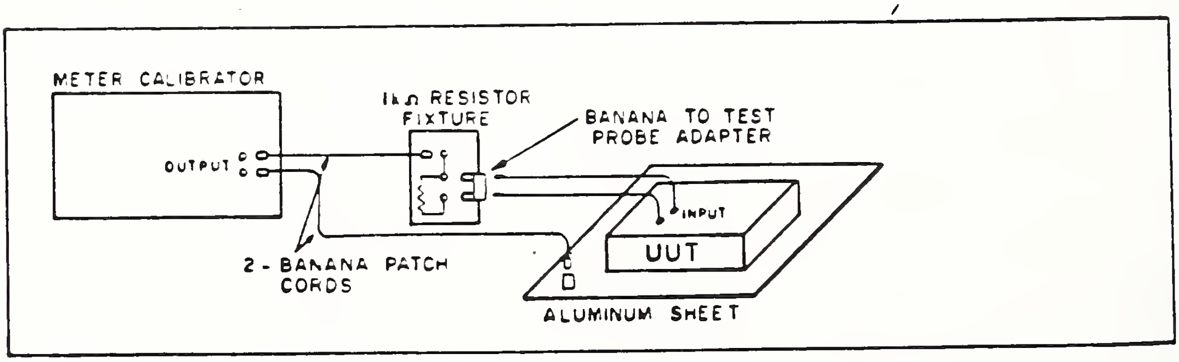

Figure 10.1.6 Test setup for measuring common mode rejection ratio.

2. Initially, set the UUT controls as follows:

Function: DC VOLTAGE
Range Mode: AUTORANGE

3. Set the calibrator to apply zero V dc to the UUT and read and record the value displayed on the UUT. This reading will be designated V_0.

4. Set the calibrator to apply 100 V dc to the two leads of the UUT and read and record the dc voltage displayed on the UUT. This reading will be designated V_1.

5. Calculate the common mode rejection ratio according to the formula:

$$CMRR = 20 \cdot \log_{10} \frac{ABS\ (V_1 - V_0)}{100}$$

(Note: ABS in the equation above indicates the absolute value, in order to make the numerator always positive.)

6. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.1.6 Common Mode Rejection Ratio (DC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
0 V dc reading	______				V dc
100 V dc reading	______				V dc
DC Rejection Ratio	______	±0.5	-80		dB

10.1 DC Voltage

10.1.7 Overload Protection

Specification:

Shall provide a minimum of 1000 V (dc or peak ac) protection on all ranges.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Clock	General Electric 2908 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

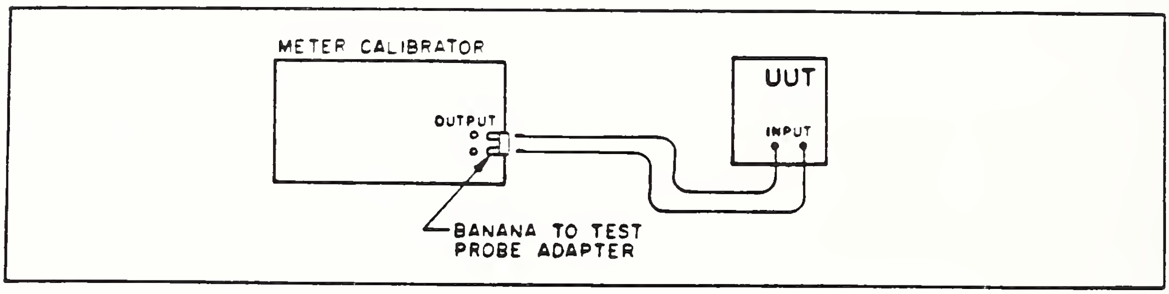

Fig. 10.1.7 Test setup for measuring voltage overload protection.

2. Set the UUT controls as follows:

   Function: DC VOLTS
   Range Mode: MANUAL RANGE, Minimum

3. Apply 1000 V dc from the meter calibrator to the leads of the UUT. Note the time on the clock.

4. After five minutes has elapsed, note any evidence of smoking, arcing, or charring of the UUT. Record the presence of any evidence of damage on the data sheet.

5. Set the output voltage of the meter calibrator to zero. Reverse the leads between the UUT and the meter calibrator, and repeat steps 3 and 4, above.

6. Apply 707 V ac (rms), 1 kHz signal to the UUT from the meter calibrator and repeat steps 3 and 4, above.

7. Repeat steps 3 through 6 (inclusive) on each dc voltage range and record the presence of any evidence of damage on the data sheet.

8. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.1.7 Overload Protection (DC Voltage Mode)

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC V Range 20.0 mV	______	N/A	No Damage		N/A
200 mV	______	N/A	No Damage		N/A
2.0 V	______	N/A	No Damage		N/A
20.0 V	______	N/A	No Damage		N/A
200.0 V	______	N/A	No Damage		N/A
1000. V	______	N/A	No Damage		N/A

10.1 DC Voltage

10.1.8 Resolution

Specification:

Shall be 100 µV or less on lowest range and 1 V or less on highest range.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

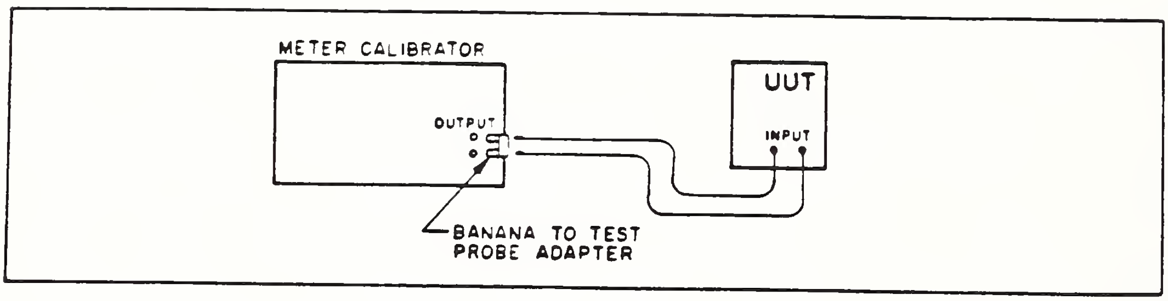

Fig. 10.1.8 Test setup for measuring voltage resolution.

2. Set the UUT controls as follows:

   Function: DC VOLTS
   Range Mode: MANUAL RANGE, Minimum

3. Set the output amplitude of the meter calibrator to 22 mV dc.

4. Increase the output amplitude of the meter calibrator by 100 µV dc.

5. Read and record on the data sheet the incremental voltage change displayed on the UUT.

6. Set the UUT controls as follows:

   Function: DC VOLTS
   Range Mode: MANUAL RANGE, Maximum

7. Set the output amplitude of the meter calibrator to approximately 980 V dc.

8. Increase the output amplitude of the meter calibrator by 1 V dc.

9. Read and record on the data sheet the incremental voltage change displayed on the UUT.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.1.8 Resolution (DC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
DC Voltage Range Min.	____________	±9.5		100	μV dc
DC Voltage Range Max.	____________	±0.007		1	V dc

10.2 AC Voltage

Specification:

Shall meet the specified performance herein across the full voltage range (see para. 10.2.2).

10.2.1 Detection

Specification:

Shall be true rms detection for signals with crest factors up to 3:1, or greater, across the full voltage range of the equipment.

Equipment:

Items	Model
Function Generator	HP 3325A or equivalent
Arbitrary Waveform Generator	Wavetek 275 or equivalent
Power Amplifier	Fluke 5205A or equivalent
Oscilloscope	Tektronix 465 or equivalent
Resistor Summing Network, 3 kΩ	See Appendix D, Item 15
3:1 Crest Factor Generator	See Appendix D, Item 7
Power Supply for 3:1 Crest Factor Generator	See Appendix D, Item 13
Variable Attenuator	See Appendix D, Item 2
Precision Digital Multimeter	Fluke 8506 or equivalent
BNC Male to BNC Male Cable 24 inches (61 cm) 4 ea.	Pomona BNC-C-24 or equivalent
BNC "T" Adapter (Female-Male-Female)	Pomona 3285 or equivalent
BNC female to Banana Plug Adapter	Pomona 1269 or equivalent
BNC male to Binding Post Adapter	Pomona 1296 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

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

Note: The first part of this test checks whether the UUT is true-rms responding. The basis for this test is taken from ANSI C39.6-1983 and consists of adding a signal containing 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; 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. Thus, 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°.

The second part of the test determines if the UUT maintains the required accuracy in the presence of a 3:1 crest factor signal.

Part 1. True-rms voltage detection

1. Connect the equipment as shown below:

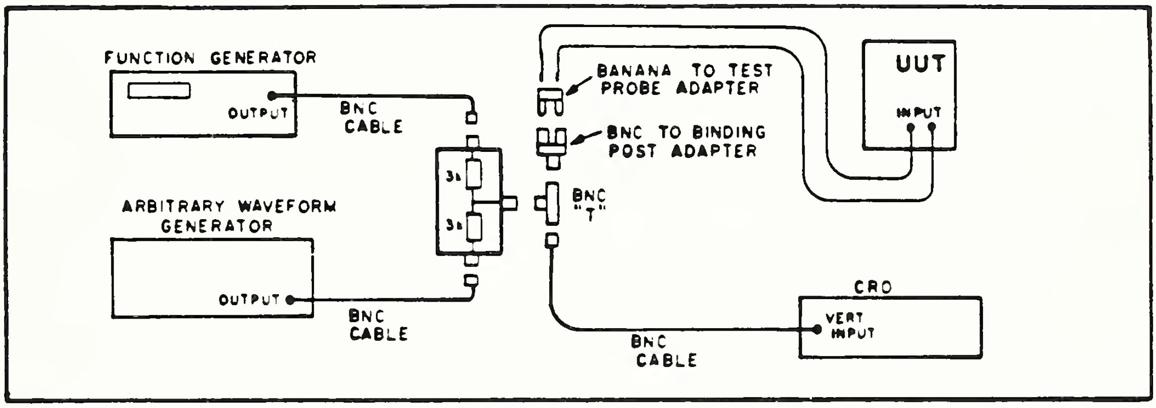

Fig. 10.2.1a Test setup for rms voltage detection

2. To set up the arbitrary waveform generator, set the following controls on the front panel:

   2.1. Turn on power switch.

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

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

   Steps 2.1 through 2.3 set up the function generator to its default values of 1 kHz and 5 V.

3. Set up the function generator to provide approximately 3 kHz and 1.5 V ac (rms). Set the following controls on the front panel.

   3.1. Turn on power switch

   3.2. FREQ, 3, kHz

   3.3. AMPTD, 1.5, V RMS.

This sequence should produce an image of a distorted sine wave on the oscilloscope. Since the frequency setting of the arbitrary waveform generator may not be exactly 1 kHz, a fine adjustment of the frequency of the function generator may be necessary. To adjust the frequency, proceed as follows:

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

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

3.6. 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 between the two waveforms shown in figure 10.2.1b. The time for the pattern to return to its original shape should take approximately 10 seconds.

4. While the waveform pattern is changing slowly, observe the output reading of the UUT under test, and enter into the data sheet the highest and lowest readings obtained.

5. Subtract the minimum ac voltage from the maximum ac voltage observed in the previous step and enter the value into the data sheet. The value of difference should not exceed 0.5 percent of 1.5 V rms plus the value represented by five least significant digits.

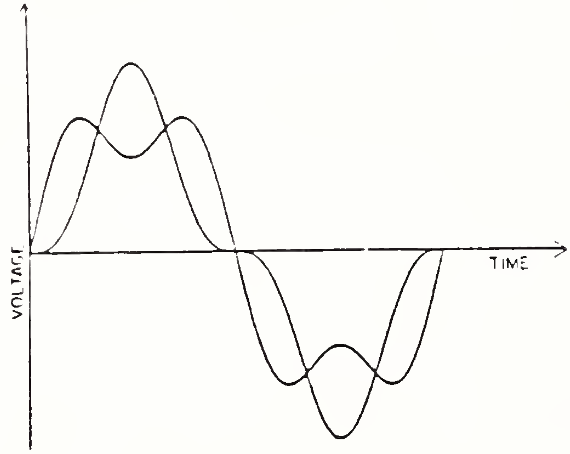

Figure 10.2.1b Waveforms for type of response test

Table 10.2.1a AC Voltage RMS Detection

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage Reading - Min.	______________	N/A			V ac
AC Voltage Reading - Max.	______________	N/A			V ac
Difference of Voltage Read'gs	______________	N/A		±(0.5% + 5 lsd*)	V ac

* least significant digit on display

Part 2. 3:1 Crest Factor Response

1. Set the output voltage from the power amplifier to zero.

2. Connect the equipment as shown in the figure below.

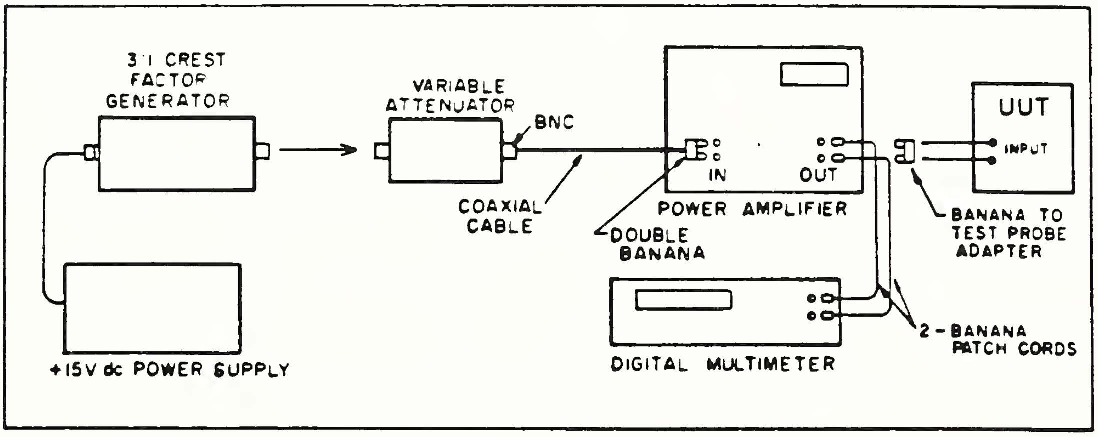

Fig. 10.2.1c Test setup for the crest factor test

3. Set the UUT controls as follows:

Function: AC VOLTS
Range Mode: AUTORANGE

4. Set the precision digital multimeter controls as follows:

Function: AC VOLTS
Range Mode: AUTORANGE

5. Adjust the output level of the variable attenuator to obtain a nominal indication on the precision digital multimeter of 190 V ac (rms).

6. Read and record the ac voltage as displayed on the UUT.

7. Read and record the ac voltage as displayed on the precision digital multimeter.

8. Calculate the percentage error between the ac voltage as displayed on the UUT and that displayed on the precision digital multimeter according to the following formula:

$$\text{Error} = \frac{Vu - Vm}{Vm} \cdot 100.$$

9. Record the percentage error as calculated above.

Table 10.2.1b 3:1 Crest Factor Response.

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage Reading - Vu	______	N/A			V ac
AC Voltage Reading - Vm	______	N/A			V ac
Error for 3:1 Crest Factor	______	N/A		±0.5% + ± 5 lsd*	pct

* least significant digit on display

10.2 AC Voltage

10.2.2 Range

Specification:

Shall be at least 20 mV (rms) to 750 V (rms) in no less than four ranges.

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the ac voltage range covers the limits specified.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.2.2 Range

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
AC Voltage Range Min.	____________	N/A		20	mV ac
AC Voltage Range Max.	____________	N/A	750		V ac
Number of AC Voltage Ranges	____________	N/A	4		units

10.2 AC Voltage

10.2.3 Frequency Response

<u>Specification</u>:

Shall be at least 20 Hz to 20 kHz.

Passage or failure of the test in section 10.2.4 shall constitute passage or failure, respectively, of this test.

If the UUT meets the specifications for accuracy over its voltage and frequency range, as verified by the tests in section 10.2.4, then the UUT has demonstrated sufficient frequency response to meet the above specification.

10.2 AC Voltage

10.2.4 Accuracy

Specification:

Shall be at least as specified, or better, over the operating temperature range of 18° C to 28° C, up to 90% humidity.

Accuracy	Frequency
1.5% of input + 5 counts	*20 Hz to 40 Hz*
0.5% of input + 3 counts	*40 Hz to 1 kHz*
0.5% of input + 5 counts	*1 kHz to 10 kHz*
1.0% of input + 40 counts	*10 kHz to 20 kHz*

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5200A or equivalent
Power Amplifier	Fluke 5205A or equivalent
Binding Post to Binding Post Adapter	See Appendix D, Item 4
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

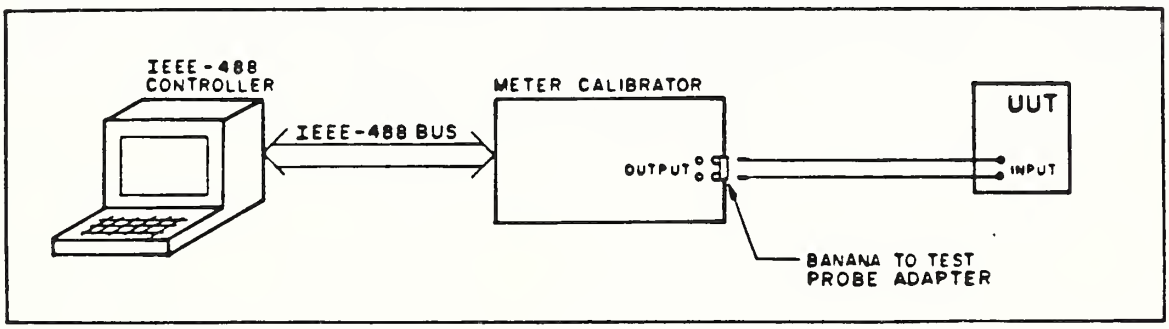

Fig. 10.2.4a Test setup for measuring ac voltage accuracy for voltages up to 100 V rms, inclusive.

2. Set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "AC VOLTAGE (5200/5205)" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the calibrator to apply a voltage to the UUT and then ask the operator to enter the reading displayed on the UUT into the 488 controller via the keyboard.

7. When the displayed value has been entered, press the key marked ENTER.

8. The computer program will test the UUT using the following sequence of ac voltage (rms) and frequency combinations:

5.0000 mV		
10.0000 mV		
18.0000 mV		
50.000 mV		
100.000 mV		
180.000 mV		
0.50000 V		
1.00000 V		20 Hz
1.80000 V	at	200 Hz
5.0000 V	frequencies	2 kHz
10.0000 V	of	20 kHz
18.0000 V		
50.000 V		
100.000 V		

9. Connect the equipment as shown below, including the power amplifier into the test setup:

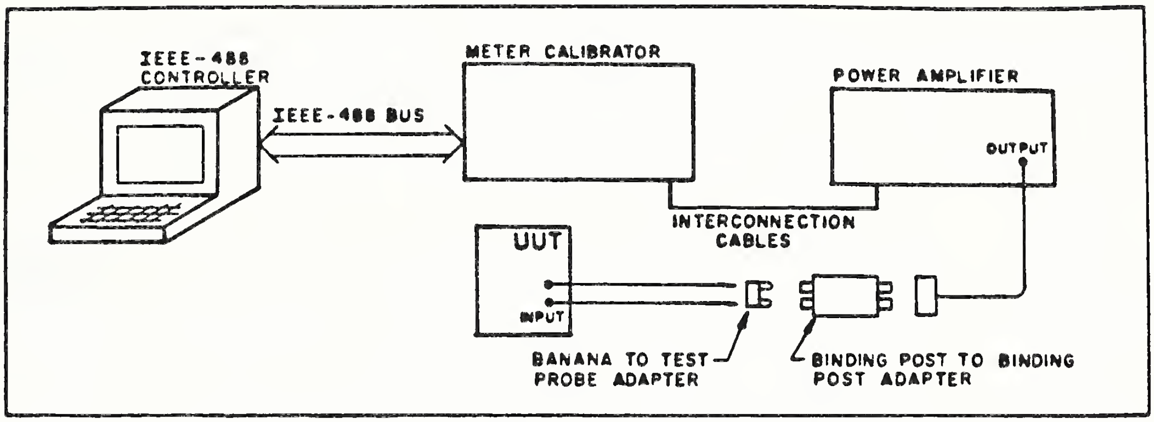

Fig. 10.2.4b Test setup for measuring ac voltage accuracy for voltages above 100 V rms.

10. The computer program will request that the operator reconnect the UUT to the power amplifier output terminals.

11. The computer program will then test the UUT using the following sequence of ac voltage and frequency combinations:

180.00 V 730.00 V	at frequencies of	20 Hz 200 Hz 2 kHz

and

180.00 V 500.00 V	at a frequency of 20 kHz

12. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.2.4a Accuracy - 20 Hz

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage (rms) 5.00 mV	______	±0.015	4.8	5.2	mV ac
10.00 mV	______	±0.020	9.8	10.2	mV ac
18.00 mV	______	±0.028	17.6	18.4	mV ac
50.00 mV	______	±0.060	48.7	51.3	mV ac
100.0 mV	______	±0.110	98.0	102.0	mV ac
180.0 mV	______	±0.230	176.8	183.2	mV ac
0.5 V	______	±0.00055	0.487	0.513	V ac
1.0 V	______	±0.00105	0.980	1.020	V ac
1.80 V	______	±0.0023	1.768	1.832	V ac
5.00 V	______	±0.0055	4.87	5.13	V ac
10.00 V	______	±0.0105	9.80	10.20	V ac
18.00 V	______	±0.023	17.68	18.32	V ac
50.00 V	______	±0.055	48.7	51.3	V ac
100.0 V	______	±0.105	98.0	102.0	V ac
180.0 V	______	±0.266	176.8	183.2	V ac
730.0 V	______	±0.926	714	746	V ac

Table 10.2.4b Accuracy - 200 Hz

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage (rms) 5.00 mV	______	±0.011	4.9	5.1	mV
10.00 mV	______	±0.012	9.9	10.1	mV
18.00 mV	______	±0.014	17.8	18.2	mV
50.00 mV	______	±0.020	49.2	50.8	mV
100.0 mV	______	±0.030	99.0	101.0	mV
180.0 mV	______	±0.056	178.6	181.4	mV
0.5 V	______	±0.00012	0.492	0.508	V
1.0 V	______	±0.00022	0.990	1.010	V
1.80 V	______	±0.00056	1.786	1.814	V
5.00 V	______	±0.0012	4.92	5.08	V
10.00 V	______	±0.0022	9.90	10.10	V
18.00 V	______	±0.0056	17.86	18.14	V
50.00 V	______	±0.012	49.2	50.8	V
100.0 V	______	±0.022	99.0	101.0	V
180.0 V	______	±0.092	178.6	181.4	V
730.0 V	______	±0.312	721	739	V

Table 10.2.4c Accuracy - 2 kHz

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage (rms) 5.00 mV	____________	±0.011	4.9	5.1	mV ac
10.00 mV	____________	±0.012	9.9	10.1	mV ac
18.00 mV	____________	±0.014	17.8	18.2	mV ac
50.00 mV	____________	±0.020	49.2	50.8	mV ac
100.0 mV	____________	±0.030	99.0	101.0	mV ac
180.0 mV	____________	±0.056	178.6	181.4	mV ac
0.5 V	____________	±0.00012	0.492	0.508	V ac
1.0 V	____________	±0.00022	0.990	1.010	V ac
1.80 V	____________	±0.00056	1.786	1.814	V ac
5.00 V	____________	±0.0012	4.92	5.08	V ac
10.00 V	____________	±0.0022	9.90	10.10	V ac
18.00 V	____________	±0.0056	17.86	18.14	V ac
50.00 V	____________	±0.012	49.2	50.8	V ac
100.0 V	____________	±0.022	99.0	101.0	V ac
180.0 V	____________	±0.112	178.6	181.4	V ac
730.0 V	____________	±0.332	721	739	V ac

Table 10.2.4d Accuracy - 20 kHz

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage (rms) 5.00 mV	____________	±0.011	4.5	5.5	mV ac
10.00 mV	____________	±0.012	9.5	10.5	mV ac
18.00 mV	____________	±0.014	17.4	18.6	mV ac
50.00 mV	____________	±0.020	45.5	54.5	mV ac
100.0 mV	____________	±0.030	95.0	105.0	mV ac
180.0 mV	____________	±0.056	174.2	185.8	mV ac
0.5 V	____________	±0.00012	0.455	0.545	V ac
1.0 V	____________	±0.00022	0.950	1.050	V ac
1.80 V	____________	±0.00056	1.742	1.858	V ac
5.00 V	____________	±0.0012	4.55	5.45	V ac
10.00 V	____________	±0.0022	9.50	10.50	V ac
18.00 V	____________	±0.0056	17.42	18.58	V ac
50.00 V	____________	±0.012	45.5	54.5	V ac
100.0 V	____________	±0.022	95.0	105.0	V ac
180.0 V	____________	±0.112	175.9	184.1	V ac
500.0 V	____________	±0.240	485	515	V ac

10.2 AC Voltage

10.2.5 Volt-Hertz Product

Specification:

Shall be at least $1x10^7$ or better.

Passage or failure of the test in section 10.2.4. shall constitute passage or failure of this test.
If the UUT meets the specifications for accuracy over its voltage and frequency range, as verified by the tests in section 10.2.4, then the UUT has demonstrated a sufficient volt-hertz product capability to meet the above specification.

10.2 AC Voltage

10.2.6 Resolution

<u>Specification</u>:

Shall be 100 microvolts or less on the lowest range; 1 volt or less on highest range.

<u>Equipment</u>:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

<u>Procedure</u>:

> 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:

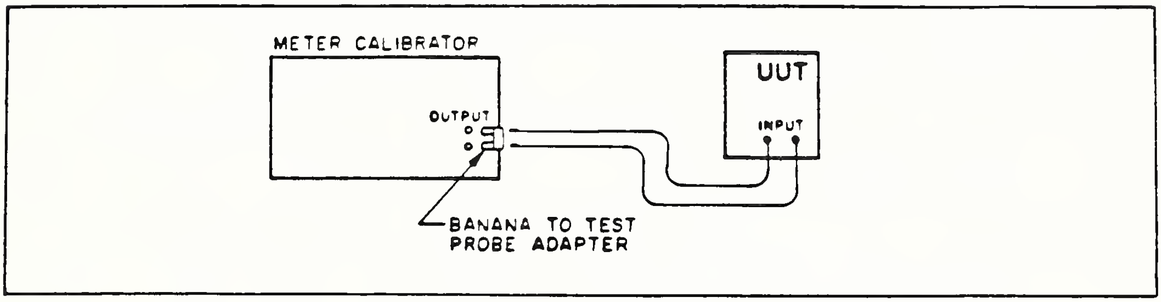

Fig. 10.2.6 Test setup for measuring resolution.

2. Set the UUT controls as follows:

    Function: AC VOLTS
    Range Mode: MANUAL RANGE, Minimum

3. Set the output amplitude of the meter calibrator to 22 mV ac (rms) at 1 kHz.

4. Increase the output amplitude of the meter calibrator by 100 μV ac.

5. Read and record on the data sheet the incremental voltage change displayed on the UUT.

6. Set the UUT controls as follows:

   Function: AC VOLTS
   Range Mode: MANUAL RANGE, Maximum

7. Set the output amplitude of the meter calibrator to approximately 980 V ac (rms) at 1 kHz.

8. Increase the output amplitude of the meter calibrator by 1 V ac (rms).

9. Read and record on the data sheet the incremental voltage change displayed on the UUT.

Table 10.2.6 Resolution (AC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Voltage Range Min.	__________	±9.5		100	μV ac
AC Voltage Range Max.	__________	±0.007		1	V ac

10.2 AC Voltage

10.2.7 Response Time

Specification:

Shall be 5 seconds or less to rated accuracy.

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

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

10. Connect the equipment as shown below:

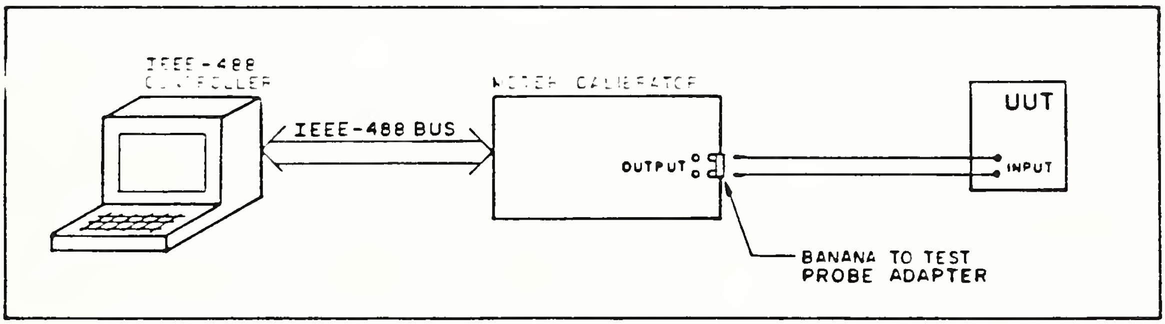

Fig. 10.2.7 Test setup for measuring response time.

11. Set the UUT controls as follows:

    Function: AC VOLTAGE
    Range Mode: AUTORANGE

12. Load and run the program "MENU" from the disk marked TMDE3A.

13. Select the program "RESPONSE TIMES" from the menu provided by the 488 controller.

14. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

15. The program will then instruct the operator to press the ENTER key. At the end of five seconds, a tone will be emitted from the controller.

16. At the time the tone is heard, the operator should mentally note the value of the voltage displayed on the UUT. Note: The operator may wish to practice this part of the procedure before recording the data. The program allows for this option.

17. Record the value of the observed voltage on the data sheet.

18. Steps 5 through 7 (inclusive) of this test will be repeated for voltage input changes of 0.1, 1.0, 10.0, and 100.0 V at a frequency of 1 kHz.

19. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.2.7 Response Time (AC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
AC V Response 0.1 V	________	±0.00011	0.099	0.1010	V ac
1.0 V	________	±0.0065	0.990	1.010	V ac
10.0 V	________	±0.00605	9.90	10.10	V ac
100.0 V	________	±0.06005	99.0	101.0	V ac

10.2 AC Voltage

10.2.8 Input Impedance

Specification:

Shall be 2 MΩ or greater shunted by 100 pF capacitance or less.

Equipment:

Items	Model
Digital LCR Meter	HP 4262A or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

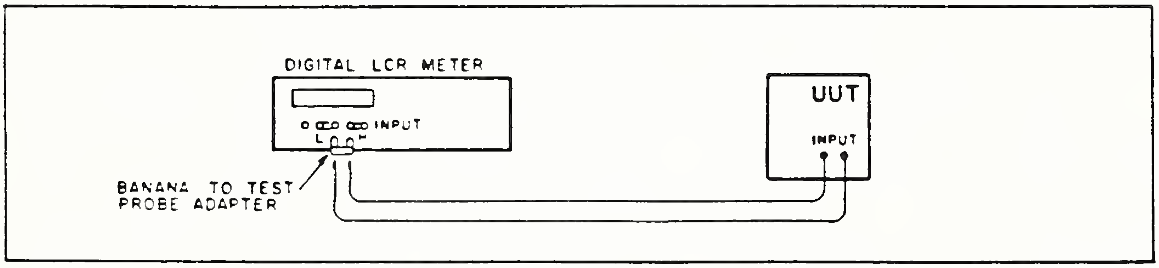

Fig. 10.2.8 Test setup for measuring input impedance.

2. Set the UUT controls as follows:

Function:	AC VOLTAGE
Range Mode:	AUTORANGE

3. Set the controls on the digital 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 cables at the input of the UUT.

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

9. Place the digital LCR meter into the mode to read resistance by depressing the R/ESR button.

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

Table 10.2.8 Input Impedance (AC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Cable Cap.	____________				pF
Cable + Input	____________				pF
Input Cap.	____________	±2.1		100	pF
Input Resist.	____________	±0.05	2		MΩ

10.2 AC Voltage

10.2.9 Common Mode Rejection Ratio (CMRR)

Specification:

CMRR shall be at least 60 dB at 50, 60 and 400 Hz and with 1000 Ω unbalance in low lead.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101A or equivalent
1 kΩ Resistor Fixture for CMRR Test	See Appendix D, Item 14
Aluminum Sheet	12" x 12" x 0.0625" thick with connection point attached. See Appendix D, Item 1
Banana Patch Cord, 2 ea.	Pomona Electronics B-12 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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:

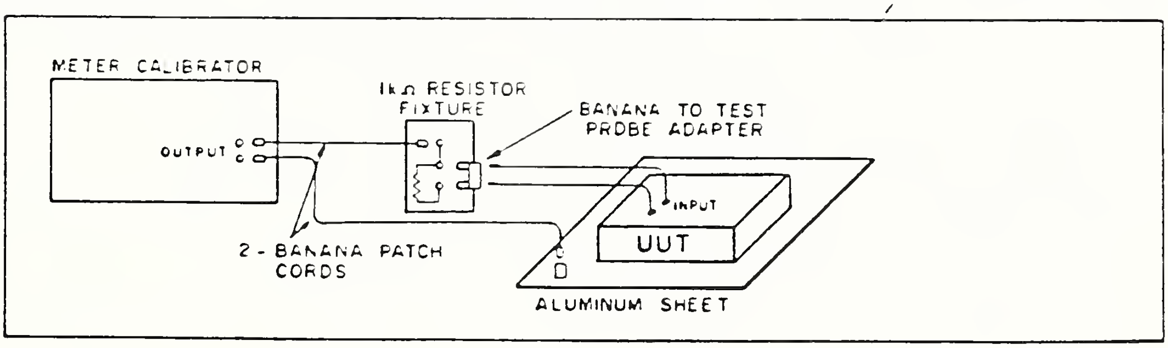

Figure 10.2.9 Test setup for measuring common mode rejection ratio.

2. Initially, set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: AUTORANGE

3. Set the calibrator to apply zero volts to the UUT and note the reading displayed on the UUT. This reading will be designated V_0. Note: It is sufficient to set the ac calibrator to its minimum setable value instead of exactly zero volts.

4. Set the calibrator to apply 100 V ac (rms) at 50 Hz to the two leads of the UUT and note the ac voltage reading displayed on the UUT. This reading will be designated V_1.

5. Calculate the common mode rejection ratio according to the formula:

$$CMRR = 20 \cdot \log_{10} \frac{ABS(V_1 - V_0)}{100}$$

   for each of the frequencies (50 Hz, 60 Hz, and 400 Hz). Record this value on the data sheet.
   (Note: ABS in the equation above indicates the absolute value, in order to make the numerator always positive.)

6. Repeat steps 3 through 5 at frequencies of 60 Hz and 400 Hz.

7. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.2.9 Common Mode Rejection Ratio (AC Voltage Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
50 Hz V_0	________				V ac
V_1	________				V ac
DC Rejection Ratio - 50 Hz	________	±0.086	-60		dB
60 Hz V_0	________				V ac
V_1	________				V ac
DC Rejection Ratio - 60 Hz	________	±0.086	-60		dB
400 Hz V_0	________				V ac
V_1	________				V ac
DC Rejection Ratio - 400 Hz	________	±0.086	-60		dB

10.2 AC Voltage

10.2.10 Overload Protection

Specification:

Shall provide a minimum of 1000 V protection (dc or peak ac) or 750 V (rms).

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Clock	General Electric 2908 or equivalent

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:

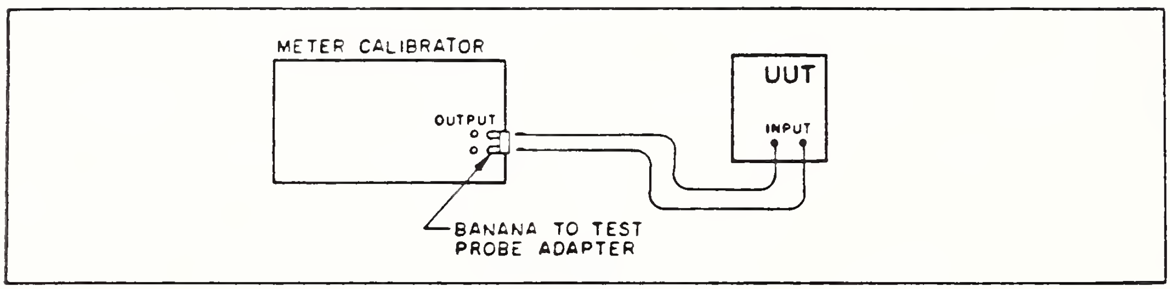

Fig. 10.2.10 Test setup for measuring overload protection.

2. Set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: MANUAL - 20 mv range

3. Apply 1000 V dc from the meter calibrator to the leads of the UUT. Note time on the clock.

4. After five minutes has elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage on the data sheet.

5. Set the output voltage of the meter calibrator to zero. Reverse the leads between the UUT and the meter calibrator, and repeat steps 3 and 4, above.

6. Set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: MANUAL - 200 mv range.

7. Repeat steps 3 through 5, inclusive, above.

8. Set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: MANUAL - 20 mv range.

9. Apply 750 V ac (rms), 1 kHz signal to the voltage leads of the UUT. Note time on the clock.

10. After five minutes has elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage.

11. Set the UUT controls as follows:

    Function: AC VOLTAGE
    Range Mode: MANUAL - 200 mv range.

12. Repeat steps 9 and 10, above.

13. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.2.10a Overload Protection - DC Voltage

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC V Range 20.0 mV	____________	N/A	No Damage		
200 mV	____________	N/A	No Damage		

Table 10.2.10b Overload Protection - AC Voltage

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC V Range 20.0 mV	____________	N/A	No Damage		
200 mV	____________	N/A	No Damage		

10.3 DC Current

Specification:

Shall meet the specified performance herein across the full dc current range (see para. 10.3.1).

10.3.1 Range

Specification:

Shall be at least 2 milliamps to 2 amps in no less than three ranges.

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the dc current range covers the limits specified.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.3.1 Range

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
DC Current Range Min.	____________	N/A		2.0	mA
DC Current Range Max.	____________	N/A	2.0		A
Number of DC Current Ranges	____________	N/A	3		units

10.3 DC Current

10.3.2 Accuracy

Specification:

Shall be at least as specified below or better over the operating temperature range of 18° C to 28° C, up to 90% relative humidity.

Range	Accuracy
<20 milliamps:	*±0.5% of the input + 1 count*
>20 milliamps:	*±0.75% of the input + 1 count*

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

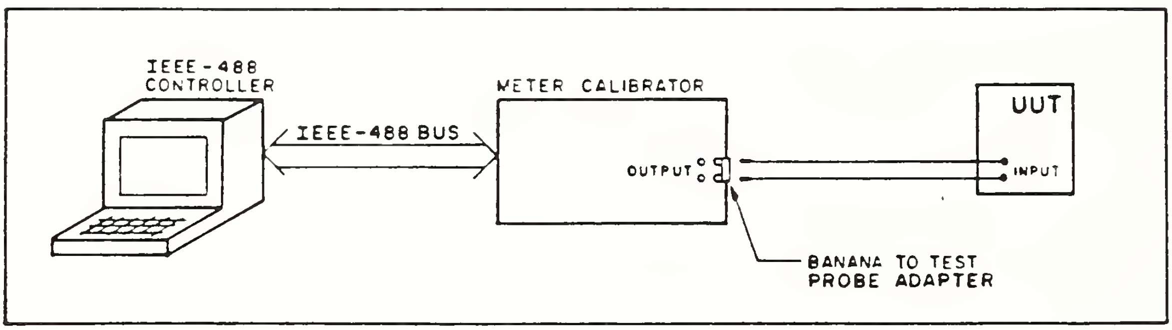

Fig. 10.3.2 Test setup for measuring dc current accuracy.

2. Set the UUT controls as follows:

   Function: DC CURRENT
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "AC and DC CURRENT" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the calibrator to apply a current to the UUT and then ask the operator to enter the reading displayed on the UUT into the 488 controller via the keyboard.

7. When the displayed value had been entered, press the key marked ENTER.

8. The computer program will test the UUT using the following sequence of dc currents:

10.000	μA
18.000	μA
50.000	μA
100.00	μA
180.00	μA
500.00	μA
1.000	mA
1.800	mA
5.000	mA
10.000	mA
18.000	mA
50.000	mA
100.00	mA
180.00	mA
500.00	mA
1.000	A
1.800	A

9. The program will then test the negative values of the current sequence.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.3.2a Accuracy - Positive

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current 10 μA	____________	±0.0175	9.8	10.2	μA dc
18 μA	____________	±0.0195	17.8	18.2	μA dc
50 μA	____________	±0.0275	49.6	50.4	μA dc
100 μA	____________	±0.040	99.4	100.6	μA dc
180 μA	____________	±0.060	179.0	181.0	μA dc
500 μA	____________	±0.185	496	504	μA dc
1.00 mA	____________	±0.000310	0.994	1.006	mA dc
1.80 mA	____________	±0.000510	1.790	1.810	mA dc
5.00 mA	____________	±0.00176	4.96	5.04	mA dc
10.0 mA	____________	±0.00301	9.94	10.06	mA dc
18.0 mA	____________	±0.00501	17.90	18.10	mA dc
50.0 mA	____________	±0.0175	49.5	50.5	mA dc
100.0 mA	____________	±0.030	99.1	100.9	mA dc

Table 10.3.2a Accuracy - Positive (continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current 180.0 mA	____________	±0.050	178.5	181.5	mA dc
500.0 mA	____________	±0.175	480	520	mA dc
1.000 A	____________	±0.0003	0.98	1.02	A dc
1.800 A	____________	±0.0005	1.77	1.83	A dc

Table 10.3.2b Accuracy - Negative

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current -10 μA	______	±0.0175	-9.8	-10.2	μA dc
-18 μA	______	±0.0195	-17.8	-18.2	μA dc
-50 μA	______	±0.0275	-49.6	-50.4	μA dc
-100 μA	______	±0.040	-99.4	-100.6	μA dc
-180 μA	______	±0.060	-179.0	-181.0	μA dc
-500 μA	______	±0.185	-496	-504	μA dc
-1.00 mA	______	±0.000310	-0.994	-1.006	mA dc
-1.80 mA	______	±0.000510	-1.790	-1.810	mA dc
-5.00 mA	______	±0.00176	-4.96	-5.04	mA dc
-10.0 mA	______	±0.00301	-9.94	-10.06	mA dc
-18.0 mA	______	±0.00501	-17.90	-18.10	mA dc
-50.0 mA	______	±0.0175	-49.5	-50.5	mA dc
-100.0 mA	______	±0.030	-99.1	-100.9	mA dc

Table 10.3.2b Accuracy - Negative (continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current -180.0 mA	______	±0.050	-178.5	-181.5	mA dc
-500.0 mA	______	±0.175	-480	-520	mA dc
-1.000 A	______	±0.0003	-0.98	-1.02	A dc
-1.800 A	______	±0.0005	-1.77	-1.83	A dc

10.3 DC Current

10.3.3 Response Time

Specification:

Less than 1 second to rated accuracy.

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

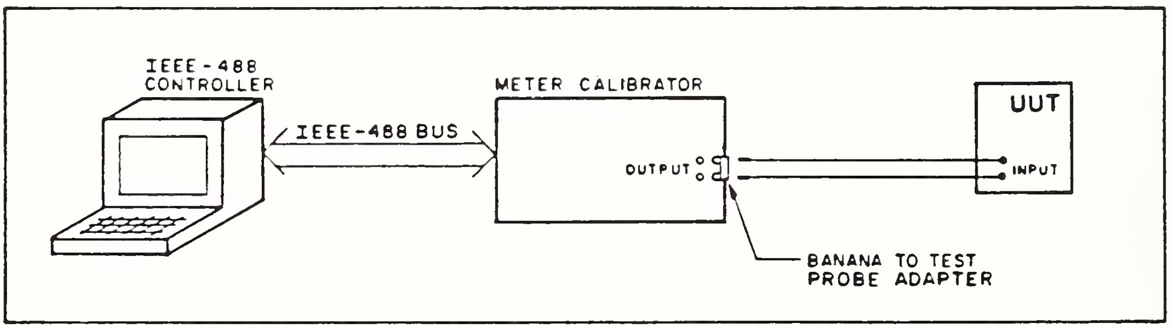

Fig. 10.3.3 Test setup for measuring response time.

2. Set the UUT controls as follows:

   Function: DC CURRENT
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "RESPONSE TIMES" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the operator to press the ENTER key. At the end of one second, a tone will be emitted from the controller.

7. At the time the tone is heard, the operator should mentally note the value of the current displayed on the UUT. Note: The operator may wish to practice this part of the procedure before recording the data.

8. Record the value of the observed current on the data sheet.

9. Steps 5 through 7, inclusive, of this test will be repeated for currents of 0.1, 1.0, 10.0, and 100.0 mA dc.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.3.3 Response Time (DC Current Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Cur. Resp. 0.1 mA	____________	±0.00004	0.0994	0.1006	mA dc
1.0 mA	____________	±0.00031	0.994	1.006	mA dc
10.0 mA	____________	±0.00301	9.94	10.06	mA dc
100.0 mA	____________	±0.030	99.1	100.9	mA dc

10.3 DC Current

10.3.4 Overload Protection

Specification:

2A/250V fuse and 3A/600V fuse in series, or a single 2A/600V fuse.

[Note: This specification is deemed a design specification not subject to performance verification test.]

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the fuses exist and conform to the specification.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.3.4 Overload Protection

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Fuses conform to specification	__________	N/A	Yes		

10.3 DC Current

10.3.5 Resolution

Specification:

10 μA or less on lowest range; 10 mA or less on highest range.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

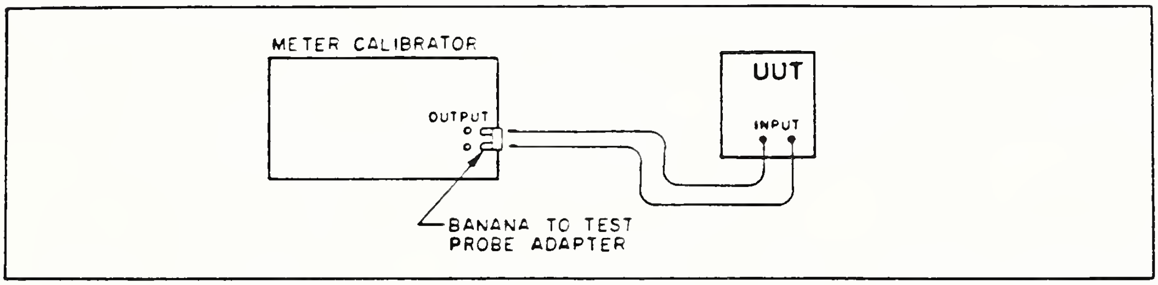

Fig. 10.3.5 Test setup for measuring resolution.

2. Set the UUT controls as follows:

   Function: DC CURRENT
   Range Mode: MANUAL RANGE, Minimum

3. Set the output amplitude of the meter calibrator to 1.8 mA dc.

4. Increase the output amplitude of the meter calibrator by 10 μA dc.

5. Read and record on the data sheet the incremental current change displayed on the UUT.

6. Set the UUT controls as follows:

   Function: DC CURRENT
   Range Mode: MANUAL RANGE, Maximum

7. Set the output amplitude to approximately 1.8 A dc.

8. Increase the output amplitude of the meter calibrator by 10 mA dc.

9. Read and record on the data sheet the incremental current change displayed on the UUT.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.3.5 Resolution (DC Current Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current Range Min.	____________	± 0.0175		10	µA dc
DC Current Range Max.	____________	±0.00301		10	mA dc

10.3 DC Current

10.3.6 Burden Voltage

Specification:

Shall be as specified below:

Range	*Burden Voltage*
For currents ≤ 0.6 mA	*< 0.3 V*
For currents ≤ 2 mA	*< 1 V*
For currents > 2 mA	*< 1.9 V*

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Precision Digital Multimeter	Fluke 8506A or equivalent
Patch Cord, Banana Plugs Both Ends (2 Required)	Pomona B-12 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

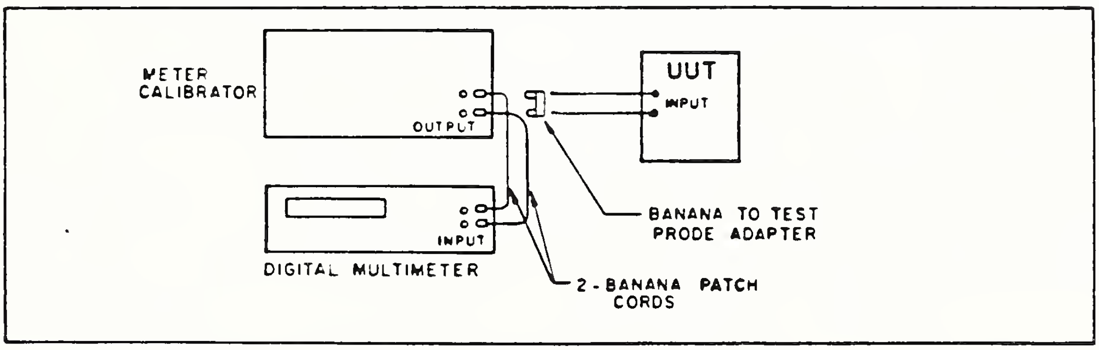

Fig. 10.3.6 Test setup for measuring burden voltage.

2. Set the UUT controls as follows:

   Function: DC CURRENT
   Range Mode: AUTORANGE

3. Apply a current to the UUT of 0.6 mA dc.

4. Record the voltage displayed on the precision digital multimeter.

5. Repeat steps 3 and 4 for the following sequence of applied dc current:

   1.9 mA
   1.9 A

6. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.3.6 Burden Voltage (DC Current Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
DC Current 0.6 mA	________	±0.000009		0.3	V
1.9 mA	________	±0.000016		1.0	V
1.9 A	________	±0.000060		1.9	V

10.4 AC Current

Specification:

Shall meet the specified performance herein across the full ac current range (see para 10.4.1).

10.4.1 Range

Specification:

Shall be at least 2 milliamps to 2 amps.

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the ac current range covers the limits specified.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.4.1 AC Current Range

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
Minimum AC Current Range	____________	N/A		2.0	mA ac
Maximum AC Current Range	____________	N/A	2.0		A ac

10.4 AC Current

10.4.2 Detection

Specification:

Shall be true rms on signals with crest factors up to 3:1, or greater.

Equipment:

Items	Model
Function Generator	HP 3325A or equivalent
Arbitrary Waveform Generator	Wavetek 275 or equivalent
Transconductance Amplifier	Fluke 5220A or equivalent
Oscilloscope	Tektronix 465 or equivalent
Resistor Summing Network, 3 kΩ	See Appendix D, Item 15
3:1 Crest Factor Generator	See Appendix D, Item 7
Power Supply for 3:1 Crest Factor Generator	See Appendix D, Item 13
Variable Attenuator	See Appendix D, Item 2
Precision Digital Multimeter	Fluke 8506A Digital Multimeter or equivalent
BNC Male to BNC Male Cable 24 inches (61 cm) 5 ea.	Pomona BNC-C-24 or equivalent
BNC "T" Adapter (Female-Male-Female)	Pomona 3285 or equivalent
BNC female to Banana Adapter, 2 ea.	Pomona 1868 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Binding Post to Binding Post Adapter	See Appendix D, Item 4

Procedure:

Note: The first part of this test checks whether the UUT is true-rms responding. The basis for this test is taken from ANSI C39.6-1983 and consists of adding a signal containing 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; 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. Thus, 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°.

The second part of the test determines if the UUT maintains the required accuracy in the presence of a 3:1 crest factor signal.

Note: This test is functionally identical to the test procedure of 10.2.1 except that a transconductance amplifier has been included to test the UUT in the ac current mode.

Part 1. True-rms current detection

1. Connect the equipment as shown below:

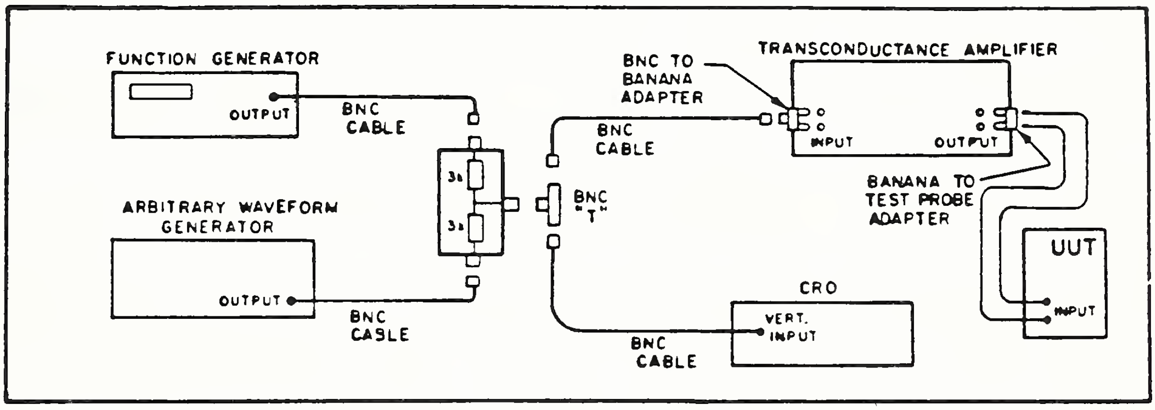

Fig. 10.4.2a Test setup for ac current detection

2. To set up the arbitrary waveform generator, push the following controls on the front panel:

   2.1. Turn on power switch.

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

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

   Steps 2.1 to 2.3 set up the function generator to its default values of 1 kHz and 5 V.

3. Set up the function generator to provide approximately 3 kHz and 1.5 V ac (rms). Set the following controls on the front panel:

   3.1. Turn on power switch

   3.2. FREQ, 3, kHz

   3.3. AMPTD, 1.5, V RMS.

This sequence should produce an image of a distorted sine wave on the oscilloscope. Since the frequency setting of the arbitrary waveform generator may not be exactly 1 kHz, a fine adjustment of the frequency of the function generator may be necessary. To adjust the frequency, proceed as follows:

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

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

3.6. 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 between the two waveforms shown in figure 10.4.2b. The time for the pattern to return to its original shape should take approximately 10 seconds.

4. While the waveform pattern is changing slowly, observe the output reading of the UUT, and enter into the data sheet the highest and lowest readings obtained.

5. Enter the percentage difference between the highest and lowest reading on the data sheet.

6. Subtract the minimum ac current from the maximum ac current observed in the previous step and enter the value into the data sheet. The value of difference should not exceed 0.5 percent of 1.5 A rms plus the value represented by five least significant digits.

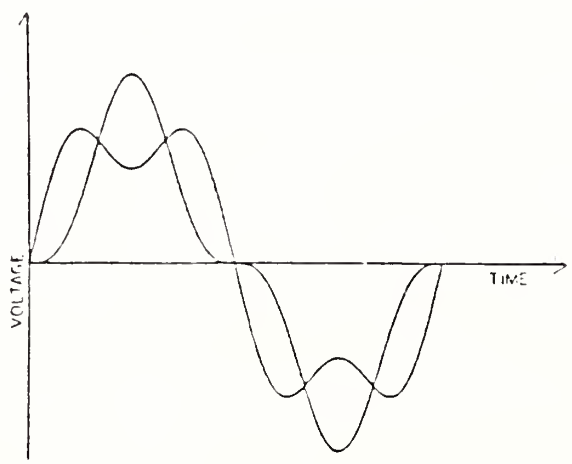

Figure 10.4.2b Waveforms for type of response test

Table 10.4.2a AC RMS Detection

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current Read'g Min.	______	N/A			A ac
AC Current Read'g Max.	______	N/A			A ac
Difference of Current Read'gs	______	N/A		±0.5% + 5 (lsd)*	A ac

* least significant digit on display

Part 2. 3:1 Crest Factor Response

1. Set the output current from the transconductance amplifier to zero.

2. Connect the equipment as shown in figure below.

3. Set the precision digital multimeter to read ac volts.

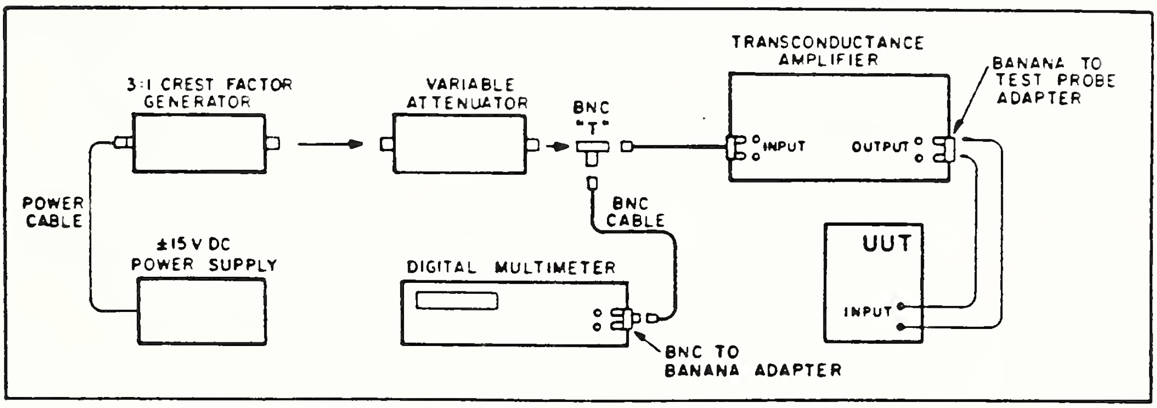

Fig. 10.4.2c Test setup for the crest factor test

4. Set the controls of the UUT as follows:

   Function: AC CURRENT
   Range Mode: AUTORANGE

5. Set the controls of the precision digital multimeter as follows:

   Function: AC VOLTS
   Range Mode: AUTORANGE

6. Adjust the attenuator to obtain a nominal reading of 1.8 v ac (rms) on the precision digital multimeter.

7. Read and record the ac current displayed on the UUT. Record this value as Iu.

8. Read and record the voltage displayed on the precision digital multimeter, in volts, as the current through the UUT, Im.

Note: The tranconductance amplifier is specified by the manufacturer to have a transconductance ratio of one ampere per volt. Thus, the voltage displayed on the precision digital multimeter is numerically equal to the current at the output of the transconductance amplifier.

9. Calculate the percentage difference (error) between the ac voltage as displayed on the UUT and that displayed on the precision digital multimeter according to the following formula:

$$\text{Error} = \frac{Iu - Im}{Im} \cdot 100.$$

Note: Although the crest factor test can be performed with the UUT in the autorange mode, operation in this mode does not ensure that the applied current 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.

Table 10.4.2b 3:1 Crest Factor Response

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Percentage Error at 3:1 Crest Factor	. ________	±0.3	-(1.5 pct + 5 lsd*)	+(1.5 pct + 5 lsd*)	pct

* least significant digit on display

4. Select the program "AC and DC CURRENT" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the calibrator to apply a current to the UUT and then ask the operator to enter the reading displayed on the UUT into the 488 controller via the keyboard.

7. When the displayed value has been entered, press the key marked ENTER.

8. The computer program will test the UUT using the following sequence of ac currents and frequencies:

10.000 μA		
18.000 μA		
50.000 μA		
100.00 μA		
180.00 μA		
500.00 μA		
1.000 mA		
1.800 mA	at	50 Hz
5.000 mA	frequencies	200 Hz
10.000 mA	of	500 Hz
18.000 mA		1 kHz
50.000 mA		
100.00 mA		
180.00 mA		
500.00 mA		
1.000 A		
1.800 A		

9. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.4.4a Accuracy (50 Hz)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 10 μA	____________	±0.047	9.3	10.7	μA ac
18 μA	____________	±0.053	17.2	18.8	μA ac
50 μA	____________	±0.075	48.7	51.3	μA ac
100 μA	____________	±0.110	98.0	102.0	μA ac
180 μA	____________	±0.166	176.8	183.2	μA ac
500 μA	____________	±0.570	487	513	μA ac
1.000 mA	____________	±0.000920	0.980	1.020	mA ac
1.800 mA	____________	±0.001480	1.768	1.832	mA ac
5.0 mA	____________	±0.00552	4.87	5.13	mA ac
10.0 mA	____________	±0.00902	9.8	10.2	mA ac
18.0 mA	____________	±0.01462	17.68	18.32	mA ac
50.0 mA	____________	±0.0550	48.7	51.3	mA ac
100.0 mA	____________	±0.090	98.0	102.0	mA ac
180.0 mA	____________	±0.146	176.8	183.2	mA ac

Table 10.4.4a Accuracy (50 Hz - continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 500 mA	__________	±0.00055	440	560	mA ac
1.0 A	__________	±0.000900	0.93	1.07	A ac
1.8 A	__________	±0.00146	1.72	1.88	A ac

Table 10.4.4b Accuracy (200 Hz)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 10 µA	______	±0.047	9.3	10.7	µA ac
18 µA	______	±0.053	17.2	18.8	µA ac
50 µA	______	±0.075	48.7	51.3	µA ac
100 µA	______	±0.110	98.0	102.0	µA ac
180 µA	______	±0.166	176.8	183.2	µA ac
500 µA	______	±0.570	487	513	µA ac
1.00 mA	______	±0.000920	0.980	1.020	mA ac
1.800 mA	______	±0.001480	1.768	1.832	mA ac
5.0 mA	______	±0.00552	4.87	5.13	mA ac
10.0 mA	______	±0.00902	9.8	10.2	mA ac
18.0 mA	______	±0.01462	17.68	18.32	mA ac
50.0 mA	______	±0.0550	48.7	51.3	mA ac
100.0 mA	______	±0.090	98.0	102.0	mA ac
180.0 mA	______	±0.146	176.8	183.2	mA ac

Table 10.4.4b Accuracy (200 Hz - continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 500 mA	______	±0.00055	440	560	mA ac
1.0 A	______	±0.000900	0.93	1.07	A ac
1.8 A	______	±0.00146	1.72	1.88	A ac

Table 10.4.4c Accuracy (500 Hz)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 10 μA	________	±0.047	9.3	10.7	μA ac
18 μA	________	±0.053	17.2	18.8	μA ac
50 μA	________	±0.075	48.7	51.3	μA ac
100 μA	________	±0.110	98.0	102.0	μA ac
180 μA	________	±0.166	176.8	183.2	μA ac
500 μA	________	±0.570	487	513	μA ac
1.000 mA	________	±0.000920	0.980	1.020	mA ac
1.800 mA	________	±0.001480	1.768	1.832	mA ac
5.0 mA	________	±0.00552	4.87	5.13	mA ac
10.0 mA	________	±0.00902	9.8	10.2	mA ac
18.0 mA	________	±0.01462	17.68	18.32	mA ac
50.0 mA	________	±0.0550	48.7	51.3	mA ac
100.0 mA	________	±0.090	98.0	102.0	mA ac
180.0 mA	________	±0.146	176.8	183.2	mA ac

Table 10.4.4c Accuracy (500 Hz - continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 500 mA	______________	±0.00055	440	560	mA ac
1.0 A	______________	±0.000900	0.93	1.07	A ac
1.8 A	______________	±0.00146	1.72	1.88	A ac

Table 10.4.4d Accuracy (1 kHz)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 10 μA	______________	±0.047	9.3	10.7	μA ac
18 μA	______________	±0.053	17.2	18.8	μA ac
50 μA	______________	±0.075	48.7	51.3	μA ac
100 μA	______________	±0.110	98.0	102.0	μA ac
180 μA	______________	±0.166	176.8	183.2	μA ac
500 μA	______________	±0.570	487	513	μA ac
1.000 mA	______________	±0.000920	0.980	1.020	mA ac
1.800 mA	______________	±0.001480	1.768	1.832	mA ac
5.0 mA	______________	±0.00552	4.87	5.13	mA ac
10.0 mA	______________	±0.00902	9.8	10.2	mA ac
18.0 mA	______________	±0.01462	17.68	18.32	mA ac
50.0 mA	______________	±0.0550	48.7	51.3	mA ac
100.0 mA	______________	±0.090	98.0	102.0	mA ac
180.0 mA	______________	±0.146	176.8	183.2	mA ac

Table 10.4.4d Accuracy (1 kHz - continued)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Current 500 mA	____________	±0.00055	440	560	mA ac
1.0 A	____________	±0.000900	0.93	1.07	A ac
1.8 A	____________	±0.00146	1.72	1.88	A ac

10.4 AC Current

10.4.5 Response Time

Specification:

Shall be 5 seconds or less to rated accuracy.

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

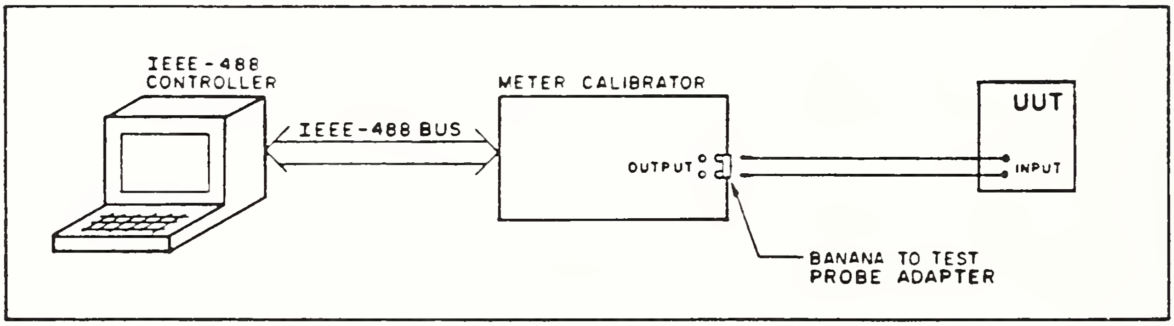

Fig. 10.4.5 Test setup for measuring response time.

2. Set the UUT controls as follows:

   Function: AC CURRENT
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "RESPONSE TIME" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the operator to press the ENTER key. At the end of five seconds, a tone will be emitted from the controller.

7. At the time the tone is heard, the operator should mentally note the value of the voltage displayed on the UUT. Note: The operator may wish to practice this part of the procedure before recording the data.

8. Record the value of the observed reading on the data sheet.

9. Steps 5 through 7 (inclusive) of this test will be repeated for current input changes of 0.1, 1.0, 10.0, and 100.0 mA ac (rms) at a frequency of 1 kHz.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.4.5 Response Time (AC Current Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Cur. Resp. 0.10 mA	________	±0.000110	0.098	0.102	mA ac
1.0 mA	________	±0.000920	0.980	1.020	mA ac
10.0 mA	________	±0.00902	9.80	10.20	mA ac
100.0 mA	________	±0.0900	98.0	102.0	mA ac

10.4 AC Current

10.4.6 Overload Protection

Specification:

2A/250V fuse and 3A/600V fuse in series, or a single 2A/600V fuse.

[Note: This specification is deemed a design specification not subject to performance verification test.]

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the fuses exist and conform to the specification.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.3.4 Overload Protection

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Fuses conform to specification	________	N/A	Yes		

10.4 AC Current

10.4.7 Resolution

Specification:

Shall be 10 μA or less on lowest range; 10 mA or less on highest range.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

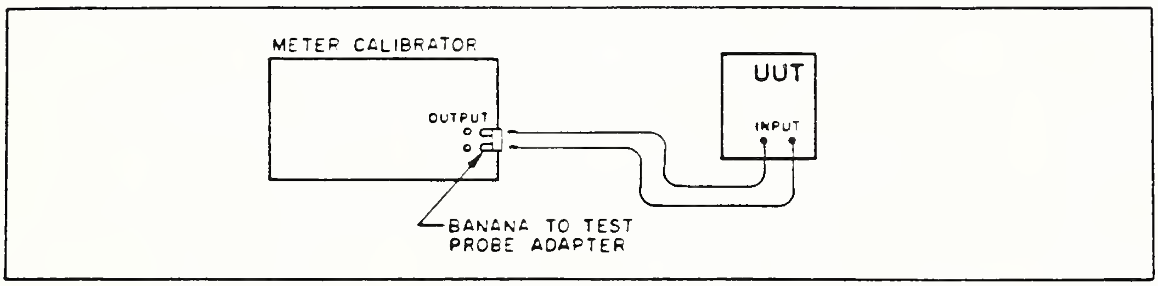

Fig. 10.4.7 Test setup for measuring resolution.

2. Set the UUT controls as follows:

   Function: AC CURRENT
   Range Mode: MANUAL RANGE, Minimum

3. Set the output amplitude of the meter calibrator to 1.8 mA ac (rms) at 1 kHz.

4. Increase the output amplitude of the meter calibrator by 10 μA ac.

5. Read and record on the data sheet the incremental current change displayed on the UUT.

6. Set the UUT controls as follows:

   Function: AC CURRENT
   Range Mode: MANUAL RANGE, Maximum

7. Set the output amplitude of the meter calibrator to approximately 1.8 A ac (rms) at 1 kHz.

8. Increase the output amplitude of the meter calibrator by 10 mA ac.

9. Read and record on the data sheet the incremental current change displayed on the UUT.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.4.7 Resolution (AC Current Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
DC Current Range Min.	________	±1.2 (est.)		10	μA ac
DC Voltage Range Max.	________	±0.7 (est.)		10	mA ac

10.4 AC Current

10.4.8 Burden Voltage

Specification:

Shall be as specified below:

Range	*Burden Voltage*
For current ≤ 0.6 mA	*< 0.3v*
For current ≤ 2 mA	*< 1 v*
For current > 2 mA	*< 1.9v*

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Precision Digital Multimeter	Fluke 8506A or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Patch Cord, Banana Plugs Both Ends (2 Required)	Pomona B-12 or equivalent

Procedure:

1. Connect the equipment as shown below:

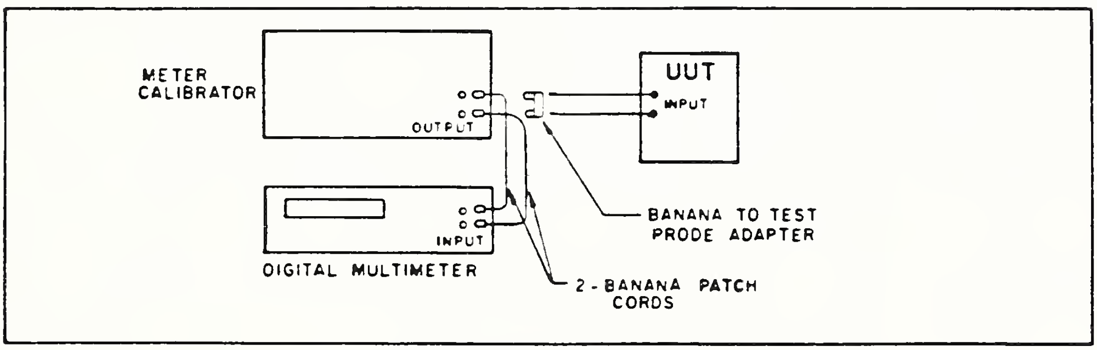

Fig. 10.4.8 Test setup for measuring burden voltage.

2. Set the UUT controls as follows:

   Function: AC CURRENT
   Range Mode: AUTORANGE

3. Apply a current to the UUT of 0.6 mA ac (rms) at a frequency of 1 kHz

4. Record the voltage displayed on the precision digital multimeter.

5. Repeat steps 3 and 4 for the following sequence of applied ac current:

1.9 mA
1.9 A

6. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.4.9 Burden Voltage (AC Current Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
AC Current 0.6 mA	________	±.00042		0.3	V
1.9 mA	________	±.00112		1.0	V
1.9 A	________	±0.00310		1.9	V

10.5 Resistance

Specification:

Shall meet the specified performance contained herein across the full resistance range (see para 10.5.1).

10.5.1 Range

Specification:

Shall be up to 20 MΩ in no less than four ranges.

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the resistance range covers the limits specified.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.5.1 Resistance Range

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Number of Resistance Ranges	________	N/A	4		ranges
Maximum Resistance Range	________	N/A	20		MΩ

10.5 Resistance

10.5.2 Accuracy

Specification:

Shall be at least as specified below or better over the operating temperature range of 18 to 28 degrees centigrade, up to 90% relative humidity.

Range	*Accuracy*
For resistance < 1 kΩ	*±0.3% of input + 2 count*
For resistance < 2 MΩ	*±0.25% of input + 1 count*
For resistance ≥ 2 MΩ	*±1% of input + 1 count*

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

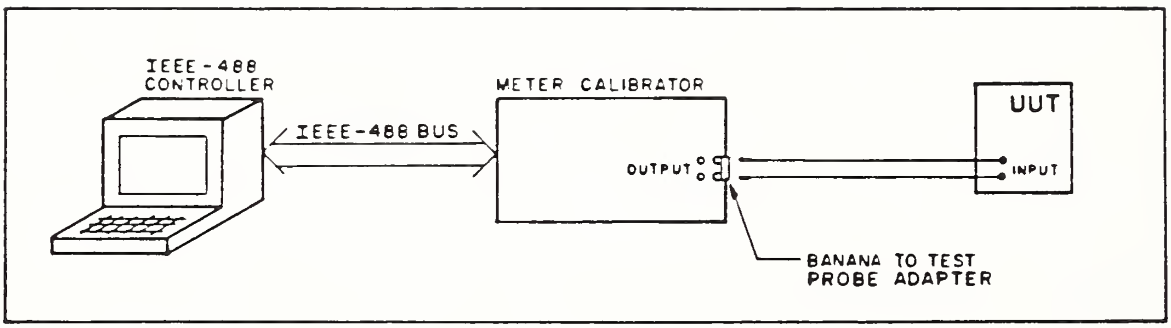

Fig. 10.5.2 Test setup for measuring resistance accuracy.

2. Set the UUT controls as follows:

   Function: RESISTANCE
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "RESISTANCE" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the calibrator to apply a resistance to the UUT and then ask the operator to enter the reading displayed on the UUT into the IEEE-488 controller via the keyboard.

7. When the displayed value has been entered, press the key marked ENTER.

8. This process will test the UUT using the following sequence of resistances:

   1 Ω
   10 Ω
   100 Ω
   1 kΩ
   10 kΩ
   100 kΩ
   1 MΩ
   10 MΩ

9. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.5.2 Resistance Accuracy

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Resistance 1 Ω	____________	±0.00020	0.8	1.2	Ω
10 Ω	____________	±0.0010	9.7	10.3	Ω
100 Ω	____________	±0.0050	99.5	100.5	Ω
1 kΩ	____________	±0.00005	0.996	1.004	kΩ
10 kΩ	____________	±0.0005	9.965	10.04	kΩ
100 kΩ	____________	±0.005	99.6	100.4	kΩ
1 MΩ	____________	±0.00010	0.996	1.004	MΩ
10 MΩ	____________	±0.0050	9.89	10.11	MΩ

10.5 Resistance

10.5.3 Overload Protection

Specification:

Shall provide a minimum of 750 V (dc + peak ac) protection on all ranges.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Clock	General Electric 2908 or equivalent

Procedure:

1. Connect the equipment as shown below:

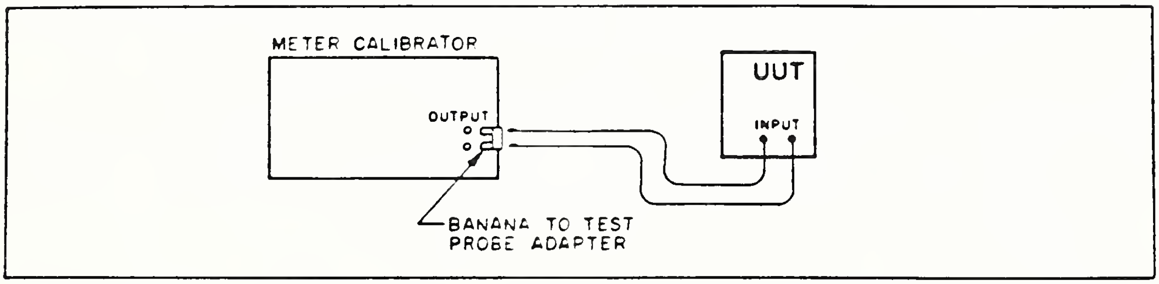

Fig. 10.5.3 Test setup for measuring overload protection.

2. Set the UUT controls as follows:

   Function: RESISTANCE
   Range Mode: MANUAL RANGE
   Resistance Range: LOWEST RANGE

3. Apply 750 V dc from the meter calibrator to the resistance leads of the UUT. Note the time on the clock.

4. After five minutes have elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage on the data sheet for the range being tested.

5. Change the resistance range of the UUT to the next higher resistance range and repeat step 4. Continue to apply 750 V dc to the resistance leads on all resistance ranges of the UUT. At the end of applying voltage to the highest resistance range, set the output of the meter calibrator to zero.

6. Set the UUT controls as follows:

   Resistance Range: LOWEST RANGE

7. Reverse the leads between the UUT and the meter calibrator and apply 750 V dc from the meter calibrator to the resistance leads of the UUT. Note the time on the clock.

8. After five minutes have elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage on the data sheet for the range being tested.

9. Change the resistance range of the UUT to the next higher resistance range and repeat step 4. Continue to apply 750 V dc to the resistance leads on all resistance ranges of the UUT. At the end of applying voltage to the highest resistance range, set the output of the meter calibrator to zero.

10. Set the UUT controls as follows:

    Function: RESISTANCE

11. Apply 530 V ac (rms) at 1 kHz from the meter calibrator to the resistance leads of the UUT. Note the time on the clock.

12. After five minutes have elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage on the data sheet.

13. Change the resistance range of the UUT to the next higher resistance range and repeat step 4. Continue to apply 530 V ac (rms) to the resistance leads on all resistance ranges of the UUT. At the end of applying voltage to the highest resistance range, set the output of the meter calibrator to zero.

Table 10.5.3a Overload Protection for 750 V DC (Resistance Mode)

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Resistance Range 1 Ω	____________	N/A	No Damage		
10 Ω	____________	N/A	No Damage		
100 Ω	____________	N/A	No Damage		
1 kΩ	____________	N/A	No Damage		
10 kΩ	____________	N/A	No Damage		
100 kΩ	____________	N/A	No Damage		
1 MΩ	____________	N/A	No Damage		
10 MΩ	____________	N/A	No Damage		

Table 10.5.3b Overload Protection for -750 V DC (Resistance Mode)

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Resistance Range 1 Ω	______	N/A	No Damage		
10 Ω	______	N/A	No Damage		
100 Ω	______	N/A	No Damage		
1 kΩ	______	N/A	No Damage		
10 kΩ	______	N/A	No Damage		
100 kΩ	______	N/A	No Damage		
1 MΩ	______	N/A	No Damage		
10 MΩ	______	N/A	No Damage		

Table 10.5.3 Overload Protection for 530 V (RMS) AC (Resistance Mode)

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Resistance Range 1 Ω	______________	N/A	No Damage		
10 Ω	______________	N/A	No Damage		
100 Ω	______________	N/A	No Damage		
1 kΩ	______________	N/A	No Damage		
10 kΩ	______________	N/A	No Damage		
100 kΩ	______________	N/A	No Damage		
1 MΩ	______________	N/A	No Damage		
10 MΩ	______________	N/A	No Damage		

10.5 Resistance

10.5.4 Resolution

Specification:

On the lowest range shall be less than 100 mΩ; highest range less than 10 kΩ.

[Note: The specifications do not state the minimum range to be measured by the ohmmeter.]

Equipment:

Items	Model
Incremental Resistance Source	See Appendix D, Item 11

Procedure:

1. Connect the equipment as shown below:

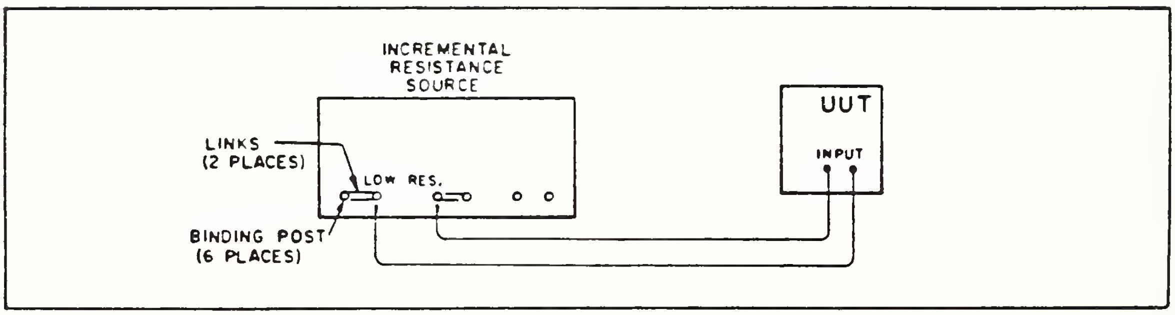

Fig. 10.5.4a Test setup for measuring resistance resolution.

2. Set the UUT controls as follows:

   Function: RESISTANCE
   Range Mode: MANUAL (minimum range)

3. Assure that the UUT is connected to the terminals marked "Low Resistance" and that the jumpers on the incremental resistance source are in place as shown, above. In addition, the switch marked "Low Resistance" should be in the "1.0 Ω" position.

4. The reading should be approximately 1 Ω. Record the value of the observed resistance on the data sheet provided.

5. Move the "Low Resistance" switch to the "1.1 Ω" position. Record the value of the observed resistance on the data sheet provided.

6. Subtract the resistance recorded in step 3 from the resistance recorded in step 5. Record the difference in reading as the resolution of the UUT in the lowest range.

7. Reconnect the equipment as shown below:

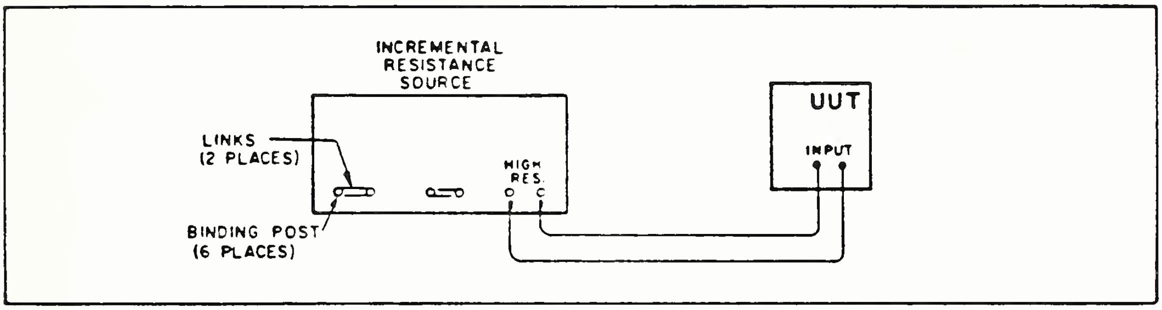

Fig. 10.5.4b Test setup for measuring resistance resolution.

8. Set the UUT controls as follows:

   Function: RESISTANCE
   Range Mode: MANUAL (maximum range)

9. Assure that the UUT is connected to the terminals marked "High Resistance" and that the switch marked "High Resistance" should be in the "10 MΩ" position.

10. The reading should be approximately 10 MΩ. Record the value of the observed resistance on the data sheet provided.

11. Move the "High Resistance" switch to the "10.01 MΩ" position. Record the value of the observed resistance on the data sheet provided.

12. Subtract the resistance recorded in step 10 from the resistance recorded in step 11. Record the difference in reading as the resolution of the UUT in the highest range.

Table 10.5.4 Resolution (Resistance Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Reading of 1.0 Ω setting	____________				Ω
Reading of 1.1 Ω setting	____________				Ω
Resolution on Lowest Range	____________	±0.02		0.1	Ω
Reading on 10.00 MΩ set.	____________				MΩ
Reading on 10.01 MΩ set.	____________				MΩ
Resolution on Highest Range	____________	±0.005		10	kΩ

10.5 Resistance

10.5.5 Diode Test

Specification:

Equipment shall check semiconductor circuits, out of circuit, and shall make in-circuit resistance measurements without burning out or damaging semiconductor junctions.

Equipment:

Items	Model
Diode Test Fixture	See Appendix D, Item 10

Procedure:

Note: Some semiconductor devices may be easily damaged in subtle ways. Especially vulnerable are those devices that exhibit high-frequency and/or low-noise characteristics such as tunnel diodes, IMPATT diodes, Gunn diodes, low-noise junction field-effect transistors, and microwave devices. Certain of these devices may experience degradation by the application of small voltages in their "reverse" direction. This test procedure will not assure that these types of semiconductors are not damaged or degraded as a result of the application of the UUT.

Additionally, semiconductor circuits (i.e. integrated circuits) are not usually "checked" with a UUT alone, since their operation requires, as a minimum, the application of a power supply voltage. Consequently, this test only checks to determine if the UUT has the capability of distinguishing the forward from reverse direction of a typical silicon switching diode.

1. Use the test probes to connect to the leads of the diode located on the diode fixture as shown below:

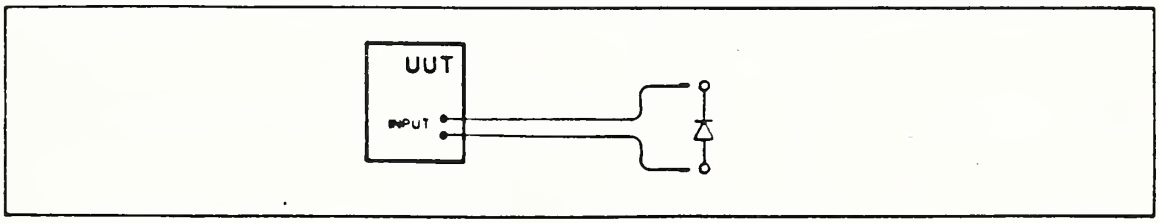

Fig. 10.5.5a Test setup for performing diode test - forward direction.

2. Set the UUT controls as follows:

Function: DIODE TEST

3. Read and record the indication on the display. Note also any tones emitted by the UUT.

4. Reverse the direction of the diode relative to the UUT leads as shown by the figure below.

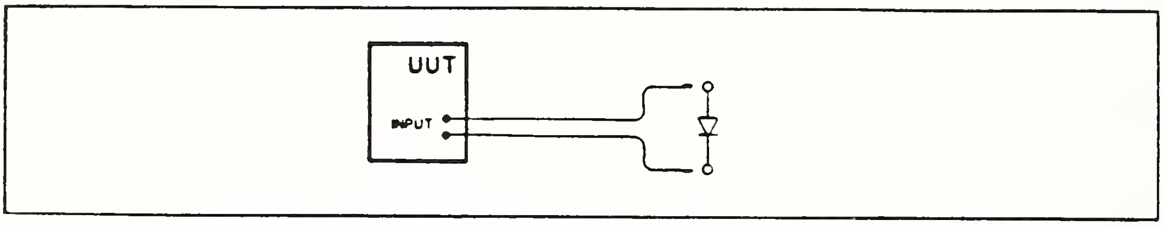

Fig. 10.5.5b Test setup for performing diode test - reverse direction.

5. With the UUT in the diode test mode, read and record the indication on the display. Note also any tones emitted by the UUT.

6. Record on the data sheet if the indications are different, such that the user of the UUT can distinguish the forward from the reverse direction of the diode.

7. Connect the test probes of the UUT across the parallel diode and 5 kΩ resistor combination as shown below:

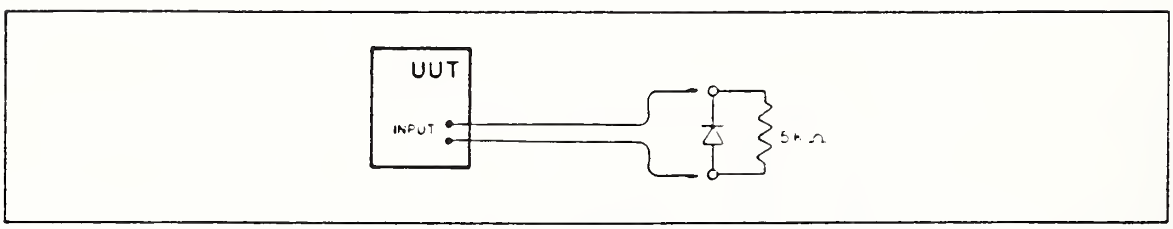

Figure 10.5.5c Test setup for performing in-circuit resistance test - forward direction.

8. Set the UUT controls as follows:

Function: IN-CIRCUIT RESISTANCE

9. Read and record the resistance displayed by the UUT.

10. Reverse the test probes across the diode and 5 kΩ resistor combination.

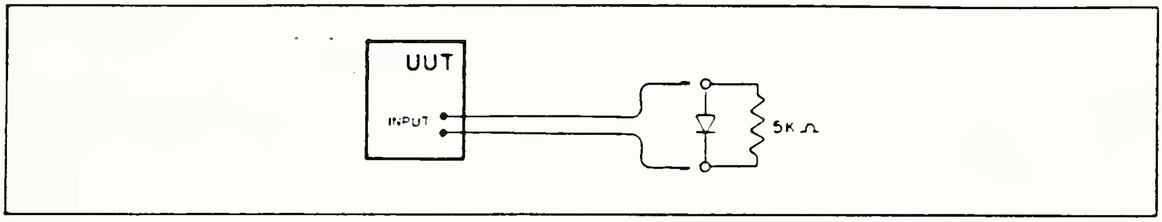

Figure 10.5.5d Test setup for performing in-circuit resistance test - reverse direction.

11. With the UUT in the in-circuit resistance measurement mode, read and record the resistance displayed.

Table 10.5.5 Diode Test

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Indication of Fwd. Diode	________	N/A			
Indication of Rev. Diode	________	N/A			
Can Distinguish Fwd/Rev?	________	N/A			
5 kΩ Fwd. Resistance	________	±0.00025	4.98	5.02	kΩ
5 kΩ Rev. Resistance	________	±0.00025	4.98	5.02	kΩ

10.5 Resistance

10.5.6 Continuity

Specification:

The equipment shall provide selection for an audible (beeper) indicating continuity. Minimum duration of continuity or open to be indicated in 200 ms. Tone shall be audible for at least 100 ms. Maximum open circuit voltage is 0.5 V. There shall also be a visual indication of continuity.

Equipment:

Items	Model
Arbitrary Waveform Generator	Wavetek 275 or equivalent
Oscilloscope	Tektronix 465 or equivalent
Precision Digital Multimeter	Fluke 8506A or equivalent
Continuity Test Fixture (Relay Fixture)	See Appendix D, Item 6
Audio Analyzer	HP 8903B
Microphone, Dynamic	Radio Shack P/N 33-1054A
BNC Male to BNC Male Cable 24 inches (61 cm) 4 ea.	Pomona 1373-24 or equivalent
BNC female to Binding Post Adapter	Pomona 1452 or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Microphone to BNC Adapter	See Appendix D, Item 12

Procedure:

1. Connect the equipment as shown below:

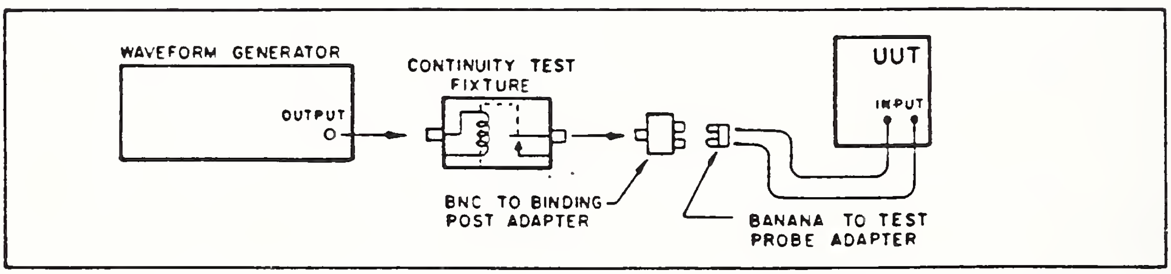

Fig. 10.5.6a Test setup for continuity.

2. Set the UUT controls as follows:

Function: CONTINUITY

3. Set the waveform generator to provide an output pulse waveform with a pulse duration of 200 ms and a period to be 1 s. The output amplitude of the pulse generator shall be 5 V dc.

4. Read and record on the data sheet the fact that the unit-under-test indicates continuity. The indication should consist of both a visual indication of continuity and an audible "beep."

5. Connect the additional equipment as shown below:

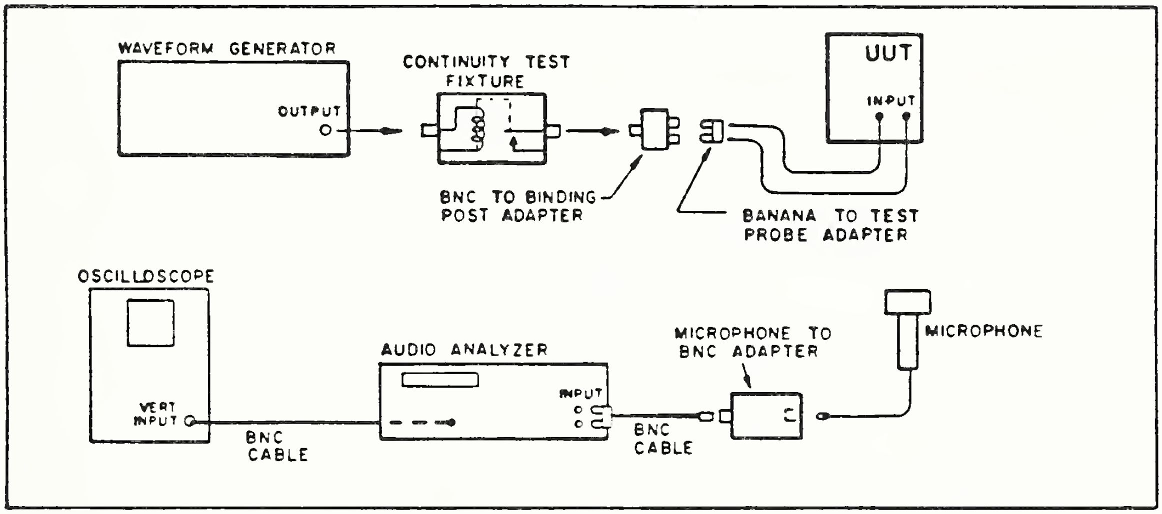

Fig. 10.5.6b Test setup for continuity beep length.

6. Set the oscilloscope for a vertical deflection factor of 1 V/cm and a sweep speed of 20 ms/cm.

7. Place the microphone adjacent to the unit-under-test. A tone burst should be displayed on the oscilloscope corresponding to the "beep" indicating the continuity function.

8. Record the time duration of the tone burst on the data sheet.

9. Connect the equipment as shown below:

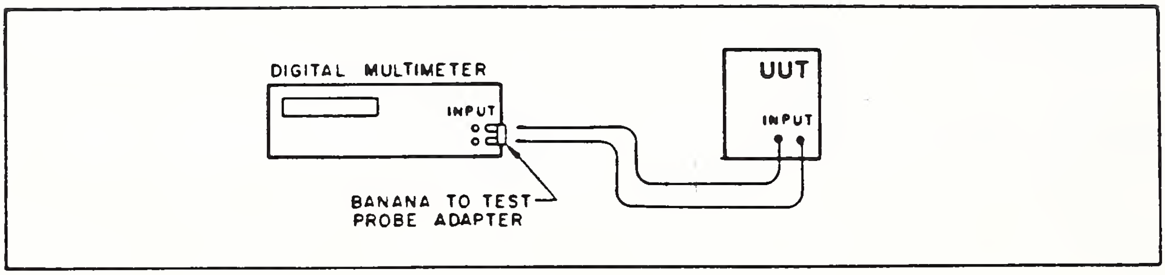

Fig. 10.5.6c Test setup for measuring continuity open-circuit voltage.

10. Set the UUT controls as follows:

    Function: RESISTANCE
    Range Mode: AUTORANGE

11. Set the controls of the precision digital multimeter as follows:

    Function: CONTINUITY

12. Read and record on the data sheet the dc voltage indicated on the precision digital multimeter.

Table 10.5.6 Continuity

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
UUT visual response?	__________	N/A	YES		
UUT audible response?	__________	N/A	YES		
Time duration of tone	__________	±10	100		ms
Open-circuit voltage	__________	±0.0001		0.50	V dc

10.5.7 Response Time

Specification:

Shall be eight seconds or less to rated accuracy.

Equipment:

Items	Model
488 Controller	HP 9836 or equivalent
Printer	HP 2671G or equivalent
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

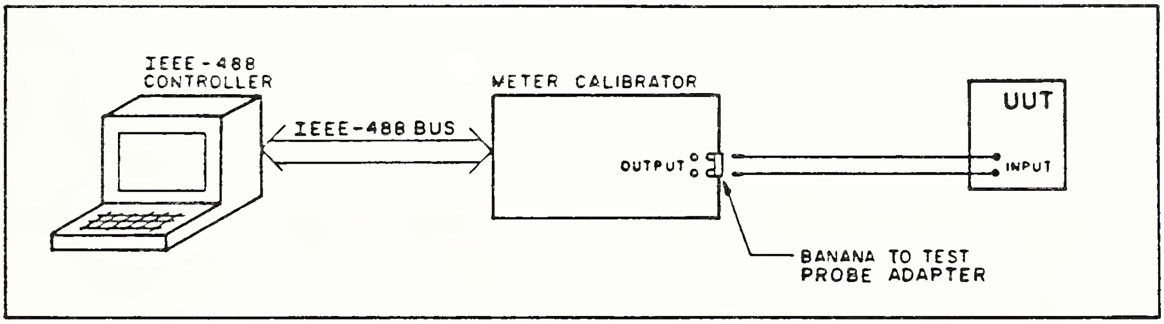

Fig. 10.5.7 Test setup for measuring response time.

2. Set the UUT controls as follows:

   Function: RESISTANCE
   Range Mode: AUTORANGE

3. Load and run the program "MENU" from the disk marked TMDE3A.

4. Select the program "RESPONSE TIMES" from the menu provided by the 488 controller.

5. For each UUT, this program prompts the user to enter (1) name of the manufacturer, (2) the model, and (3) the serial number. If the UUT does not have a serial number, enter the word <NONE>.

6. The program will then instruct the operator to press the ENTER key. At the end of eight seconds, a tone will be emitted from the controller.

7. At the time the tone is heard, the operator should mentally note the value of the resistance displayed on the UUT. Note: The operator may wish to practice this part of the procedure before recording the data.

8. Record the value of the observed resistance on the data sheet.

9. Steps 5 through 7 (inclusive) of this test will be repeated for resistance values of 100 Ω, 1.0 kΩ, 100 kΩ, and 10 MΩ.

10. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and transcribe the data from the printer to the data sheets provided.

Table 10.5.7 Response Time (Resistance Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Resistance 100 Ω	________	±0.0050	99.5	100.5	Ω
1.0 kΩ	________	±0.00005	0.996	1.004	kΩ
100 kΩ	________	±0.0050	99.6	100.4	kΩ
10 MΩ	________	±0.0050	9.89	10.11	MΩ

10.6 Frequency Counter

Specification:

Shall meet the specified performance herein across the full frequency range (see para. 10.6.1).

10.6.1 Range

Specification:

Shall be from 50 Hz to 450 Hz.

Equipment:

Manufacturer's manual for the UUT.

Procedure:

1. Read the manual(s) for the UUT and note whether the frequency counter range covers the limits specified.

2. Record the compliance (or lack of compliance) of this specification on the data sheet.

Table 10.6.1 Frequency Counter Range

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Frequency Range Min.	______	N/A		50	Hz
Frequency Range Max.	______	N/A	450		Hz

10.6 Frequency Counter

10.6.2 Accuracy

Specification:

In the temperature range of 18 degrees centigrade to 28 degrees centigrade, up to 90% relative humidity, shall be at least 0.1% or better.

Equipment:

Items	Model
AC Voltage Calibrator	Fluke 5200A or equivalent
Digital Frequency Counter	HP 5316A or equivalent
BNC Male to BNC Male Patch Cord 24 inches (61 cm), 2ea.	Pomona BNC-C-24 or equivalent

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:

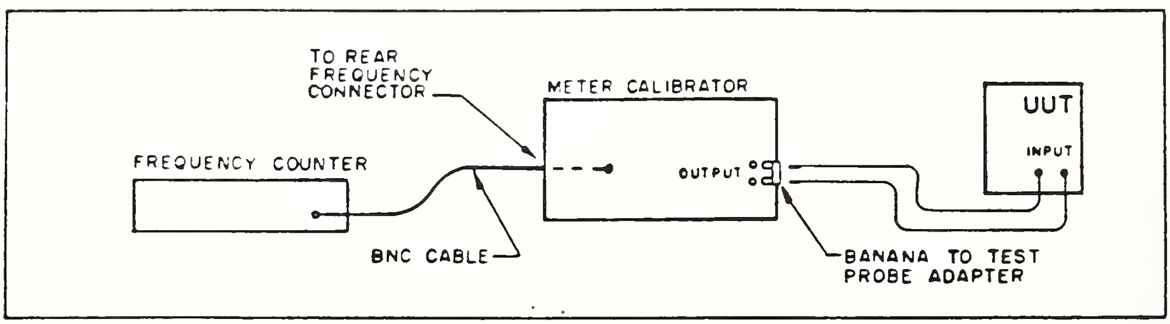

Fig. 10.6.2 Test setup for measuring frequency counter accuracy.

2. Set the UUT controls as follows:

Function:	FREQUENCY COUNTER
Range Mode:	AUTORANGE

3. Set the meter calibrator to provide 50 V ac (rms) at 50 Hz (nominal) to the UUT.

4. Read and record the frequency displayed on the digital frequency counter as Fc.

5. Read and record the frequency displayed on the UUT as Fu.

6. Calculate the percent error according to the formula,

$$\text{Percent Error} = \frac{Fc - Fu}{Fc} \cdot 100,$$

for each of the frequencies (50, 100, 200, and 450 Hz). Record this value on the data sheet.

7. Repeat steps 3 through 6 at frequencies of 100, 200, and 450 Hz.

8. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.6.2 Frequency Counter Accuracy

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
50 Hz Fc	____________				Hz
Fu	____________				Hz
Frequency Error - 20 Hz	____________	±0.01	-0.1	0.1	pct
100 Hz Fc	____________				Hz
Fu	____________				Hz
Frequency Error - 100 Hz	____________	±0.01	-0.1	0.1	pct
200 Hz Fc	____________				Hz
Fu	____________				Hz
Frequency Error - 200 Hz	____________	±0.01	-0.1	0.1	pct
450 Hz Fc	____________				Hz
Fu	____________				Hz
Frequency Error - 450 Hz	____________	±0.01	-0.1	0.1	pct

10.6 Frequency Counter

10.6.3 Voltage Range

Specification:

Shall be at least 50 V (rms) to 450 V (rms) the full frequency range of the equipment.

Equipment:

Items	Model
AC Voltage Calibrator	Fluke 5200A or equivalent
Digital Frequency Counter	HP 5316A or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

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: Connect the digital frequency counter to the rear-panel frequency output connector of the meter calibrator.

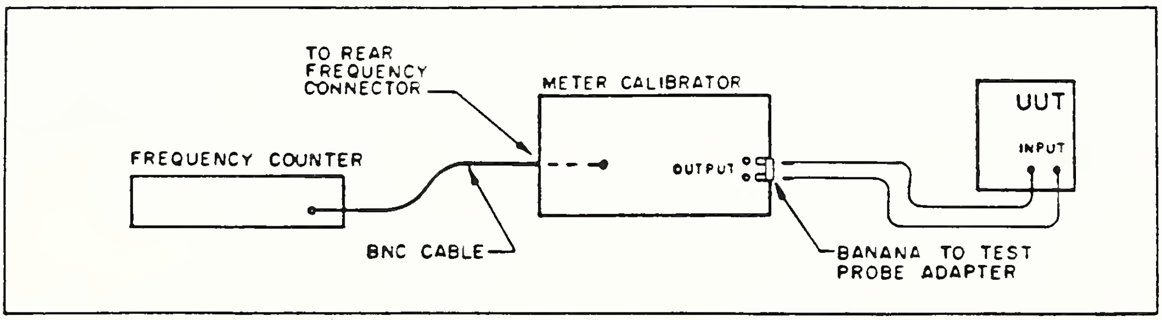

Fig. 10.6.3 Test setup for measuring frequency counter voltage range.

2. Set the UUT controls as follows:

   Function: FREQUENCY COUNTER
   Range Mode: AUTORANGE

3. Set the meter calibrator to provide 50 V ac (rms) at 50 Hz (nominal) to the UUT.

4. Read and record the frequency displayed on the digital frequency counter as Fc.

5. Read and record the frequency displayed on the UUT as Fu.

6. Calculate the percent error according to the formula

$$\text{Percent Error} = \frac{Fc - Fu}{Fc} \cdot 100,$$

for each of the input voltages of 100, 200, 300, and 450 V ac (rms). Record this value on the data sheet.

7. Repeat steps 3 through 6 at frequencies of 200 and 450 Hz.

8. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero.

Table 10.6.3a Frequency Counter Voltage Range - 50 Hz.

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
50 V Fc	______________				Hz
Fu	______________				Hz
Error at 50 V	______________	±0.01	-0.1	0.1	pct
100 V Fc	______________				Hz
Fu	______________				Hz
Error at 100 V	______________	±0.01	-0.1	0.1	pct
200 V Fc	______________				Hz
Fu	______________				Hz
Error at 200 V	______________	±0.01	-0.1	0.1	pct
300 V Fc	______________				Hz
Fu	______________				Hz
Error at 300 V	______________	±0.01	-0.1	0.1	pct
450 V Fc	______________				Hz
Fu	______________				Hz
Error at 450 V	______________	±0.01	-0.1	0.1	pct

Table 10.6.3b Frequency Counter Voltage Range - 200 Hz.

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
50 V Fc	____________				Hz
Fu	____________				Hz
Error at 50 V	____________	±0.01	-0.1	0.1	pct
100 V Fc	____________				Hz
Fu	____________				Hz
Error at 100 V	____________	±0.01	-0.1	0.1	pct
200 V Fc	____________				Hz
Fu	____________				Hz
Error at 200 V	____________	±0.01	-0.1	0.1	pct
300 V Fc	____________				Hz
Fu	____________				Hz
Error at 300 V	____________	±0.01	-0.1	0.1	pct
450 V Fc	____________				Hz
Fu	____________				Hz
Error at 450 V	____________	±0.01	-0.1	0.1	pct

Table 10.6.3c Frequency Counter Voltage Range - 450 Hz.

Measurement Description		Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
50 V	Fc	__________				Hz
	Fu	__________				Hz
Error at 50 V		__________	±0.01	-0.1	0.1	pct
100 V	Fc	__________				Hz
	Fu	__________				Hz
Error at 100 V		__________	±0.01	-0.1	0.1	pct
200 V	Fc	__________				Hz
	Fu	__________				Hz
Error at 200 V		__________	±0.01	-0.1	0.1	pct
300 V	Fc	__________				Hz
	Fu	__________				Hz
Error at 300 V		__________	±0.01	-0.1	0.1	pct
450 V	Fc	__________				Hz
	Fu	__________				Hz
Error at 450 V		__________	±0.01	-0.1	0.1	pct

10.6 Frequency Counter

10.6.4 Overload Protection

Specification:

Shall withstand at least an input voltage of 750 V (rms) or 1000 V dc.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Clock	General Electric 2908 or equivalent

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:

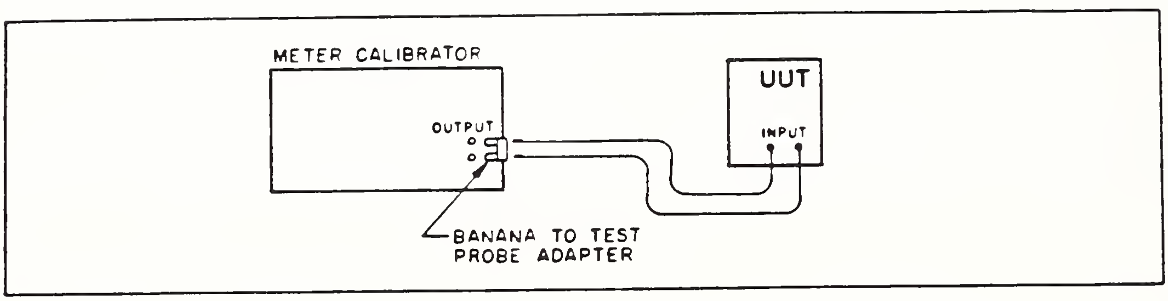

Fig. 10.6.4 Test setup for measuring overload protection.

2. Set the UUT controls as follows:

   Function: FREQUENCY
   Range Mode: AUTORANGE

3. Apply 750 V (rms), 50 Hz from the meter calibrator to the frequency input leads of the UUT. Note time on the clock.

4. After five minutes have elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage on the data sheet.

5. Apply 1000 V dc from the meter calibrator to the frequency input leads of the UUT. Note time on the clock.

6. After five minutes have elapsed, note any evidence of smoking, arcing, or charring of the UUT. Note the presence of any evidence of damage on the data sheet.

7. At the conclusion of this test, assure that the output of the meter calibrator is returned to zero.

Table 10.6.4 Overload Protection (Frequency Counter Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
750 V ac Voltage Stress	______________	N/A	No Damage		
1000V dc Voltage Stress	______________	N/A	No Damage		

10.6 Frequency Counter

10.6.5 Resolution

Specification:

Shall be at least 1 Hz.

Equipment:

Items	Model
AC Voltage Calibrator	Fluke 5200A or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Digital Frequency Counter	HP 5316A or equivalent

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. Connect the frequency counter input to the rear-panel frequency output connector of the meter calibrator.

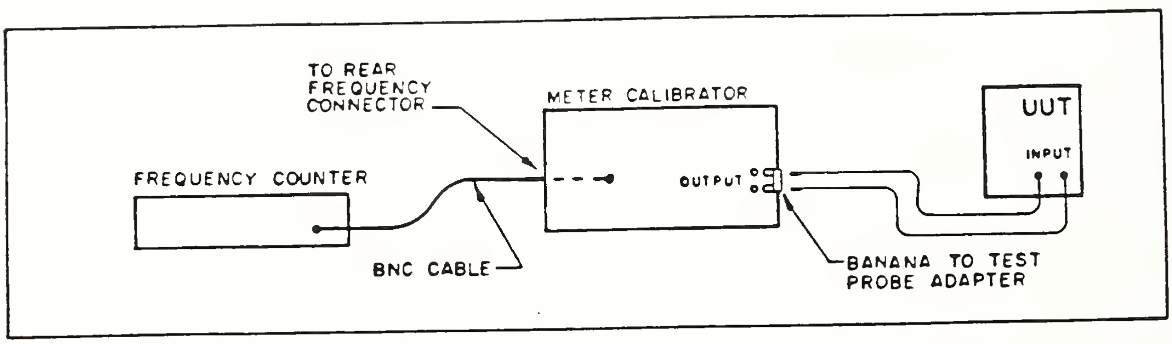

Fig. 10.6.5 Test setup for measuring frequency counter resolution.

2. Set the UUT controls as follows:

   Function: FREQUENCY COUNTER
   Range Mode: MANUAL RANGE (lowest range)

3. Set the meter calibrator to provide 50 V ac (rms) at 50 Hz (nominal) to the UUT.

4. Note the frequency displayed on the digital frequency counter.

5. Note the frequency displayed on the UUT.

6. Adjust the frequency of the meter calibrator so that the frequency indicated on the digital frequency counter increases by 1 Hz.

7. Record the change in frequency indicated on the UUT as the resolution on the lowest range.

8. Set the UUT controls as follows:

   Function: FREQUENCY COUNTER
   Range Mode: MANUAL RANGE (maximum range)

9. Set the meter calibrator to provide 50 V ac (rms) at 450 Hz (nominal) to the UUT.

10. Note the frequency displayed on the digital frequency counter.

11. Note the frequency displayed on the UUT.

12. Adjust the frequency of the meter calibrator such that the frequency indicated on the frequency counter increases by 1 Hz.

13. Record the change in frequency indicated on the UUT as the resolution on the highest range.

Table 10.6.5 Resolution (Frequency Counter Mode)

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
50 Hz on Dig. Freq. Ctr	________				Hz
Reading on UUT	________				Hz
Resolution on Lowest Range	________	±0.01		1	Hz
450 Hz on Dig. Freq. Ctr	________				Hz
Reading on UUT	________				Hz
Resolution on Highest Range	________	±0.01		1	Hz

10.7 Display

Specification:

The display shall be a liquid crystal, with at least 3½ digits, electronic digital display. It shall display voltage in units of volts and millivolts (rms), current in units of milliamps and amperes, resistance in units of ohms and kilohms, and frequency in units of kilohertz. The unit shall also have an analog bar graph display which has a 1 mV sensitivity on the lowest range.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Inspect the UUT to determine the presence of the following:

    1.1. A liquid-crystal type display,
    1.2. that the display can display at least 3 ½ digits, and
    1.3. that the display is an electronic digital type.

2. Record the compliance of these specifications on the data sheet provided.

3. Connect the meter calibrator to the UUT, as shown below, to determine the presence of readout annunciators:

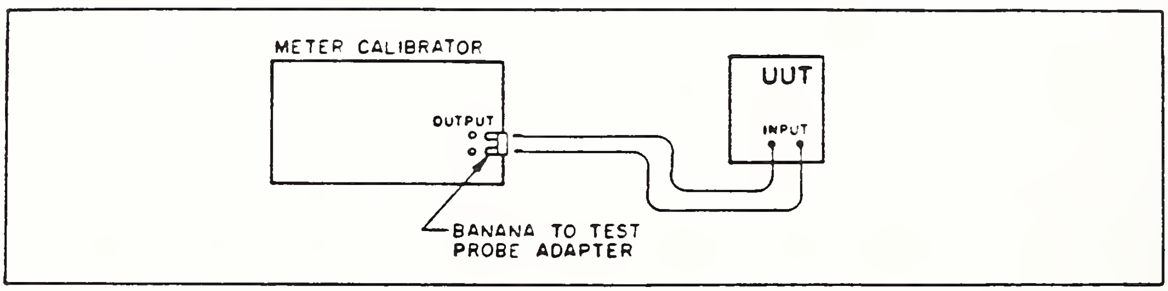

Fig. 10.8 Test setup for determining the presence of readout annunciators.

4. Using the meter calibrator, perform the following steps. The UUT passes the specification only if all the following steps are in compliance.

4.1. Set the UUT to measure dc voltage and apply 5 mV dc to the UUT and note the presence of a readout annunciator denoting millivolts.

4.2. Apply 5 V dc to the UUT and note the presence of a readout annunciator denoting volts.

4.3. Set the UUT to measure ac voltage and apply 5 mV ac (rms) at 1 kHz to the UUT and note the presence of a readout annunciator denoting millivolts rms.

4.4. Apply 5 V ac (rms) at 1 kHz to the UUT and note the presence of a readout annunciator denoting volts rms.

4.5. Set the UUT to measure dc current and apply 5 mA dc to the UUT and note the presence of a readout annunciator denoting milliamperes.

4.6. Apply 1 A dc to the UUT and note the presence of a readout annunciator denoting amperes.

4.7. Set the UUT to measure ac current and apply 5 mA ac (rms) at 1 kHz to the UUT and note the presence of a readout annunciator denoting milliamperes.

4.8. Apply 1 A ac (rms) at 1 kHz to the UUT and note the presence of a readout annunciator denoting amperes.

4.9. Set the UUT to measure resistance and apply a short circuit across the leads of the UUT and note the presence of a readout annunciator denoting ohms.

4.10. Apply 100 kΩ to the UUT and note the presence of a readout annunciator denoting kilohms.

4.11. Set the UUT to measure frequency and apply 1 V ac (rms) at 100 Hz to the UUT and note the presence of a readout annunciator denoting hertz.

4.12. Apply 1 V ac (rms) at 50 kHz to the UUT and note the presence of a readout annunciator denoting kilohertz,

5. Record the compliance of these specifications on the data sheet.

6. Set the UUT on the lowest dc voltage range in the manual ranging mode. Increase the voltage across the UUT from the meter calibrator using the EDIT knob. Note the presence of an analog bar graph. Count and record on the data sheet the maximum number of segments of the bar graph displayed.

7. Apply 1 mV dc to the UUT. Record the number of segments of the bar graph that are displayed.

Table 10.7 Display

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Liquid crystal 3½ digit disp.	________	N/A	Proper type		N/A
Proper display dc millivolts	________	N/A	Proper display		N/A
Proper display dc volts	________	N/A	Proper display		N/A
Proper display ac millivolts	________	N/A	Proper display		N/A
Proper display ac volts	________	N/A	Proper display		N/A
Proper display dc milliamps	________	N/A	Proper display		N/A
Proper display dc amperes	________	N/A	Proper display		N/A
Proper display ac milliamps	________	N/A	Proper display		N/A
Proper display ac amperes	________	N/A	Proper display		N/A
Proper display for ohms	________	N/A	Proper display		N/A
Proper display for kilohms	________	N/A	Proper display		N/A
Proper display for hertz	________	N/A	Proper display		N/A
Proper display for kilohertz	________	N/A	Proper display		N/A
Number of segments/bargraph	________	N/A			N/A
Segments disp. for 1 mV input	________	N/A		1	segment

10.8 Input Connector

Specification:

The input shall be a recessed banana male or female connector. There shall be an input terminal for volts, ohms measurement, and a separate terminal for current measurement and a common terminal; or an input terminal for volts, ohms, and low current measurement and a separate terminal for current measurements greater than 2 A if that capability is internal to the instrument.

Equipment:

None

Procedure:

1. Inspect the UUT to determine the presence of the following:

   1.1. Connectors are recessed.
   1.2. Connectors are banana, male-type or female-type.
   1.3. A connection exists for volts and ohms measurements.
   1.4. A separate connection exists for current measurements.
   1.5. There exists a common connection.

2. Record the compliance of this specification on the data sheet.

Table 10.8 Input Connector

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Connectors on the UUT comply with the specification.	____________	N/A	Yes		N/A

10.9 Ranging

Specification:

The equipment in all modes of operation except frequency shall have both autoranging and manual ranging capabilities. Measurement of frequency shall be autoranging. In measuring voltage, current, and resistance in autoranging mode, input shall uprange when the input is greater than full scale. Instrument shall downrange when the input is less than 10% of range.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

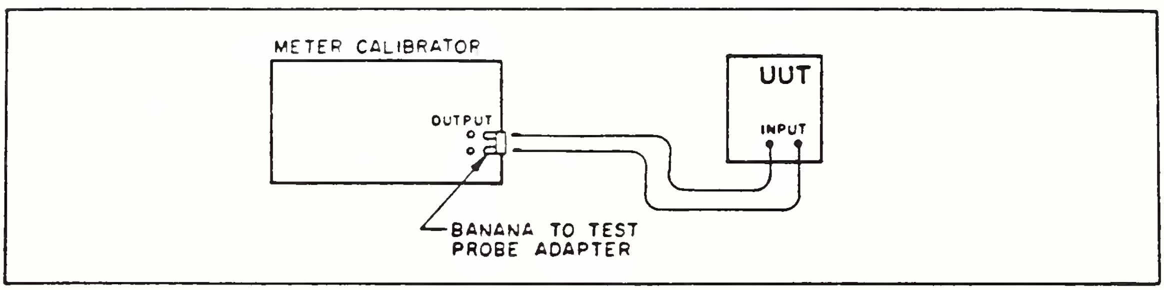

Fig. 10.9 Test setup for measuring ranging.

2. Set the UUT controls as follows:

   Function: DC VOLTAGE
   Range Mode: MANUAL RANGE
   Range: 2 V DC

   Apply a dc voltage of 1.5 V dc to the UUT. Increase the voltage, using the EDIT knob of the meter calibrator, until the voltage is greater than full scale. Assure that the scale of the UUT does not change. Set the voltage to zero. Again, assure that the UUT remains on the 2 V dc scale. Record the compliance of this specification on the data sheet.

3. Set the UUT controls as follows:

Function:	AC VOLTAGE
Range Mode:	MANUAL RANGE
Range:	2 V AC

Apply an ac voltage of 1.5 V ac (rms) at 1 kHz to the UUT. Increase the voltage, using the EDIT knob of the meter calibrator, until the voltage is greater than full scale. Assure that the scale of the UUT does not change. Set the voltage to zero. Again, assure that the UUT remains on the 2 V ac (rms) scale. Record the compliance of this specification on the data sheet.

4. Set the UUT controls as follows:

Function:	DC CURRENT
Range Mode:	MANUAL RANGE
Range:	2 mA DC

Apply a dc current of 1.5 mA dc to the UUT. Increase the current, using the EDIT knob of the meter calibrator, until the current is greater than full scale. Assure that the scale of the UUT does not change. Set the current to zero. Again, assure that the UUT remains on the 2 mA dc scale. Record the compliance of this specification on the data sheet.

5. Set the UUT controls as follows:

Function:	AC CURRENT
Range Mode:	MANUAL RANGE
Range:	2 mA AC

Apply an ac current of 1.5 mA ac (rms) at 1 kHz to the UUT. Increase the current, using the EDIT knob of the meter calibrator, until the current is greater than full scale. Assure that the scale of the UUT does not change. Set the current to zero. Again, assure that the UUT remains on the 2 mA ac (rms) scale. Record the compliance of this specification on the data sheet.

6. Set the UUT controls as follows:

Function:	RESISTANCE
Range Mode:	MANUAL RANGE
Range:	2 kΩ

Apply a resistance of 1000 Ω to the UUT. Change the resistance to 10000 Ω. Assure that the scale of the UUT does not change. Set the resistance to 10 Ω. Again, assure that the UUT remains on the 200 Ω scale. Record the compliance of this specification on the data sheet.

7. Set the UUT controls as follows:

Function: DC VOLTAGE
Range Mode: AUTO RANGE

Apply a dc voltage of 1.5 V dc to the UUT. Increase the voltage, using the EDIT knob of the meter calibrator, until the voltage is greater than full scale. Assure that the scale of the UUT changes. Decrease the voltage toward zero. Assure that the UUT ranges downward to a lower dc scale at 10 percent of current scale (approximately 0.2 V dc). Record the compliance of this specification on the data sheet.

8. Set the UUT controls as follows:

Function: AC VOLTAGE
Range Mode: AUTO RANGE

Apply an ac voltage of 1.5 V ac (rms) at 1 kHz to the UUT. Increase the voltage, using the EDIT knob of the meter calibrator, until the voltage is greater than full scale. Assure that the scale of the UUT changes. Decrease the voltage toward zero. Assure that the UUT ranges downward to a lower ac scale at 10 percent of current scale (approximately 0.2 V ac). Record the compliance of this specification on the data sheet.

9. Set the UUT controls as follows:

Function: DC CURRENT
Range Mode: AUTO RANGE

Apply a dc current of 1.5 mA dc to the UUT. Increase the current, using the EDIT knob of the meter calibrator, until the current is greater than full scale. Assure that the scale of the UUT changes. Decrease the current toward zero. Assure that the UUT ranges downward to a lower dc scale at 10 percent of current scale (approximately 0.2 mA dc). Record the compliance of this specification on the data sheet.

10. Set the UUT controls as follows:

Function: AC CURRENT
Range Mode: AUTO RANGE

Apply an ac current of 1.5 mA ac (rms) at 1 kHz to the UUT. Increase the current, using the EDIT knob of the meter calibrator, until the current is greater than full scale. Assure that the scale of the UUT changes. Decrease the current toward zero. Assure that the UUT ranges downward to a lower scale at 10 percent of current scale (approximately 0.2 mA ac). Record the compliance of this specification on the data sheet.

11. Set the UUT controls as follows:

Function: RESISTANCE
Range Mode: AUTO RANGE

Apply a resistance of 1000 Ω to the UUT. Change the resistance to

10000 Ω. Assure that the scale of the UUT changes. Set the resistance to 10 Ω. Assure that the UUT changes scale. Record the compliance of this specification on the data sheet.

12. Set the UUT controls as follows:

Function:	FREQUENCY
Range Mode:	AUTO RANGE

Apply an ac voltage of 1 V ac (rms) at a frequency of 1 kHz to the UUT. Change the frequency to 10 kHz. Assure that the scale of the UUT changes. Change the frequency to 100 Hz. Assure that the scale of the UUT changes. Record the compliance of this specification on the data sheet.

Table 10.9 Ranging

Description	Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
No ranging on dc voltage	______________	N/A	Yes		N/A
No ranging on ac voltage	______________	N/A	Yes		N/A
No ranging on dc current	______________	N/A	Yes		N/A
No ranging on ac current	______________	N/A	Yes		N/A
No ranging on ohms function	______________	N/A	Yes		N/A
Ranging on dc voltage	______________	N/A	Yes		N/A
Ranging on ac voltage	______________	N/A	Yes		N/A
Ranging on dc current	______________	N/A	Yes		N/A
Ranging on ac current	______________	N/A	Yes		N/A
Ranging on ohms	______________	N/A	Yes		N/A
Ranging on frequency	______________	N/A	Yes		N/A

10.12 Accessories

10.12.1 10 AMP Current Shunt

Specification:

A separate current shunt capable of extending the equipment's upper current limit to 10 A (ac or dc) across the full frequency range for ac (see para 10.2.2) shall be supplied with each instrument.

10.12.1.1 Sensitivity. 10 mV/A

10.12.1.2 Accuracy. ±0.5% (does not include meter accuracy)

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Transconductance Amplifier	Fluke 5220A or equivalent
Precision Digital Multimeter	Fluke 8506A or equivalent
Calibrated Current Shunt, 0.1 Ω to be supplied with correction factors.	Fluke 80J-10 or equivalent
Patch Cord, Stack-up Banana Plugs Both Ends, 5 ea.	Pomona B-12 or equivalent
BNC Male to BNC Male Patch Cord 24 inches (61 cm)	Pomona BNC-C-24 or equivalent
BNC female to Banana Plug Adapter, 2 ea.	Pomona 1452 or equivalent

Procedure:

1. Connect the equipment as shown below:

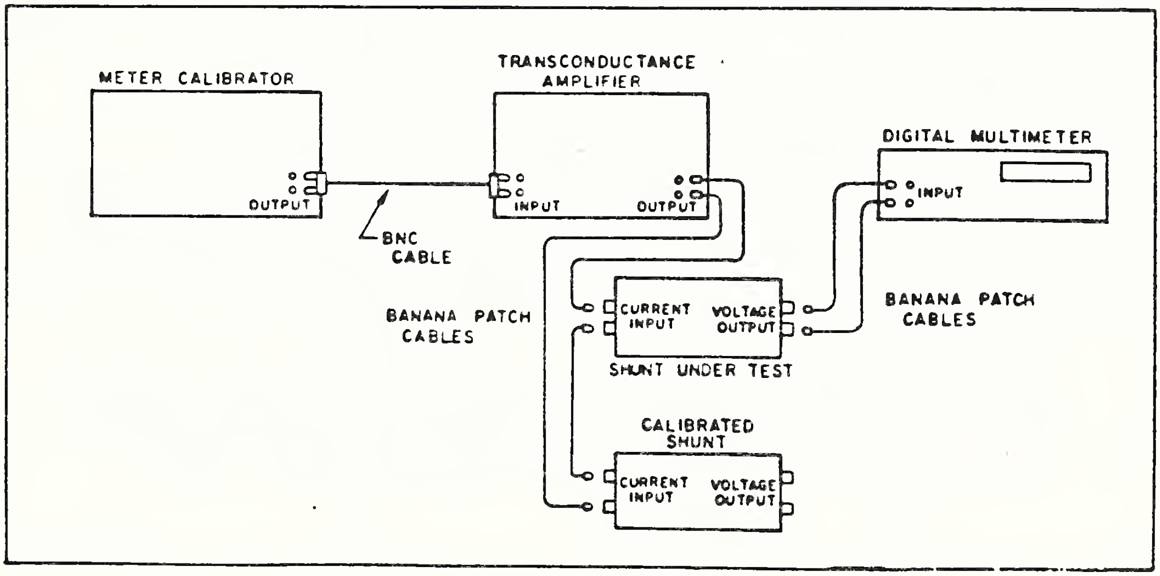

Fig. 10.12.1a Test setup for measuring current shunt accuracy

2. Set the controls of the precision digital multimeter as follows:
   Function: AC VOLTAGE
   Range Mode: AUTORANGE

3. Apply an ac voltage of 10 V ac (rms) at a frequency of 20 kHz to the input of the transconductance amplifier. The output of the amplifier should be nominally 10 A ac (rms) at 20 kHz.

4. Note voltage displayed on the precision digital multimeter as Vs.

5. Change the voltage sensing leads to connect the output of the calibrated current shunt to the precision digital multimeter as shown below:

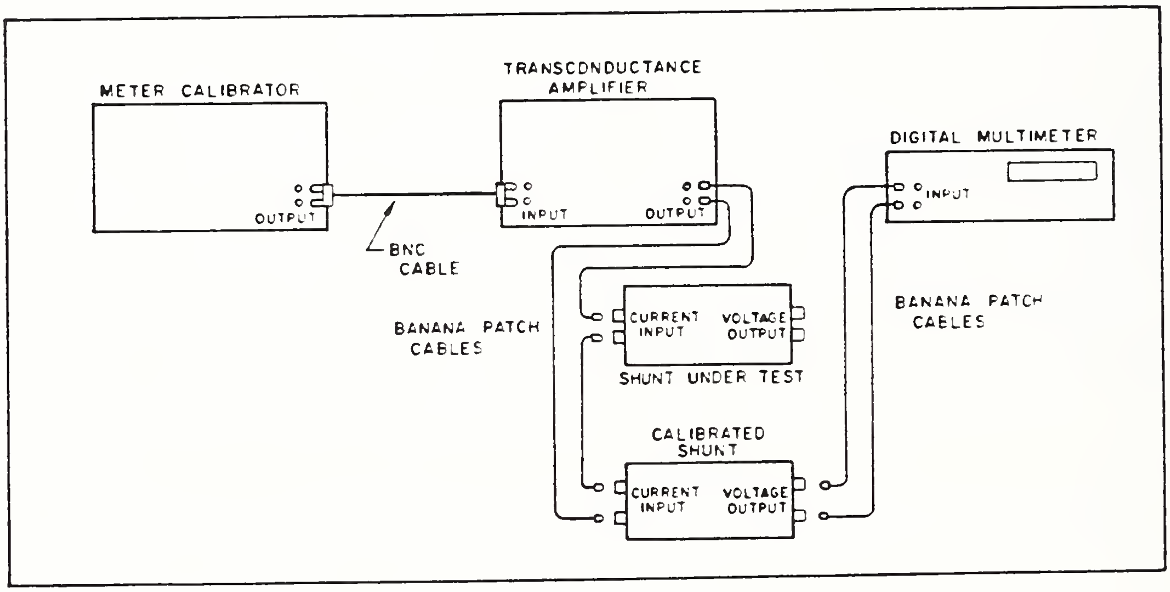

Fig. 10.12.1b Test setup for measuring current shunt accuracy.

6. Note voltage displayed on the precision digital multimeter as Vc.

7. Calculate and record the sensitivity of the shunt using the following formula:

$$\text{AC Sensitivity} = (10\ \text{mV/A}) \cdot \frac{\text{Vs} \cdot (\text{AC Shunt Corrections})}{\text{Vc}}.$$

Note: The AC Shunt Corrections are given in terms of a multiplicative factor which correct for the systematic errors of the shunt at 20 kHz compared to an ideal 0.01 Ω resistor. The AC Shunt Corrections must be provided with the shunt used in this test.

8. Calculate the ac accuracy of the shunt using the following formula:

$$\text{AC Accuracy} = \frac{(Vs) - (Vc \ / \ \text{AC Shunt Corrections})}{(Vc \ / \ \text{AC Shunt Corrections})} \ .$$

9. Set the controls of the precision digital multimeter as follows:

Function: DC VOLTAGE
Range Mode: AUTORANGE

10. Apply a dc voltage of 10 V to the input of the transconductance amplifier. The output of the amplifier should nominally be 10 A dc.

11. Record the voltage displayed on the precision digital multimeter as Vc.

12. Change the voltage sensing leads to connect the output of the shunt under test to the precision digital multimeter as shown in figure 10.12.1a.

13. Record the voltage displayed on the precision digital multimeter as Vs.

14. Calculate the dc sensitivity of the shunt using the following formula:

$$\text{DC Sensitivity} = (10 \ \text{mV/A}) \cdot \frac{Vs \cdot (\text{DC Shunt Corrections})}{Vc} \ .$$

Note: The DC Shunt Corrections are given in terms of a multiplicative factor which correct for the systematic errors of the shunt at dc compared to an ideal 0.01 Ω resistor.

15. Calculate the dc accuracy of the shunt using the following formula:

$$\text{DC Accuracy} = \frac{(Vs) - (Vc \ / \ \text{DC Shunt Corrections})}{(Vc \ / \ \text{DC Shunt Corrections})} \ .$$

16. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and that the transconductance amplifier is in the standby state before removing connections to the shunts.

Table 10.12.1 10 Amp Current Shunt

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
AC Sensi-tivity	______	±0.12	10 mV/A	nominal	mV/A
AC Accuracy	______	±0.01	-0.5	+0.5	pct
DC Sensi-tivity	______	±0.12	10 mV/A	nominal	mV/A
DC Accuracy	______	±0.01	-0.5	+0.5	pct

10.12 Accessories

10.12.2 High Voltage Probe

<u>Specification</u>:

A separate high voltage probe capable of extending the equipment upper voltage (ac and dc) across the frequency range of 20 Hz-1 kHz to at least a minimum of 5000 V shall be supplied with each equipment.

10.12.2.1 AC and DC Accuracy: (Does not includes meter (UUT) accuracy) ≤ 5%.

[Note: Exception is taken to the specification "does not include meter (UUT) accuracy." Usually, the statement of accuracy states that a high-voltage probe is specified to operate with a given UUT. Alternatively, the input impedance of the UUT must be given in order to test the accuracy of the high-voltage probe independently of the UUT. The specification limits on the data sheets for this test procedure are computed by adding the accuracy of the high-voltage probe (5%) to the voltage accuracy of the UUT on the respective ac or dc ranges. Also note that the frequency response of the high-voltage probe is determined at 1100 V ac (rms) rather than 5000 V. This limitation is imposed by the maximum voltage capability of the meter calibrator.]

<u>Equipment</u>:

Items	Model
DC Meter Calibrator	Fluke 5101B or equivalent
AC Meter Calibrator	Fluke 5200A or equivalent
Power Amplifier	Fluke 5205A or equivalent
Binding Post to Binding Post Adapter	See Appendix D, Item 4

<u>Procedure</u>:

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:

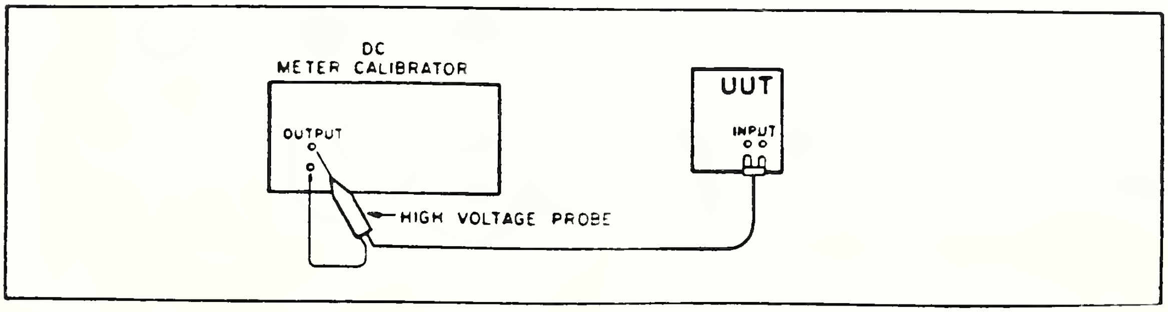

Figure 10.12.2a Test setup for measuring dc voltage accuracy of high-voltage probe.

2. Apply 500 V dc from the dc meter calibrator to the high-voltage probe.

3. Note the voltage indicated on the UUT display.

4. Calculate and record on the data sheet the percentage error according to the formula:

$$\text{Error} = \frac{\text{Displayed Voltage Reading} - \text{Applied Voltage}}{\text{Applied Voltage}} \cdot 100.$$

5. Repeat steps 2 through 4 for applied voltages of 750 and 1100 V dc.

6. Reconnect the equipment as shown below:

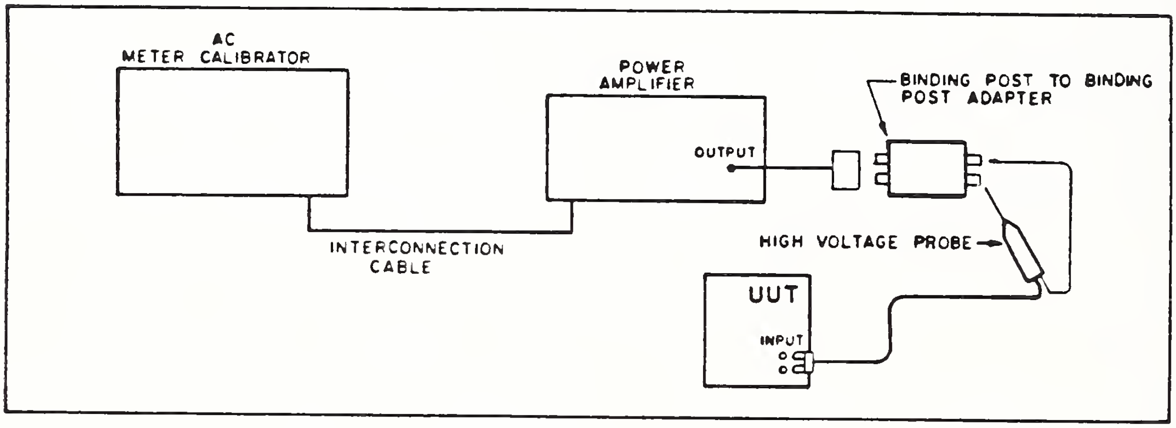

Fig. 10.12.2b Test setup for measuring ac voltage accuracy of high-voltage probe.

7. Apply 500 V ac (rms) at a frequency of 20 Hz from the ac meter calibrator to the high-voltage probe.

8. Note the voltage indicated on the UUT display.

9. Calculate and record on the data sheet the percentage error according to the formula:

$$\text{Error} = \frac{\text{Displayed Voltage Reading} - \text{Applied Voltage}}{\text{Applied Voltage}} \cdot 100 .$$

10. Repeat steps 7 through 9 for applied voltages of 750 and 1100 V ac.

11. Repeat steps 7 through 10 for applied frequency of 1 kHz.

Table 10.12.2 High-Voltage Probe Accuracy

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Voltage 500 V	________	±0.01	-5.2	+5.2	pct
750 V	________	±0.01	-5.2	+5.2	pct
1100 V	________	±0.01	-5.2	+5.2	pct
20 Hz 500 V	________	±0.01	-6.8	+6.8	pct
750 V	________	±0.01	-6.8	+6.8	pct
1100 V	________	±0.01	-6.8	+6.8	pct
1 kHz 500 V	________	±0.01	-5.7	+5.7	pct
750 V	________	±0.01	-5.7	+5.7	pct
1100 V	________	±0.01	-5.7	+5.7	pct

10.12 Accessories

10.12.3 Clamp-on AC Adapter Accuracy

Specification:

The equipment shall be capable of being used with an external clamp-on ac current adapter which will extend the ac current measuring capability of equipment to 300 A (across the full frequency range, see para 10.13.3.3). This accessory must be available if requested by the procuring activity.

10.12.3.1 Current Range. 2 A to 300 A.
10.12.3.2 Accuracy. (Does not include meter (UUT) accuracy.) ± 5%
10.12.3.3 Frequency Range. 45 Hz-450 Hz.
10.12.3.4 Insulation. 5 kV

[Note: Exception is taken to the specification "does not include meter (UUT) accuracy." Usually, the statement of accuracy states that a clamp-on current adapter is specified to operate with a given UUT. Alternatively, the burden impedance of the (UUT) must be given to test the accuracy of the clamp on current adapter independently of the UUT. The specification limits on the data sheets for this test procedure are computed by adding the accuracy of the clamp-on current adapter (5%) to the current accuracy of the UUT on the respective ac or dc ranges.

The insulation requirements of the clamp-on current adapter is not covered in this section.]

Equipment:

Items	Model
Meter Calibrator	Fluke 5200A or equivalent
Transconductance Amplifier	Fluke 5220A or equivalent
Precision Digital Multimeter	Fluke 8506A or equivalent
Calibrated Current Shunt, 0.1 Ω	Fluke 80J-10 or equivalent
Patch Cord, Stack-up Banana Plugs Both Ends, 5 ea.	Pomona B-12 or equivalent
BNC Male to BNC Male Patch Cord 24 inches (61 cm)	Pomona BNC-C-24 or equivalent
BNC female to Banana Plug Adapter, 2 ea.	Pomona 1269 or equivalent
Current Loop, Single Turn	See Appendix D, Item 8
Current Loop, 30 Turns	See Appendix D, Item 9
Binding Post to Binding Post Adapter	See Appendix D, Item 4

Procedure:

1. Connect the equipment as shown below:

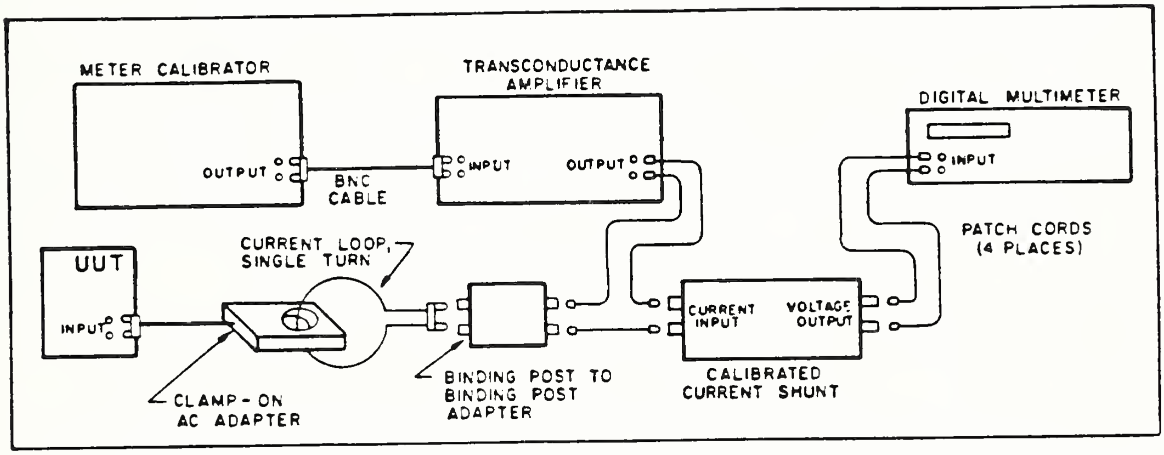

Fig. 10.12.3 Test setup for measuring clamp-on ac adapter accuracy.

2. Set the controls of the precision digital multimeter as follows:

   Function: AC VOLTAGE
   Range Mode: AUTORANGE

3. Set the meter calibrator to apply an ac voltage of 2 V ac (rms) at a frequency of 45 Hz to the input of the transconductance amplifier. The output of the amplifier should be nominally 2 A ac (rms) at 45 Hz.

4. Note the voltage displayed on the precision digital multimeter as Vs.

5. Note the current displayed on the UUT as sensed by the clamp-on ac adapter as It.

6. Calculate and record on the data sheet the percentage error of the clamp-on ac adapter as follows:

$$\text{Error} = \frac{It - (Vs / 0.01)}{(Vs / 0.01)} \cdot 100$$

7. Change the output frequency of the meter calibrator to 450 Hz and repeat steps 3 through 6 above.

8. Remove the one-turn current loop and replace it with the 30-turn current loop.

9. Set the meter calibrator to apply an ac voltage of 10 V ac (rms) at a frequency of 45 Hz to the input of the transconductance amplifier. The output of the amplifier should be nominally 10 A ac (rms) at 45 Hz.

10. Note the voltage displayed on the precision digital multimeter as Vs.

11. Note the current displayed on the UUT as sensed by the clamp-on ac adapter as It.

12. Calculate and record on the data sheet the percentage error of the clamp-on ac adapter as follows:

$$\text{Error} = \frac{It - (30 \cdot Vs / 0.01)}{(30 \cdot Vs / 0.01)} \cdot 100$$

13. Change the frequency to 450 Hz and repeat steps 3 through 6 above.

14. At the conclusion of the test, assure that the output of the meter calibrator is returned to zero and that the transconductance amplifier is in the standby state before removing connections to the shunts.

Table 10.12.3 Clamp-on AC Adapter Accuracy

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
45 Hz 2 A	________	±0.20	- 5.0	+ 5.0	pct
450 Hz 2 A	________	±0.20	- 5.0	+ 5.0	pct
45 Hz 300 A	________	±0.20	- 5.0	+ 5.0	pct
450 Hz 300 A	________	±0.20	- 5.0	+ 5.0	pct

10.12 Accessories

10.12.4 Temperature Probe

Specification:

A separate temperature probe accessory must be available as an option to use with the hand-held digital multimeter (UUT). The measurement of temperatures may also be internal to the instrument. The following specs apply.

10.12.4.1 Temperature Range. -50° C to 150° C, (-58° F to 302° F).

10.12.4.2 Sensitivity. 1 mv per °C or °F.

10.12.4.3 Accuracy. (+15° C to +35° C ambient temperature operation; includes ±0.1% + 1 count UUT accuracy). ±2° C in the range of 0° C to 100° C, derated linearly to ±4° C at -50° C and +150° C. Above +35° C and below +15° C ambient temperature, add 1° C to accuracies stated above.

10.12.4.4 Settling Time. 8 s maximum to settle within 2° C after a 50° C step change at sensor tip.

[It is assumed in the following procedure that the sensitivity of the temperature probe is 1 mV/°C. If the sensitivity of the temperature probe is 1 mV/°F, convert all temperatures in °F to °C by the formula

$$°C = (5/9) \cdot (°F - 32).]$$

Equipment:

Items	Model
Precision Digital Multimeter	Fluke 8506A or equivalent
Thermometer, Immersion, -20° C to +150° C, 76 mm scale length, ±0.5° C accuracy	S-W Type 12C or equivalent
Thermometer Reading Lens	Parr Model 3003 or equivalent
Hot Plate	Corning Model PC-35 or equivalent
Beaker, 800 mL	Corning, Pyrex, Model 1000 or equivalent.
Clock	General Electric 2908 or equivalent
Manufacturer's manual for temperature probe	

Procedure:

1. Set up the equipment as shown below:

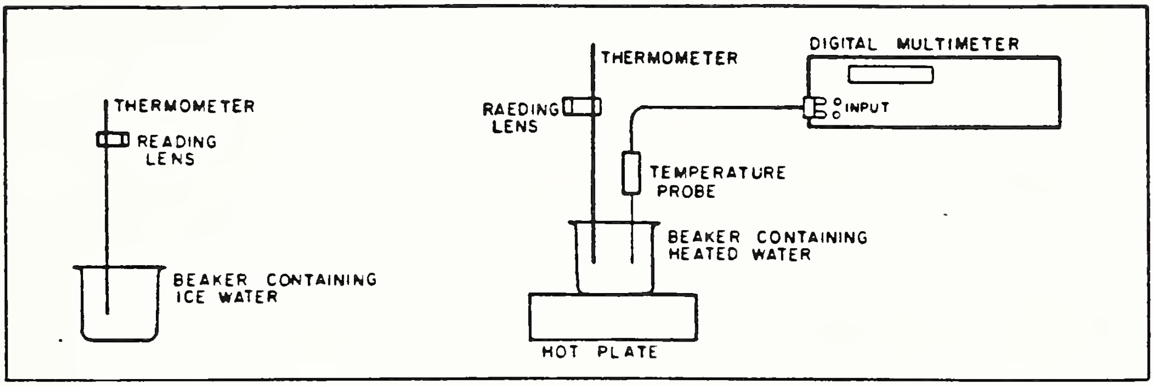

Fig. 10.12.4 Test setup for measuring temperature probe accuracy.

2. Fill one beaker with approximately 600 mL of cold tap water. Assure that the temperature of the tap water is less than 20° C. Place this beaker on the hot plate. Fill the second beaker with approximately 400 grams of crushed ice and 200 mL of water. Place this beaker beside the hot plate. Into each beaker insert a thermometer. Place the reading lens on each thermometer.

3. Set the controls of the precision digital multimeter as follows:

   Function: DC VOLTAGE
   Range Mode: AUTORANGE

4. Set the control of the hot plate to the LOW position.

5. If the temperature probe has a switch-selectable sensitivity, set the temperature probe to provide a 1 mV/°C sensitivity (as opposed to a 1 mV/°F sensitivity).

6. Use the thermometer to stir the water in the beaker on the hot plate. Starting at 20° C and at intervals of 10° C thereafter, note the temperature indicated by the thermometer and the voltage indicated by the precision digital multimeter. (This procedure may require two people, one watching the thermometer, the second watching the precision digital multimeter and recording the data. The rate of temperature rise of the water bath should not exceed 2° C per minute to provide an adequate isothermal environment for this test and to allow sufficient time for the operators to observe the temperature measurements.)

7. Convert the millivoltage indicated by the precision digital multimeter to temperature (in °C) by multiplying by 1 °C/mV.

8. Calculate the temperature difference between the thermometer and the temperature probe by subtracting the temperature indicated on the thermometer from the temperature calculated in step 7.

9. Continue recording the temperatures until the water boils at approximately 100° C by repeating steps 6 through 8, above.

10. Discard the boiling water and refill the beaker with room-temperature water.

11. Use the thermometer to stir the water in the beaker on the hot plate. At a temperature of 50° C as indicated by the thermometer, note the millivoltage indicated by the precision digital multimeter. (This procedure may require two people, one watching the thermometer, the second watching the precision digital multimeter and recording the data.)

12. Remove the temperature probe from the beaker on the hot plate and plunge the probe into the ice water.

13. After eight seconds as determined by the clock, note the millivoltage indicated by the precision digital multimeter. Convert the millivoltage to temperature (in °C) by multiplying by 1 °C/mV. Record this value on the data sheet.

14. After an additional 30 seconds as determined by the clock, again note the millivoltage indicated by the precision digital multimeter. Convert the millivoltage to temperature (in °C) by multiplying by 1 °C/mV. Record this value on the data sheet.

15. Subtract the temperature obtained in step 13 from that obtained in step 14 and record the difference on the data sheet.

16. Read the manual(s) for the temperature probe and note whether the temperature range covers the limits specified.

17. Record the compliance (or lack of compliance) of this specification on the data sheet.

18. From the data obtained in steps 6 through 9, calculate and record the sensitivity of the temperature probe by calculating the change in output millivoltage for a 80° C temperature change (20° C to 100° C) according to the following formula:

$$\text{Sensitivity} = \frac{(\text{mV at } 100°\text{ C}) - (\text{mV at } 20°\text{ C})}{80°\text{ C}} .$$

19. Turn off and disconnect the hot plate, discard the water in beakers, and replace the thermometers in the containers.

Table 10.12.4 Temperature Probe Accuracy

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
20° C	___________	±0.5	- 2.0	+ 2.0	°C
30° C	___________	±0.5	- 2.0	+ 2.0	°C
40° C	___________	±0.5	- 2.0	+ 2.0	°C
50° C	___________	±0.5	- 2.0	+ 2.0	°C
60° C	___________	±0.5	- 2.0	+ 2.0	°C
70° C	___________	±0.5	- 2.0	+ 2.0	°C
80° C	___________	±0.5	- 2.0	+ 2.0	°C
90° C	___________	±0.5	- 2.0	+ 2.0	°C
100° C	___________	±0.5	- 2.0	+ 2.0	°C
Temperature after 8 sec.	___________				°C
Temperature after 30 sec.	___________				°C
Settling Temp Difference	___________		+ 0.0	+ 2.0	°C
Temperature Range Min.	___________	N/A		-50	°C
Temperature Range Max.	___________	N/A	+150		°C
Sensitivity	___________	0.2	Nominally 10.		mV/°C

10.12 Accessories

10.12.5 DC Clip-on Milliammeter

Specification:

An accessory shall be provided, on request, that shall measure in conjunction with the multimeter dc current without interruption to the circuit under test. The following specifications apply.

10.12.5.1 Current Range. 1 mA - 10 A.
10.12.5.2 Probe Inductance. Less than 0.5 μH.
10.12.5.3 Probe Induced Voltages. Less than 15 mV peak.
10.12.5.4 Accuracy. Shall be at least ±3% of input + 0.1 mA or better.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Transconductance Amplifier	Fluke 5220A or equivalent
BNC Male to BNC Male Patch Cord 24 inches (61 cm)	Pomona BNC-C-24 or equivalent
BNC female to Banana Plug Adapter, 2 ea.	Pomona 1269 or equivalent
Digital LCR Meter	HP 4262 or equivalent
Oscilloscope	Tektronix 465 or equivalent
Current Loop, Single Turn	See Appendix D, Item 8
BNC Male to Binding Post Adapter	Pomoma 1296 or equivalent

Procedure:

1. Connect the equipment as shown below:

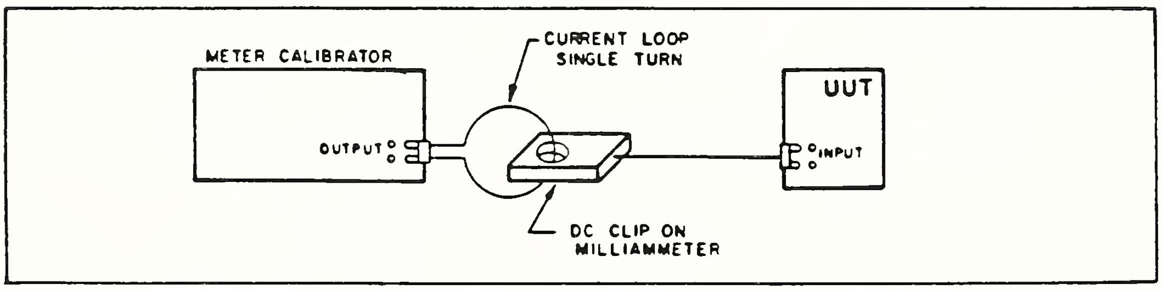

Fig. 10.12.5a Test setup for measuring dc clip on milliammeter current accuracy for currents of 1.8 A and less.

2. Apply a current from the meter calibrator through the single-turn current loop of 1.0 mA.

3. Read and record the current displayed on the UUT.

4. Repeat steps 2 and 3 for the following sequence of applied dc current:

1.8	mA
5.0	mA
10.0	mA
18.0	mA
50.0	mA
100.0	mA
180.0	mA
500.0	mA
1.0	A
1.8	A

5. Remove the single-turn current loop from the meter calibrator and replace the single-turn current loop through the dc clip-on milliammeter such that the current direction is reversed. (Turn the single-turn current loop over 180° and re-insert it in the connectors or reverse the leads to the meter calibrator.)

6. Repeat steps 2 through 4, above.

7. Connect the equipment as shown below:

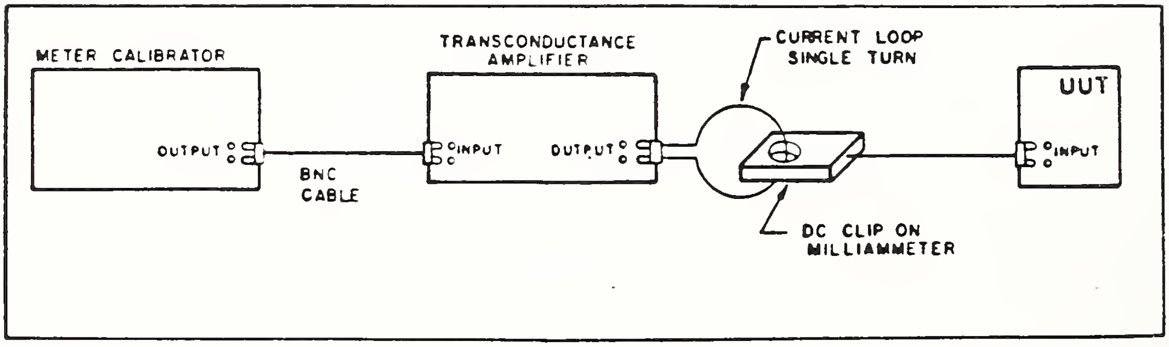

Fig. 10.12.5b Test setup for measuring dc clip on milliammeter current accuracy for currents greater than 1.8 A.

8. Apply a voltage from the meter calibrator to the input of the transconductance amplifier of 5 V dc. The transconductance amplifier will generate a current of 5 A.

9. Read and record the current displayed on the UUT.

10. Repeat steps 8 and 9 for an applied voltage of 10 V dc. The transconductance amplifier will generate a current of 10 A.

11. Remove the current loop from the transconductance amplifier and replace the loop such that the current direction is reversed. (Turn the loop over 180° and re-insert it in the connectors.)

12. Repeat steps 8 through 10, above.

13. Connect the equipment as shown below:

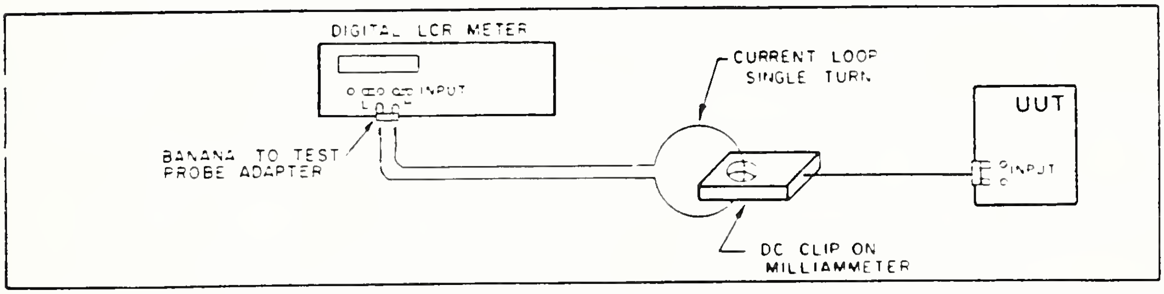

Figure 10.12.5c Test setup for measuring dc clip-on milliammeter probe inductance.

14. Remove the clip-on milliammeter from the current loop and connect the current loop to the input terminals of the digital LCR meter as shown in the figure below.

15. To set up the digital LCR meter for the measurement of inductance in the autorange mode at a frequency of 10 kHz, push the following sequence of front-panel controls:

Power:	ON	Test Signal:	10 kHz
Function:	L	Trigger:	INT
LCR Range:	AUTO		
Loss:	Q		

16. Adjust the ZERO ADJ to obtain a reading of 00.00 μH on the display of the digital LCR meter.

17. Replace the clip-on milliammeter on the current loop. Read and record the inductance.

18. Remove the clip-on milliammeter from the current loop. Remove the current loop from the digital LCR meter.

19. Connect the equipment as shown below:

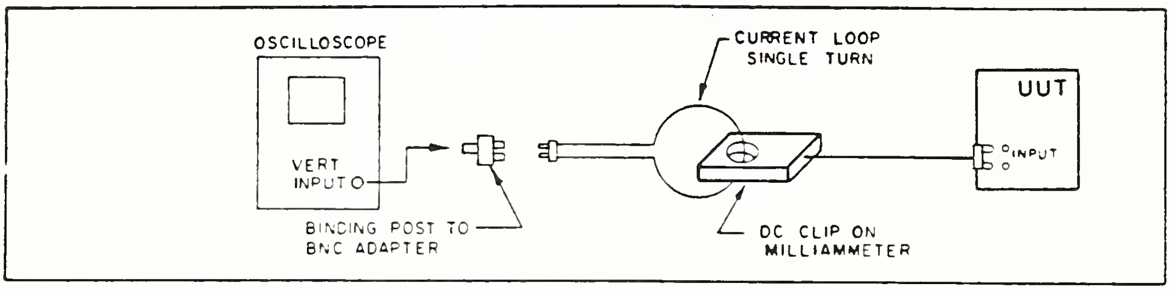

Figure 10.12.5c Test setup for measuring dc clip-on milliammeter probe induced voltages.

20. Place the current loop on the CH 1 vertical input connector. Adjust the oscilloscope to obtain a free-running, focussed trace.

21. Adjust the front panel controls of the oscilloscope as follows:

Vertical Controls		Horizontal Controls	
CH 1 Volts/Div.:	5 mV	Time/Div:	0.1 ms
Vert. Mode:	CH 1	Trig Mode:	AUTO
Coupling:	AC	Coupling:	AC
		Source:	CH 1

22. Replace the clip-on milliammeter on the current loop. Read and record the peak-to-peak signal displayed on the oscilloscope.

Table 10.12.5a DC Clip-on Milliammeter Accuracy - Positive

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current 1.0 mA	________	±0.000310	0.870	1.130	mA
1.8 mA	________	±0.000510	1.646	1.954	mA
5.0 mA	________	±0.00176	4.75	5.25	mA
10 mA	________	±0.00301	9.60	10.40	mA
18 mA	________	±0.00501	17.36	18.64	mA
50 mA	________	±0.0175	48.40	51.60	mA
100 mA	________	±0.030	96.90	103.1	mA
180 mA	________	±0.050	174.5	185.5	mA
500 mA	________	±0.175	485	515	mA
1.0 A	________	±0.0003	0.970	1.030	A
1.8 A	________	±0.0005	1.746	1.854	A
5.0 A	________	±0.0175	4.85	5.15	A
10.0 A	________	±0.030	9.67	10.30	A

Table 10.12.5b DC Clip-on Milliammeter Accuracy - Negative

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
DC Current -1.0 mA	______	±0.000310	-0.870	-1.130	mA
-1.8 mA	______	±0.000510	-1.646	-1.954	mA
-5.0 mA	______	±0.00176	-4.75	-5.25	mA
-10 mA	______	±0.00301	-9.60	-10.40	mA
-18 mA	______	±0.00501	-17.36	-18.64	mA
-50 mA	______	±0.0175	-48.40	-51.60	mA
-100 mA	______	±0.030	-96.90	-103.1	mA
-180 mA	______	±0.050	-174.5	-185.5	mA
-500 mA	______	±0.175	-485	-515	mA
-1.0 A	______	±0.0003	-0.970	-1.030	A
-1.8 A	______	±0.0005	-1.746	-1.854	A
-5.0 A	______	±0.0175	-4.85	-5.15	A
-10.0 A	______	±0.030	-9.67	-10.30	A

Table 10.12.5c DC Clip-on Current Probe Inductance and Induced Voltages

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Inductance	______	±0.03		0.5	μH
Probe Induced Voltage	______	±1.5 (est)		15	mV p-p

10.13 Zero Reference

Specification:

The hand-held digital multimeter (UUT) shall have the capability to set a zero reference on any measurement made by the multimeter.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Prod Adapter	See Appendix D, Item 3

Procedure:

1. Connect the equipment as shown below:

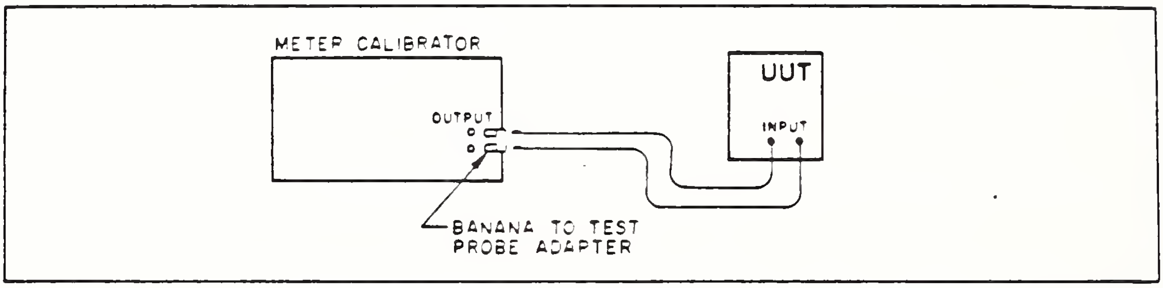

Fig. 10.13 Test setup for zero reference.

2. Set the UUT controls as follows:

   Function: DC VOLTAGE
   Range Mode: MANUAL RANGE
   Range: 2 V DC

   Using the meter calibrator, apply a dc voltage of 1.5 V dc to the UUT. Set the UUT to zero reference mode. Assure that the UUT displays the value of zero. Increase the voltage of the meter calibrator, using the EDIT knob, until the voltage is 1.8 V dc. Assure that the UUT now displays approximately 0.3 V dc. Record the compliance of this specification on the data sheet provided.

3. Set the UUT controls as follows:

Function:	AC VOLTAGE
Range Mode:	MANUAL RANGE
Range:	2 V AC

Using the meter calibrator, apply an ac voltage of 1.5 V (rms) at a frequency of 1 kHz to the UUT. Set the UUT to zero reference mode. Assure that the UUT displays the value of zero. Increase the voltage of the meter calibrator, using the EDIT knob, until the voltage is 1.8 V ac. Assure that the UUT now displays approximately 0.3 V ac. Record the compliance of this specification on the data sheet.

4. Set the UUT controls as follows:

Function:	DC CURRENT
Range Mode:	MANUAL RANGE
Range:	2 mA DC

Using the meter calibrator, apply a dc current of 1.5 mA dc to the UUT. Set the UUT to zero reference mode. Assure that the UUT displays the value of zero. Increase the current of the meter calibrator, using the EDIT knob, until the voltage is 1.8 mA dc. Assure that the UUT now displays approximately 0.3 mA dc. Record the compliance of this specification on the data sheet.

5. Set the UUT controls as follows:

Function:	AC CURRENT
Range Mode:	MANUAL RANGE
Range:	2 mA AC

Using the meter calibrator, apply an ac current of 1.5 mA (rms) at a frequency of 1 kHz to the UUT. Set the UUT to zero reference mode. Assure that the UUT displays the value of zero. Increase the current of the meter calibrator, using the EDIT knob, until the current is 1.8 mA ac. Assure that the UUT now displays approximately 0.3 mA ac. Record the compliance of this specification on the data sheet.

6. Set the UUT controls as follows:

Function:	RESISTANCE
Range Mode:	MANUAL RANGE
Range:	2 kΩ

Using the meter calibrator, apply a resistance of 100 Ω to the UUT. Set the UUT to zero reference mode. Assure that the UUT displays the value of zero. Increase the resistance until the resistance is 1000 Ω. Assure that the UUT now displays approximately 900 Ω. Record the compliance of this specification on the data sheet.

7. Set the UUT controls as follows:

Function: FREQUENCY
Range Mode: AUTO RANGE

Using the meter calibrator, apply a ac voltage of 100 V ac (rms) at a frequency of 100 Hz to the UUT. Set the UUT to zero reference mode. Assure that the UUT displays the value of zero. Increase the frequency to 200 Hz. Assure that the UUT now displays approximately 100 Hz. Record the compliance of this specification on the data sheet.

Table 10.13 Zero Reference

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Specification Limits Max.	Units
Proper zero ref. - dc v.	____________	N/A	Yes		
Proper zero ref. - ac v.	____________	N/A	Yes		
Proper zero ref. - dc cur.	____________	N/A	Yes		
Proper zero ref. - ac cur.	____________	N/A	Yes		
Proper zero ref. - ohms	____________	N/A	Yes		
Proper zero ref. - freq.	____________	N/A	Yes		

10.14 Measurement Hold

Specification:

The equipment shall have a measurement hold capability in which an audible beeper will indicate after a stable reading, i.e. a reading which is stable to within ±40 counts, has been achieved. The instrument shall hold this reading on the display until a new measurement is needed.

Equipment:

Items	Model
Meter Calibrator	Fluke 5101B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3

Procedure:

1. Set the UUT controls as follows:

   Function: DC VOLTAGE
   Range Mode: MANUAL RANGE
   Range: 2 V DC

Using the meter calibrator, apply a 1.8 V dc voltage from the calibrator to the UUT. Assure that the UUT beeps and holds a reading that is within 40 least significant digits of the 1.8 V dc value. Record the compliance of this specification on the data sheet.

2. Set the UUT controls as follows:

   Function: AC VOLTAGE
   Range Mode: MANUAL RANGE
   Range: 2 V AC

Using the meter calibrator, apply a 1.8 V ac (rms) voltage at a frequency of 1 kHz to the UUT. Assure that the UUT beeps and holds a reading that is within 40 least significant digits of the 1.8 V ac (rms) value. Record the compliance of this specification on the data sheet.

3. Set the UUT controls as follows:

   Function: DC CURRENT
   Range Mode: MANUAL RANGE
   Range: 20 mA DC

Using the meter calibrator, apply a dc current of 18 mA to the UUT. Assure that the UUT beeps and holds a reading that is within 40 least significant digits of the 18 mA value. Record the compliance of this specification on the data sheet.

4. Set the UUT controls as follows:

Function:	AC CURRENT
Range Mode:	MANUAL RANGE
Range:	20 mA AC

Using the meter calibrator, apply a ac current of 18 mA (rms) at a frequency of 1 kHz to the UUT. Assure that the UUT beeps and holds a reading that is within 40 least significant digits of the 18 V ac (rms) value. Record the compliance of this specification on the data sheet.

Table 10.14 Measurement Hold

Measurement Description	Measurement Data	Estimated Measurement Uncertainty	Specification Limits Min.	Max.	Units
Proper meas. hold - dc v.	______	±0.000115	1.757	1.843	V
Proper meas. hold - ac v.	______	±0.00034	1.746	1.854	V
Proper meas. hold - dc cur.	______	±0.00501	17.50	18.60	mA
Proper meas. hold - ac cur.	______	±0.01462	17.28	18.72	mA

APPENDIX C

SOFTWARE FOR THE AUTOMATIC TESTS FOR
THE AN/PSM-51 DIGITAL MULTIMETER

```
10    !****************MENU**********************
20    !
30    !
40    !  Main Program to Test AN/PSM-51 Digital Multimeter
50    ! VOL=TMDE3A. PRG=MENU. KJL.
60    ! VERSION 1.1
70    !
80    !
90    !
100   !
110   Printer=701
120   CLEAR 7
130   OUTPUT 2;"SCRATCH KEY"&CHR$(255)&CHR$(88);    ! CLEAR SOFTKEYS
140   OFF KEY
150   PRINTER IS CRT
160   PRINT CHR$(12)                          ! Roll the screen to clear it
170   !
180   Valid$=""
190   BEEP
200   PRINT "********************** MAIN MENU ************************"
210   PRINT
220   PRINT
230   PRINT
240   PRINT " DO YOU WANT A LIST OF THE BUS ADDRESSES REQUIRED FOR THE TEST? NO=<ENTER> YES=<Y>"
250   INPUT Valid$
260   IF Valid$="Y" OR Valid$="y" THEN GOSUB Address_instruc
270   PRINT CHR$(12)
280   !
290   PRINT "********************** MAIN MENU ************************"
300   PRINT
310   PRINT "PROGRAM SELECTIONS FOR TESTS OF AN/PSM-51 DIGITAL MULTIMETER"
320   !
330 Timedate:   !
340   !
350   PRINT
360   PRINT
370   BEEP
380   DIM Yes_no$[1],Date$[15],Time$[10]
390   PRINT "DATE : ";DATE$(TIMEDATE)
400   PRINT "TIME : ";TIME$(TIMEDATE)
410   Yes_no$=""
420   INPUT "ARE DATE AND TIME CORRECT? (Y/N)!",Yes_no$
430   IF Yes_no$="" THEN Timedate
440   IF Yes_no$="Y" OR Yes_no$="y" THEN Headings
450   BEEP
460   INPUT "ENTER DATE AS 25 JUN 1986",Date$
470   BEEP
480   INPUT "ENTER TIME AS 16:09:21",Time$
490   SET TIMEDATE DATE(Date$)+TIME(Time$)
500   GOTO Timedate
510   !
520   !*****************************************************************
530   !
540 Headings:   !
550   BEEP
560   Yes_no$=""
570   INPUT "DO YOU WANT A PRINTED TEST HEADING? (Y/N).",Yes_no$
580   IF Yes_no$="" THEN Headings
590   IF Yes_no$="N" OR Yes_no$="n" THEN Ok
600   BEEP
610   INPUT "OPERATOR NAME",Name$
620   BEEP
630   INPUT "MANUFACTURER NAME",Mfg$
640   BEEP
650   INPUT "MODEL NUMBER",Model$
660   BEEP
670   INPUT "METER SERIAL NUMBER",Sernumber$
```

```
680   PRINT
690   PRINT CHRS(12)
700   BEEP
710   PRINT "*****************AN/PSM-51 DIGITAL MULTIMETER ACCEPTANCE TESTS*****************"
720   OUTPUT Printer;CHRS(12)      ! FORM FEED FOR EXTERNAL PRINTER
730   OUTPUT Printer;"*****************AN/PSM-51 DIGITAL MULTIMETER ACCEPTANCE TESTS**************"
740   PRINT
750   OUTPUT Printer;CHRS(10)     ! LINE FEED FOR EXTERNAL PRINTER
760   PRINT "OPERATOR: ";NameS
770   OUTPUT Printer;"     OPERATOR: ";NameS
780   PRINT "MANUFACTURER: ";MfgS
790   OUTPUT Printer;"     MANUFACTURER: ";MfgS
800   PRINT "MODEL: ";ModelS
810   OUTPUT Printer;"     MODEL: ";ModelS
820   PRINT "SERIAL NUMBER: ";SernumberS
830   OUTPUT Printer;"     SERIAL NUMBER: ";SernumberS
840   PRINT
850   PRINT DATES(TIMEDATE)&" "&TIMES(TIMEDATE)
860   OUTPUT Printer;"     "&DATES(TIMEDATE)&" "&TIMES(TIMEDATE)
870   PRINT
880   OUTPUT Printer;CHRS(10)     ! LINE FEED FOR EXTERNAL PRINTER
890   PRINTER IS CRT
900   PRINT "PAUSED. PRESS <CONTINUE> WHEN READY."
910   PAUSE
920   !
930   !*********************************************************************
940   !
950 Ok:    !
960   !
970   FOR N=1 TO 20
980     PRINT
990   NEXT N
1000  BEEP
1010  PRINT "     Run the test for :"
1020  PRINT
1030  PRINT "                           1.  AC and DC VOLTAGE     (5101B) "
1040  PRINT "                           2.  AC VOLTAGE        (5200/5205) "
1050  PRINT "                           3.  AC and DC CURRENT     (5101B) "
1060  PRINT "                           4.  RESISTANCE            (5101B) "
1070  PRINT "                           5.  RESPONSE TIMES        (5101B) "
1080  PRINT "                               (ac and dc voltages and currents, and resistance)"
1090  PRINT "                           6.  STOP TEST          "
1100  PRINT
1110  ! PRINT "    USE KNOB TO SCROLL THE SCREEN!"
1120  PRINT
1130  PRINT "          ENTER THE NUMBER OF CHOICE                       "
1140  INPUT Choice
1150  !
1160  PRINT
1170  PRINT "              WAIT -- Loading program number ";Choice
1180  IF Choice<1 OR Choice>6 THEN PRINT "            Improper Choice"
1190  IF Choice<1 OR Choice>6 THEN WAIT 2.0
1200  IF Choice<1 OR Choice>6 THEN GOTO Ok
1210  IF Choice=1 THEN LOAD "VOLTS51"
1220  IF Choice=2 THEN LOAD "VOLTS52"
1230  IF Choice=3 THEN LOAD "AMPS"
1240  IF Choice=4 THEN LOAD "OHMS"
1250  IF Choice=5 THEN LOAD "RESP"
1260  IF Choice=6 THEN
1270    PRINT CHRS(12)
1280    BEEP 400,.5
1290    PRINT TABXY(10,10),"TEST STOPPED AT OPERATORS CHOICE!"
1300    PRINT
1310    PRINT
1320    PRINT TAB(10),"PRESS <RUN> TO RESTART THE PROGRAM."
1330    PAUSE
1340  END IF
```

```
1350  !
1360  !******************************************
1370  !
1380 Address_instruc:  !  IEEE BUS ADDRESS INSTRUCTIONS
1390  !
1400  PRINT CHR$(12)
1410  PRINT
1420  BEEP
1430  PRINT
1440  PRINT
1450  PRINT "THE EQUIPMENT USED MUST BE SET TO THE FOLLOWING IEEE BUS ADDRESSES:"
1460  PRINT
1470  PRINT "     (1) PRINTER = 701"
1480  PRINT
1490  PRINT "     (2) FLUKE 5101B CALIBRATOR = 702"
1500  PRINT
1510  PRINT "     (3) FLUKE 5200A CALIBRATOR = 703"
1520  PRINT
1530  PRINT
1540  PRINT "PRESS <CONTINUE> WHEN READY!"
1550  BEEP
1560  PAUSE
1570  PRINT CHR$(12)
1580  RETURN
1590  !
1600  !******************************************
1610  !
1620  END
```

```
10    !************VOLTS51**********************
20    !
30    ! Routine to test ac and dc voltage
40    ! PRG=VOLTS51. KJL
50    ! DISC VOLUME = TMDE3A. VERSION 1.1
60    !
70    !
80    !
90    !*****************************************
100   !
110 Start:     !
120   !
130   CLEAR 7
140   GOSUB Initialize
150   DIM Vdc(50)                    ! Vector that contains dc sequence
160   DIM Vac(50,9)                  ! Vector that contains ac sequence
170   DIM Freq_seq(5)                !  .... Not presently used
180   DIM Meter_reading$[15]
190   PRINTER IS CRT
200   PRINT CHR$(12)                 ! Roll screen to clear it
210   LOAD KEY "ABORTKEYS"
220   !
230   ! ------------------------------------------------------------------
240   !          Test  Data Definition Section
250   ! ------------------------------------------------------------------
260   !
270   ! DC Voltage Test Data
280   !
290   Dctest_length=34                 ! Number of DC Voltage Tests
300   !
310   ! POSITIVE VALUES
320   !
330   DATA 0.005,    0.010,    0.018,     0.050,     0.100,    0.180,   0.500,
340   DATA 1.000,    1.800,    5.000,     10.00,     18.00,    50.00,   100.0,
350   DATA 180.0,    500.0,    800.0,
360   !
370   ! NEGATIVE VALUES
380   !
390   DATA -0.005,   -0.010,   -0.018,    -0.050,    -0.100,   -0.180,  -0.500,
400   DATA -1.000,   -1.800,   -5.000,    -10.00,    -18.00,   -50.00,  -100.0,
410   DATA -180.0,   -500.0,   -800.0
420   !
430   FOR N=1 TO Dctest_length         ! Loop number of ac Voltage Tests
440     READ Vdc(N)                    ! Read sequence into Vdc(*)
450   NEXT N
460   !
470   !  AC VOLTAGE TEST DATA
480   !
490   Actest_length=16                       ! Number of AC Voltage Tests
500   !
510   !     Voltage !# Freqs !------- Frequencies ---------------------------!
520   DATA      0.005,  4,    50.,     200.,    2000.,     20000.
530   DATA      0.010,  4,    50.,     200.,    2000.,     20000.
540   DATA      0.018,  4,    50.,     200.,    2000.,     20000.
550   DATA      0.050,  4,    50.,     200.,    2000.,     20000.
560   DATA      0.100,  4,    50.,     200.,    2000.,     20000.
570   DATA      0.180,  4,    50.,     200.,    2000.,     20000.
580   DATA      0.500,  4,    50.,     200.,    2000.,     20000.
590   DATA      1.000,  4,    50.,     200.,    2000.,     20000.
600   DATA      1.800,  4,    50.,     200.,    2000.,     20000.
610   DATA      5.000,  4,    50.,     200.,    2000.,     20000.
620   DATA      10.00,  4,    50.,     200.,    2000.,     20000.
630   DATA      18.00,  4,    50.,     200.,    2000.,     20000.
640   DATA      50.00,  4,    50.,     200.,    2000.,     20000.
650   DATA      100.0,  4,    50.,     200.,    2000.,     20000.
660   DATA      180.0,  2,    50.,     200.
670   DATA      730.0,  2,    50.,     200.
```

```
680    !
690    FOR N=1 TO Actest_length              !  Loop each Vac Test
700      READ Vac(N,1)                       !  Read the Voltage into Vac(*)
710      READ Vac(N,2)                       !  Read the number of frequency pts.
720      FOR M=1 TO Vac(N,2)                 !  Loop the frequency points
730        READ Vac(N,M+2)                   !  Read the frequency points
740      NEXT M
750    NEXT N
760    !
770    ! ------------------------------------------------------------------
780    !                 End of Test Data Definition Section
790    ! ------------------------------------------------------------------
800    !
810    !  Clear the screen and query operator for type of test to be performed
820    !
830 Restart:  !
840    !
850    CLEAR 7
860    PRINT CHR$(12)
870    BEEP
880    PRINT
890    BEEP
900    PRINT "       DO YOU WISH TO PERFORM A DC OR AC VOLTAGE ACCURACY TEST?"
910    PRINT
920    PRINT "                    (1)  DC                                       "
930    PRINT "                    (2)  AC                                       "
940    PRINT "                    (3)   RETURN TO MAIN MENU                        "
950    PRINT
960    PRINT "       ENTER   1 or 2 or 3                                      "
970    PRINT
980    INPUT Response
990    PRINT CHR$(12)
1000   IF Response<1 OR Response>3 THEN 870
1010   IF Response=3 THEN LOAD "MENU"
1020   IF Response=2 THEN GOTO Actests
1030   !
1040 Dctests: ! -------------------------------------------------------------------
1050   !                Start of dc test sequence
1060   ! -----------------------------------------------------------------
1070   !
1080   BEEP
1090   PRINT
1100   PRINT "SET METER TO RESPOND TO DC VOLTAGE"
1110   PRINT
1120   PRINT "CONNECT METER TO 5101B CALIBRATOR"
1130   PRINT
1140   PRINT "PRESS <CONTINUE> WHEN READY!"
1150   PRINT
1160   PAUSE
1170   !
1180   FOR T=1 TO Dctest_length
1190     PRINT CHR$(12)                         ! Clear the screen
1200     BEEP
1210     PRINT "DC test number ";T;" of ";Dctest_length! Displays test sequence
1220     Volts=Vdc(T)
1230     Freq=0
1240     PRINT "PROGRAMMED FREQUENCY = DC"
1250     PRINT "PROGRAMMED VOLTAGE = ";Volts
1260     GOSUB Volts
1270     GOSUB Entry
1280     GOSUB Record
1290   NEXT T
1300   CLEAR 7
1310   PRINT
1320   BEEP 500,.5
1330   PRINT "ALL DC VOLTAGE TESTS COMPLETED! WAIT 3 SECONDS."
1340   WAIT 3
```

```
1350  PRINTER IS Printer
1360  PRINT
1370  PRINT TAB(23),"ALL DC VOLTAGE TESTS COMPLETED"
1380  PRINT
1390  PRINTER IS CRT
1400  LOAD "MENU"
1410  !
1420 Actests: ! -------------------------------------------------------------------
1430  !                  Start of ac test sequence
1440  ! -------------------------------------------------------------------
1450  !
1460  BEEP
1470  PRINT
1480  PRINT "SET METER TO RESPOND TO AC VOLTAGE"
1490  PRINT
1500  PRINT "CONNECT METER TO 5101B CALIBRATOR"
1510  PRINT
1520  PRINT "PRESS <CONTINUE> WHEN READY!"
1530  PRINT
1540  PAUSE
1550  !
1560  FOR Freqnum=1 TO 4                      ! Loop up to 4 freqs / voltage
1570    FOR T=1 TO Actest_length              ! Loop voltages
1580      PRINT CHR$(12)
1590      BEEP
1600      PRINT "AC test number ";T;" of ";Actest_length! Displays test sequence
1610      Volts=Vac(T,1)
1620      Freq=Vac(T,Freqnum+2)
1630      IF Freq=0 THEN 1690
1640      PRINT "PROGRAMMED FREQUENCY = ";Freq;"Hz."
1650      PRINT "PROGRAMMED VOLTAGE  = ";Volts
1660      GOSUB Volts
1670      GOSUB Entry
1680      GOSUB Record
1690    NEXT T
1700  NEXT Freqnum
1710  CLEAR 7
1720  PRINT
1730  BEEP
1740  PRINT "ALL AC VOLTAGE TESTS COMPLETED! WAIT 3 SECONDS."
1750  WAIT 3
1760  PRINTER IS Printer
1770  PRINT
1780  PRINT TAB(15),"ALL AC VOLTAGE TESTS AT ALL FREQUENCIES COMPLETED"
1790  PRINT
1800  PRINTER IS CRT
1810  GOTO Restart
1820  !
1830  ! ********************************************************************
1840  !             Start of Subroutines
1850  ! ********************************************************************
1860  !
1870 Volts: !
1880  ! --- VOLTS - Subroutine to program a Fluke Mfg Co., Inc. Model 5101 Meter
1890  !             Calibrator for ac and dc voltage output.
1900  !
1910  ! --- Parameters
1920  !             VOLTS   - the voltage to be output
1930  !                       expressed in volts (FP)              - INPUT
1940  !             FREQ    - the frequency of the output voltage
1950  !                       if FREQ = 0 then output is dc
1960  !                       if FREQ <>0 then output is ac
1970  !                       frequency is expressed in Hz (FP)
1980  !                       50. <=  FREQ  <= 50000.              - INPUT
1990  !             ADDR    - IEEE-488 address of JF 5101 calibrator
2000  !                       0 <= ADDR <= 31                      - INPUT
2010  !             MESS    - the command output string provided
```

```
2020  !                        by this subroutine - normally sent
2030  !                        to the 5101 via the IEEE-488 bus.   - OUTPUT
2040  !              ERROR$  - an error message for error conditions
2050  !                        (such as out-of-range, overload, etc)
2060  !                        generated by the 5101             - OUTPUT
2070  !              ERRFLG  - a flag = 0 if no error condition
2080  !                               = 1 if error condition      - OUTPUT
2090  !
2100  !-----------------------------------------------------------------------
2110  !
2120  Checkout=0      ! FOR DEBUG SET=1
2130  !
2140  DIM Errorcode$(10)[80]
2150  DIM Error$[80]
2160  DIM Mes$[80]
2170  Addr=Addr+0                             ! Get HP address from IEEE address
2180  Errflg=0
2190  Error$="No  Error Mesage"
2200  !
2210  RESTORE 2230
2220  !
2230  DATA "No Error Message (status message only)",
2240  DATA "Invalid character or sequence",
2250  DATA "Invalid frequency or resistance entry",
2260  DATA "Programmed output exceeds entry limits or instrument capabilities",
2270  DATA "Invalid frequency/output combination",
2280  DATA "Overload or overcompliance voltage",
2290  DATA "Module accessed inoperative or not installed",
2300  DATA "String command exceeds 32 characters",
2310  DATA "Tape load/feed problem or write protected",
2320  DATA "Unable to read tape"
2330  !
2340  FOR N=0 TO 9
2350    READ Errorcode$(N)                    ! Read the Error Codes in form of
2360  NEXT N                                  ! Table 2-10.
2370  !
2380  IF Volts=0 THEN OUTPUT Addr;"CC"        ! Remove voltage source
2390  IF Volts=0 THEN RETURN
2400  !
2410  OUTPUT Addr;"CC"                        ! Reset - stay in remote
2420  WAIT .5
2430  IF Freq<>0 THEN 2770                     ! Go to ac voltage section
2440  IF ABS(Volts)<.0000001 OR ABS(Volts)>1100 THEN Error$="Programmed dc voltage limit exceeded"
2450  IF ABS(Volts)<.0000001 OR ABS(Volts)>1100 THEN Errflg=1
2460  V$=VAL$(Volts)
2470  OUTPUT Addr;V$                          ! Append the voltage value
2480  OUTPUT Addr;"V"                         ! Add the V
2490  WAIT .5
2500  OUTPUT Addr;","                         ! Add the terminator
2510  WAIT .5
2520  OUTPUT Addr;"N"                         ! Go to operate condition
2530  !
2540  ! Check for abnormal condition from 5101
2550  !
2560  WAIT 1.0                                ! Allow 5101 to settle to error
2570  OUTPUT Addr;"!?"                        ! Request central display message
2580  ENTER Addr;Stat$                        ! Store message in Stat$
2590  !
2600  IF Checkout=1 THEN PRINT "STATUS = ";Stat$
2610  !
2620  Error_num=VAL(Stat$[1,1])
2630  IF VAL(Stat$[1,1])>0 THEN Error$=Errorcode$(Error_num)
2640  IF VAL(Stat$[1,1])>0 THEN Errflg=1
2650  !
2660  IF Checkout=1 THEN PRINT Error$
2670  IF Checkout=1 THEN PRINT "Errflg = ";Errflg
2680  !
```

```
2690  IF Errflg=1 THEN OUTPUT Addr;"CC"     ! It's an error - shut it off
2700  RETURN
2710  Subexit
2720  !
2730  ! -------------------------------------------------------------------
2740  !      End of the dc section    ---   Start of the ac section
2750  ! -------------------------------------------------------------------
2760  !
2770  OUTPUT Addr;"CC"                      ! Reset - stay in remote
2780  WAIT .5
2790  IF Volts<.0000001 OR Volts>1100 THEN ErrorS="Programmed dc voltage limit exceeded"
2800  IF Volts<.0000001 OR Volts>1100 THEN Errflg=1
2810  VS=VALS(Volts)
2820  OUTPUT Addr;VS                        ! Append the voltage value
2830  OUTPUT Addr;"V"                       ! Add the V
2840  WAIT .5
2850  OUTPUT Addr;","                       ! Add the terminator
2860  FS=VALS(Freq)
2870  OUTPUT Addr;FS                        ! Append the frequency
2880  OUTPUT Addr;"H"
2890  WAIT .5
2900  OUTPUT Addr;","                       ! Append the terminator
2910  WAIT .5
2920  OUTPUT Addr;"N"                       ! Go to operate condition
2930  !
2940  ! Check for abnormal condition from 5101
2950  !
2960  WAIT 1.0                              ! Allow 5101 to settle to error
2970  OUTPUT Addr;"!?"                      ! Request central display message
2980  ENTER Addr;StatS                      ! Store message in StatS
2990  IF Checkout=1 THEN PRINT StatS
3000  Error_num=VAL(StatS[1,1])
3010  IF VAL(StatS[1,1])>0 THEN ErrorS=ErrorcodeS(Error_num)
3020  IF VAL(StatS[1,1])>0 THEN Errflg=1     ! Check error codes 4,5,6,8, & 9
3030  IF VAL(StatS[2,4])=41 THEN ErrorS=ErrorcodeS(2)
3040  IF VAL(StatS[2,4])=41 THEN Errflg=1    ! Check for invalid frequency
3050  IF VAL(StatS[2,4])=141 THEN ErrorS=ErrorcodeS(2)
3060  IF VAL(StatS[2,4])=141 THEN Errflg=1   ! Check for invalid frequency
3070  IF VAL(StatS[3,5])=412 THEN ErrorS=ErrorcodeS(3)
3080  IF VAL(StatS[3,5])=412 THEN Errflg=1   ! Check for invalid voltage
3090  IF Checkout=1 THEN PRINT ErrorS
3100  IF Checkout=1 THEN PRINT "Errflg = ";Errflg
3110  IF Errflg=1 THEN OUTPUT Addr;"CC"     ! It's an error - shut it off
3120  RETURN
3130  !
3140  !*******************************************
3150  !
3160 Entry:  !
3170  !
3180  !  This subroutine records the operator's entry of the UUT reading
3190  !  and check for the validity of response.  In addition, it uses the
3200  !  numerical entry to determine the range the meter is set to, i.e.
3210  !  volts, millivolts, etc.
3220  !
3230  !
3240  PRINT
3250  PRINT
3260  BEEP
3270  PRINT "  Enter the Reading Displayed on the Digital Multimeter:"
3280  PRINT
3290  Meter_readingS=""
3300  INPUT Meter_readingS                  ! The operator's entry of reading
3310  IF Meter_readingS="" THEN 3260
3320  ValidS=""                             ! Clear the flag for bad entry
3330  IF Meter_readingS="OL" THEN Meter_readingS="10000"
3340  IF Meter_readingS="-OL" THEN Meter_readingS="-10000"
3350  !
```

```
3360 Convert:   ! Convert Meter_reading$ to Volts
3370  !
3380  FOR D=-6 TO +6                         ! Go through the ranges to determine
3390    Reading=VAL(Meter_reading$)*(10^D)!  the meter's range
3400    IF ABS(Reading/Volts-1)<.3 THEN Decade=D
3410  NEXT D
3420  !
3430 Range_check:  !Check to assure that a reasonable range has been entered
3440  !
3450  IF Decade=-6 THEN PRINT "        Meter reading  = ";Meter_reading$;"  microvolts"
3460  IF Decade=-5 THEN PRINT "        Data entered   = ";Meter_reading$;"  CHECK IT!"
3470  IF Decade=-4 THEN PRINT "        Data entered   = ";Meter_reading$;"  CHECK IT!"
3480  IF Decade=-3 THEN PRINT "        Meter reading  = ";Meter_reading$;"  millivolts"
3490  IF Decade=-2 THEN PRINT "        Data entered   = ";Meter_reading$;"  CHECK IT!"
3500  IF Decade=-1 THEN PRINT "        Data entered   = ";Meter_reading$;"  CHECK IT!"
3510  IF Decade=0 THEN PRINT "         Meter reading  = ";Meter_reading$;"  volts"
3520  IF Decade=+1 THEN PRINT "        Data entered   = ";Meter_reading$;"  CHECK IT!"
3530  IF Decade=+2 THEN PRINT "        Data entered   = ";Meter_reading$;"  CHECK IT!"
3540  IF Decade=+3 THEN PRINT "        Meter reading  = ";Meter_reading$;"  kilovolts"
3550  !
3560  !  If the operator's entry is more than 30 percent in error, question it.
3570  !
3580  IF ABS(((VAL(Meter_reading$)*(10^Decade))/Volts)-1)>.3 THEN
3590    BEEP 500,1.1
3600    PRINT
3610    PRINT "           RECHECK THE READING!"
3620    BEEP 400,1.5
3630  END IF
3640  PRINT
3650  BEEP
3660  PRINT "IS THE READING ENTERED CORRECTLY?   Yes= <ENTER>;  No = <N>"
3670  INPUT Valid$                           !  Check for valid entry
3680  IF Valid$="n" OR Valid$="N" THEN 3250    !  Re-enter data
3690  RETURN
3700  !
3710  !******************************************
3720  !
3730 Record: !
3740  !
3750  IF Decade=-6 THEN Meter_reading$=Meter_reading$&" uV"
3760  IF Decade=-3 THEN Meter_reading$=Meter_reading$&" mV"
3770  IF Decade=0 THEN Meter_reading$=Meter_reading$&" V"
3780  IF Decade=+3 THEN Meter_reading$=Meter_reading$&" kV"
3790  PRINTER IS CRT
3800  BEEP
3810  IF T=1 THEN Record1
3820  PRINTER IS Printer
3830  PRINT USING "16X,2D,11X,5D.3D,11X,9A";T,Volts,Meter_reading$
3840  !
3850 Return:      !
3860  !
3870  PRINTER IS CRT
3880  RETURN
3890  !
3900 Record1:     !
3910  !
3920  PRINTER IS Printer
3930  IF Freq=0 THEN
3940    PRINT
3950    PRINT USING "24X,24A";"DC VOLTAGE ACCURACY TEST"
3960    PRINT USING "24X,24A";"------------------------"
3970  ELSE
3980    PRINT
3990    IF Freq=2000 THEN PRINT CHR$(12)
4000    PRINT USING "20X,28A,K,3A";"AC VOLTAGE ACCURACY TEST AT";Freq;" Hz."
4010    PRINT USING "20X,35A";"-----------------------------------"
4020  END IF
```

```
4030  PRINT USING "15X,4A,10X,10A,10X,9A";"TEST","PROGRAMMED"," METER "
4040  PRINT USING "14X,6A,10X,7A,12X,9A";"NUMBER","VOLTAGE","READING"
4050  PRINT USING "14X,6A,9X,10A,10X,7A";"------","----------","----------"
4060  PRINT USING "16X,2D,11X,5D.3D,11X,9A";T,Volts,Meter_reading$
4070  PRINTER IS CRT
4080  GOTO Return
4090  !
4100  !*******************************************
4110  !
4120 Initialize:       !
4130  ON KEY 0 LABEL "TO" GOTO Abort
4140  ON KEY 1 LABEL "SAFELY" GOTO Abort
4150  ON KEY 2 LABEL "ABORT" GOTO Abort
4160  ON KEY 3 LABEL "THE" GOTO Abort
4170  ON KEY 4 LABEL "RUNNING" GOTO Abort
4180  ON KEY 5 LABEL "PROGRAM" GOTO Abort
4190  ON KEY 6 LABEL "PRESS" GOTO Abort
4200  ON KEY 7 LABEL "ANY" GOTO Abort
4210  ON KEY 8 LABEL "SOFT-" GOTO Abort
4220  ON KEY 9 LABEL "KEY!" GOTO Abort
4230  Addr=702
4240  Printer=701
4250  RETURN
4260  !
4270  !*******************************************
4280  !
4290 Abort:     !
4300  !
4310  CLEAR 7
4320  PRINT
4330  BEEP 500,.4
4340  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4350  PRINT
4360  WAIT 3
4370  PRINTER IS Printer
4380  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4390  PRINT
4400  PRINTER IS CRT
4410  GOTO Restart
4420   !
4430   !*******************************************
4440 Abort1:     !
4450   !
4460  CLEAR 7
4470  PRINT
4480  BEEP 500,.4
4490  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4500  PRINT
4510  WAIT 3
4520  PRINTER IS 701
4530  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4540  PRINT
4550  PRINTER IS CRT
4560  GOTO Start
4570  !
4580  !*******************************************
4590  !
4600  END
```

```
10    !************** VOLTS52 ******************
20    !
30    !
40    ! ROUTINE FOR AC VOLTAGE ACCURACY TESTS USING THE FLUKE 5200A PROGRAMMABLE SOURCE.
50    ! PRG=VOLTS52. KJL.
60    ! VERSION 1.1.   DISC VOLUME = TMDE3A.
70    !
80    !
90    !
100   !******************************************
110   !
120 Start: !
130      !
140   CLEAR 7
150   GOSUB Initialize
160   !
170   ! ----------------------------------------------------------------
180   !         Test  Data Definition Section
190   ! ----------------------------------------------------------------
200   !
210   !
220   !  AC Voltage Test Data
230   !
240   Actest_length=16                         ! Number of AC Voltage Tests
250   !
260   !     Voltage !# Freqs !------- Frequencies ---------------------------!
270   DATA     0.005,  5, 20,    50.,     200.,    2000.,     20000.
280   DATA     0.010,  5, 20,    50.,     200.,    2000.,     20000.
290   DATA     0.018,  5, 20,    50.,     200.,    2000.,     20000.
300   DATA     0.050,  5, 20,    50.,     200.,    2000.,     20000.
310   DATA     0.100,  5, 20,    50.,     200.,    2000.,     20000.
320   DATA     0.180,  5, 20,    50.,     200.,    2000.,     20000.
330   DATA     0.500,  5, 20,    50.,     200.,    2000.,     20000.
340   DATA     1.000,  5, 20,    50.,     200.,    2000.,     20000.
350   DATA     1.800,  5, 20,    50.,     200.,    2000.,     20000.
360   DATA     5.000,  5, 20,    50.,     200.,    2000.,     20000.
370   DATA     10.00,  5, 20,    50.,     200.,    2000.,     20000.
380   DATA     18.00,  5, 20,    50.,     200.,    2000.,     20000.
390   DATA     50.00,  5, 20,    50.,     200.,    2000.,     20000.
400   DATA     100.0,  5, 20,    50.,     200.,    2000.,     20000.
410   DATA     180.0,  3, 20,    50.,     200.
420   DATA     730.0,  3, 20,    50.,     200.
430   !
440   !
450   FOR N=1 TO Actest_length              !  Loop each Vac Test
460     READ Vac(N,1)                       !  Read the Voltage into Vac(*)
470     READ Vac(N,2)                       !  Read the number of frequency pts.
480     FOR M=1 TO Vac(N,2)                 !  Loop the frequency points
490       READ Vac(N,M+2)                   !  Read the frequency points
500     NEXT M
510   NEXT N
520   PRINT
530   PRINT
540   PRINT
550   !
560   ! -----------------------------------------------------------------
570   !              End of Test Data Definition Section
580   ! -----------------------------------------------------------------
590   !
600   ! ------------------------------------------------------------------
610   !                Start of ac test sequence
620   ! ------------------------------------------------------------------
630   !
640 Restart:   !
650   !
660   CLEAR 7
670   OUTPUT 2;Clear$;       ! CLEAR THE CRT
```

```
680   BEEP
690   PRINT
700   PRINT "SET METER TO RESPOND TO AC VOLTAGE"
710   PRINT
720   PRINT "PRESS <CONTINUE> WHEN READY!"
730   PRINT
740   PAUSE
750   !
760   FOR Freqnum=1 TO 5                        ! Loop up to 5 freqs / voltage
770     FOR T=1 TO Actest_length                ! Loop voltages
780       OUTPUT 2;ClearS;
790       BEEP
800       PRINT "AC test number ";T;" of ";Actest_length! Displays test sequence
810       Volts=Vac(T,1)
820       Freq=Vac(T,Freqnum+2)
830       PRINT "PROGRAMMED FREQUENCY = ",Freq
840       PRINT "PROGRAMMED   VOLTAGE = ",Volts
850       GOSUB Volt_hertz! Volts*Freq<=1E7
860       GOSUB Volts
870       GOSUB Entry
880       GOSUB Record
890       !
900 Next_voltage:NEXT T
910   NEXT Freqnum
920   !
930   CLEAR 7
940   OUTPUT 2;ClearS;
950   BEEP 550,.5
960   PRINT
970   PRINT "ALL VOLTAGE TESTS AT ALL FREQUENCIES COMPLETED! WAIT 3 SECONDS."
980   PRINT
990   PRINT "TESTS DONE USING FLUKE 5200A/5205A AC VOLTAGE CALIBRATORS."
1000  PRINT
1010  PRINTER IS Printer
1020  PRINT
1030  PRINT TAB(15),"ALL AC VOLTAGE TESTS AT ALL FREQUENCIES COMPLETED"
1040  PRINT
1050  PRINT TAB(15),"TESTS DONE USING FLUKE 5200A/5205A AC VOLTAGE CALIBRATORS."
1060  PRINT
1070  PRINTER IS CRT
1080  WAIT 3
1090  LOAD "MENU"
1100  !
1110  ! ***********************************************************************
1120  !              Start of Subroutines
1130  ! ***********************************************************************
1140  !
1150 Volts: !
1160  !
1170  Checkout=1
1180  Addr=Addr+0                          ! Get HP address from IEEE address
1190  OUTPUT Addr;"*"                      ! Reset
1200  BEEP
1210  PRINT
1220  IF T=1 THEN
1230    PRINT TABXY(15,5),"CONNECT DMM TO 5200A CALIBRATOR"
1240    PRINT
1250    PRINT TAB(15),"PRESS <CONTINUE> WHEN READY!"
1260    PAUSE
1270  END IF
1280  PRINT
1290  VS=VALS(Volts)
1300  OUTPUT Addr;VS                  ! Append the voltage value
1310  OUTPUT Addr;"V"                      ! Add the V
1320  FS=VALS(Freq)
1330  OUTPUT Addr;FS                  ! Append the frequency
1340  OUTPUT Addr;"H"
```

```
1350  IF Volts>119.9999 THEN Highv
1360  OUTPUT Addr;"F0X0N"                        ! Go to operate condition
1370  !
1380  RETURN
1390  !
1400  !*********************************************************************
1410  !
1420 Entry:  !
1430  !
1440  !  This subroutine records the operator's entry of the UUT reading
1450  !  and checks for the validity of response.  In addition, it uses the
1460  !  numerical entry to determine the range the meter is set to, i.e.
1470  !  volts, millivolts, etc.
1480  !
1490  PRINT
1500  PRINT
1510  BEEP
1520  Meter_readingS=""
1530  PRINT "  Enter the Reading Displayed on the Digital Multimeter:"
1540  PRINT
1550  INPUT Meter_readingS                 ! The operator's entry of reading
1560  ! ValidS=""                             ! Clear the flag for bad entry
1570  IF Meter_readingS="" THEN 1500
1580  !
1590 Convert:   ! Convert Meter_readingS to Volts
1600  !
1610  FOR D=-6 TO +6                       ! Go through the ranges to determine
1620    Reading=VAL(Meter_readingS)*(10^D) !  the meter's range
1630    IF ABS(Reading/Volts-1)<.3 THEN Decade=D
1640  NEXT D
1650  !
1660 Range_check:  !  Check to assure that a reasonable range has been entered
1670  !
1680  BEEP
1690  IF Decade=-6 THEN PRINT "         Meter reading  = ";Meter_readingS;"  microvolts"
1700  IF Decade=-5 THEN PRINT "         Data entered   = ";Meter_readingS;"  CHECK IT!"
1710  IF Decade=-4 THEN PRINT "         Data entered   = ";Meter_readingS;"  CHECK IT!"
1720  IF Decade=-3 THEN PRINT "         Meter reading  = ";Meter_readingS;"  millivolts"
1730  IF Decade=-2 THEN PRINT "         Data entered   = ";Meter_readingS;"  CHECK IT!"
1740  IF Decade=-1 THEN PRINT "         Data entered   = ";Meter_readingS;"  CHECK IT!"
1750  IF Decade=0 THEN PRINT "          Meter reading  = ";Meter_readingS;"  volts"
1760  IF Decade=+1 THEN PRINT "         Data entered   = ";Meter_readingS;"  CHECK IT!"
1770  IF Decade=+2 THEN PRINT "         Data entered   = ";Meter_readingS;"  CHECK IT!"
1780  IF Decade=+3 THEN PRINT "         Meter reading  = ";Meter_readingS;"  kilovolts"
1790  !
1800  !  If the operator's entry is more than 30 percent in error, question it.
1810  !
1820  IF ABS(((VAL(Meter_readingS)*(10^Decade))/Volts)-1)>.3 THEN
1830    BEEP 400,1.5
1840    WAIT .5
1850    BEEP 500,1
1860    PRINT "           RECHECK THE READING!"
1870  END IF
1880  PRINT
1890  ValidS=""
1900  PRINT "IS THE READING ENTERED CORRECTLY?   Yes= <ENTER>;  No = <N>"
1910  INPUT ValidS                              !  Check for valid entry
1920  IF ValidS="n" OR ValidS="N" THEN 1500     !  Re-enter data
1930  RETURN
1940  !
1950  !*********************************************************************
1960  !
1970 Record: !
1980  !
1990  IF Decade=-6 THEN Meter_readingS=Meter_readingS&" uV"
2000  IF Decade=-3 THEN Meter_readingS=Meter_readingS&" mV"
2010  IF Decade=0 THEN Meter_readingS=Meter_readingS&" V"
```

```
2020  IF Decade=3 THEN Meter_reading$=Meter_reading$&" kV"
2030  BEEP
2040  IF T=1 THEN Record1
2050  PRINTER IS Printer
2060  PRINT USING "16X,2D,11X,5D.3D,12X,9A";T,Volts,Meter_reading$
2070  !
2080 Return:    !
2090  !
2100  PRINTER IS CRT
2110  OUTPUT 2;Clear$;     ! CLEARS SCREEN
2120  RETURN
2130  !
2140  !*********************************************************
2150  !
2160 Record1:    !
2170  !
2180  PRINTER IS Printer
2190  PRINT
2200  IF Freq=200 THEN PRINT CHR$(12)
2210  IF Freq=20000 THEN PRINT CHR$(12)
2220  PRINT USING "20X,28A,K,3A";"AC VOLTAGE ACCURACY TEST AT";Freq;" Hz."
2230  PRINT USING "20X,35A";"-----------------------------------"
2240  PRINT USING "15X,4A,10X,10A,10X,9A";"TEST","PROGRAMMED"," METER "
2250  PRINT USING "14X,6A,10X,7A,12X,9A";"NUMBER","VOLTAGE","READING"
2260  PRINT USING "14X,6A,9X,10A,10X,7A";"------","----------","-------"
2270  PRINT USING "16X,2D,11X,5D.3D,12X,11A";T,Volts,Meter_reading$
2280  PRINTER IS CRT
2290  GOTO Return
2300  !
2310  !*****************************************************************
2320  !
2330 Initialize:   !
2340  !
2350  Addr=703
2360  Printer=701
2370  ASSIGN @Hpib TO 7
2380  REMOTE @Hpib
2390  LOAD KEY "ABORTKEYS"
2400  ON KEY 0 LABEL "TO     " GOSUB Abort
2410  ON KEY 1 LABEL "SAFELY  " GOSUB Abort
2420  ON KEY 2 LABEL "ABORT   " GOSUB Abort
2430  ON KEY 3 LABEL "THE     " GOSUB Abort
2440  ON KEY 4 LABEL "RUNNING " GOSUB Abort
2450  ON KEY 5 LABEL "PROGRAM " GOSUB Abort
2460  ON KEY 6 LABEL "PRESS   " GOSUB Abort
2470  ON KEY 7 LABEL "ANY     " GOSUB Abort
2480  ON KEY 8 LABEL "SOFT-   " GOSUB Abort
2490  ON KEY 9 LABEL "KEY     " GOSUB Abort
2500  PRINTER IS CRT
2510  DIM Clear$[2],Home$[2],Scratch_key$[13],Vac(50,9)
2520  DIM V$[20],H$[20],A$[3]
2530  Clear$=CHR$(255)&CHR$(75)      ! CLEAR THE CRT
2540  Home$=CHR$(255)&CHR$(84)       ! PLACE THE CURSOR IN THE UPPER LEFT TOP OF          THE SCREEN.
2550  Scratch_key$="SCRATCH KEY"&CHR$(255)&CHR$(88)  ! ERASE THE SOFT-KEYS
2560  GRAPHICS OFF
2570  CONTROL 2,1;0       ! PRINTALL OFF
2580  CONTROL 1,4;0       ! DISPLAY FUNCTIONS OFF
2590  OUTPUT 2;Clear$;
2600  RETURN
2610  !
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$,"FOX1S"
2740  PRINT
2750  BEEP 500,.4
2760  IF T>15 THEN 2820
2770  PRINT "CONNECT METER TO HIGH VOLTAGE AMPLIFIER!"
2780  PRINT
2790  PRINT "PRESS <CONTINUE> WHEN READY"
2800  PRINT
2810  PAUSE
2820  BEEP 500,.4
2830  PRINT "LETHAL VOLTAGE PRESENT!!!!!"
2840  PRINT
2850  DISP "LETHAL VOLTAGE PRESENT!!!!!"
2860  IF Freq<30 THEN
2870    WAIT 5
2880    GOTO 2990
2890  END IF
2900  IF Freq<120 THEN
2910    WAIT 3
2920    GOTO 2990
2930  END IF
2940  IF Freq<1200 THEN
2950    WAIT 2
2960    GOTO 2990
2970  END IF
2980  WAIT .3
2990  OUTPUT Addr;V$,H$,"FOX1N"
3000  RETURN
3010  !
3020  !************************************************
3030  !
3040 Volt_hertz:  !
3050  !
3060  IF Volts*Freq<=1.E+7 THEN
3070    RETURN
3080  ELSE
3090    PRINT
3100    BEEP 500,.4
3110    PRINT "VOLTAGE*FREQUENCY > 1E7"
3120    PRINT "CALCULATED PRODUCT =",Volts*Freq,"WAIT"
3130    BEEP
3140  END IF
3150  WAIT 5
3160  GOSUB Volts
3170  !
3180  !************************************************
3190  !
3200 Abort:  !
3210         !
3220  CLEAR 7
3230  OUTPUT Addr;"*"
3240  OUTPUT 2;Clear$;
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!",TIMES(TIMEDATE)&" "&DATES(TIMEDATE)
3450  PRINT
3460  WAIT 3
3470  PRINTER IS 701
3480  PRINT "     RUN ABORTED! ";TIMES(TIMEDATE)&" "&DATES(TIMEDATE)
3490  PRINT
3500  PRINTER IS CRT
3510  GOTO Start
3520  !
3530 !*****************************************************
3540  !
3550 End:  !
3560  !
3570  OUTPUT 2;ClearS;
3580  BEEP 500,.4
3590  OFF KEY
3600  ! LOAD KEY "KEYAIDS"
3610  PRINT
3620  PRINT "ALL AC VOLTAGE TESTS COMPLETED! WAIT."
3630  WAIT 5
3640  LOAD "MENU"
3650  BEEP 500,.4
3660  !
3670  !******************************************
3680  !
3690  END
```

```
10    !************ AMPS ************************
20    !
30    ! Routine to test ac and dc current.
40    ! PRG = AMPS. KJL.
50    ! DISC VOLUME = TMDE3A. VERSION 1.2
60    !
70    !
80    !
90    !
100   !*******************************************
110   !
120 Start: !
130   !
140   RetestS=""            ! CLEAR THE RETEST FLAG
150   CLEAR 7
160   GOSUB Initialize
170   DIM Adc(50)                     ! Vector that contains dc sequence
180   DIM Aac(50,9)                   ! Vector that contains ac sequence
190   DIM Freq_seq(5)                 !  .... Not presently used
200   DIM Meter_readingS[15]
210   PRINTER IS CRT
220   PRINT CHRS(12)                  ! Roll screen to clear it
230   LOAD KEY "ABORTKEYS"
240   !
250   ! ------------------------------------------------------------------
260   !          Test  Data Definition Section                           .
270   ! ------------------------------------------------------------------
280   !
290   ! DC CURRENT TEST DATA
300   !
310   Dctest_length=34                  ! Number of DC Current Tests
320   !
330   ! POSITIVE DC VALUES
340   !
350   DATA 1E-5, 18E-6, 50E-6, 0.00010, 0.000180, 0.00050,
360   DATA 0.001000, 0.001800, 0.005000, 0.01000, 0.018000,  0.05000,
370   DATA 0.100000, 0.180000, 0.500000, 1.000000, 1.800000,
380   !
390   ! NEGATIVE DC VALUES
400   !
410   DATA -0.000010, -0.000018, -0.000050, -0.000100, -0.000180, -0.00050,
420   DATA -0.001000, -0.0018000, -0.005000, -0.010000, -0.018000, -.050000,
430   DATA -0.100000, -.1800000, -0.500000, -1.000000 , -1.800000
440   !
450   FOR N=1 TO Dctest_length            ! Loop number of DC CURRENT Tests
460     READ Adc(N)                       ! Read sequence into Adc(*)
470   NEXT N
480   !
490   !  AC CURRENT Test Data
500   !
510   Actest_length=17                        ! Number of AC CURRENT Tests
520   !
530   !      Current !# Freqs !------- Frequencies ---------------------------!
540   DATA  0.000010,  4,    50.,    200.,   500.,    1000.
550   DATA  0.000018,  4,    50.,    200.,   500.,    1000.
560   DATA  0.000050,  4,    50.,    200.,   500.,    1000.
570   DATA  0.000100,  4,    50.,    200.,   500.,    1000.
580   DATA  0.000180,  4,    50.,    200.,   500.,    1000.
590   DATA  0.000500,  4,    50.,    200.,   500.,    1000.
600   DATA  0.001000,  4,    50.,    200.,   500.,    1000.
610   DATA  0.001800,  4,    50.,    200.,   500.,    1000.
620   DATA  0.005000,  4,    50.,    200.,   500.,    1000.
630   DATA  0.010000,  4,    50.,    200.,   500.,    1000.
640   DATA  0.018000,  4,    50.,    200.,   500.,    1000.
650   DATA  0.050000,  4,    50.,    200.,   500.,    1000.
660   DATA  0.100000,  4,    50.,    200.,   500.,    1000.
670   DATA  0.180000,  4,    50.,    200.,   500.,    1000.
```

```
680   DATA  0.500000,  4,    50.,    200.,   500.,    1000.
690   DATA  1.000000,  4,    50.,    200.,   500.,    1000.
700   DATA  1.800000,  4,    50.,    200.,   500.,    1000.
710   !
720   FOR N=1 TO Actest_length              !  Loop each Aac Test
730     READ Aac(N,1)                       !  Read the Current into Aac(*)
740     READ Aac(N,2)                       !  Read the number of frequency pts.
750     FOR M=1 TO Aac(N,2)                 !  Loop the frequency points
760       READ Aac(N,M+2)                   !  Read the frequency points
770     NEXT M
780   NEXT N
790   !
800   ! ---------------------------------------------------------------------
810   !                End of Test Data Definition Section
820   ! ---------------------------------------------------------------------
830   !
840   !  Clear the screen and query operator for type of test to be performed
850   !
860 Restart:        !
870   !
880   PRINT CHRS(12)
890   CLEAR 7
900   RetestS=""         ! CLEAR THE RETEST FLAG
910   !
920   !
930   !
940 Choice:       !
950   !
960   BEEP
970   PRINT "         DO YOU WISH TO PERFORM A DC OR AC CURRENT ACCURACY TEST?"
980   PRINT
990   PRINT "                    (1)  DC "
1000  PRINT
1010  PRINT "                    (2)  AC "
1020  PRINT
1030  PRINT "                    (3)  RETURN TO MAIN MENU"
1040  PRINT
1050  PRINT "        ENTER   1 or 2 or 3                                  "
1060  PRINT
1070  INPUT Response
1080  PRINT CHRS(12)
1090  IF Response<1 OR Response>3 THEN Choice
1100  IF Response=3 THEN LOAD "MENU"
1110  IF Response=2 THEN GOTO Actests
1120  !
1130  ! -------------------------------------------------------------------
1140  !               Start of dc test sequence
1150  ! -------------------------------------------------------------------
1160  !
1170 Dctests:    !
1180  !
1190  RetestS=""          ! CLEAR THE RETEST FLAG
1200  BEEP
1210  PRINT
1220  PRINT "SET METER TO RESPOND TO DC CURRENT!"
1230  PRINT
1240  PRINT "PRESS <CONTINUE> WHEN READY!"
1250  PRINT
1260  PAUSE
1270  FOR T=1 TO Dctest_length
1280    PRINT CHRS(12)                         ! Clear the screen
1290    BEEP
1300    PRINT "DC test number ";T;" of ";Dctest_length! Displays test sequence
1310    Amps=Adc(T)
1320    Freq=0
1330    PRINT "PROGRAMMED FREQUENCY = DC"
1340    PRINT "PROGRAMMED CURRENT = ";Amps
```

```
1350    GOSUB Range     !     CHECK FOR PROPER DMM CONNECTIONS AND RANGE SETTINGS
1360    GOSUB Amps
1370    GOSUB Entry
1380    GOSUB Retest
1390    GOSUB Record
1400  NEXT T
1410  CLEAR 7
1420  PRINT
1430  BEEP 500,.5
1440  PRINTER IS Printer
1450  PRINT
1460  PRINT TAB(25);"ALL DC CURRENT TESTS COMPLETED"
1470  PRINT
1480  PRINTER IS CRT
1490  PRINT "ALL DC CURRENT TESTS COMPLETED! WAIT 5 SECONDS."
1500  WAIT 5
1510  LOAD "MENU"
1520  !
1530  ! ------------------------------------------------------------------------
1540  !                    Start of ac test sequence
1550  ! ------------------------------------------------------------------------
1560  !
1570 Actests:      !
1580  !
1590  Retest$=""           ! CLEAR THE RETEST FLAG
1600  BEEP
1610  PRINT
1620  PRINT "SET METER TO RESPOND TO AC CURRENT!"
1630  PRINT
1640  PRINT "PRESS <CONTINUE> WHEN READY!"
1650  PRINT
1660  PAUSE
1670  FOR Freqnum=1 TO 4                        ! Loop up to 4 freqs / current
1680    FOR T=1 TO Actest_length                ! Loop currents
1690      PRINT CHR$(12)
1700      BEEP
1710      PRINT "AC test number ";T;" of ";Actest_length! Displays test sequence
1720      Amps=Aac(T,1)
1730      Freq=Aac(T,Freqnum+2)
1740      IF Freq=0 THEN 1820
1750      PRINT "PROGRAMMED FREQUENCY = ";Freq;"Hz."
1760      PRINT "PROGRAMMED CURRENT  = ";Amps
1770      GOSUB Range    !  CHECK FOR PROPER DMM CONNECTIONS AND RANGE SETTINGS
1780      GOSUB Amps
1790      GOSUB Entry
1800      GOSUB Retest
1810      GOSUB Record
1820    NEXT T
1830  NEXT Freqnum
1840  CLEAR 7
1850  PRINT
1860  BEEP 500,.5
1870  PRINTER IS Printer
1880  PRINT
1890  PRINT TAB(12);"ALL AC CURRENT TESTS AT ALL FREQUENCIES COMPLETED"
1900  PRINT
1910  PRINTER IS CRT
1920  PRINT "ALL AC CURRENT TESTS COMPLETED! WAIT 5 SECONDS."
1930  WAIT 5
1940  GOTO Restart
1950  !
1960  ! **********************************************************************
1970  !               Start of Subroutines
1980  ! **********************************************************************
1990  !
2000 Amps: !
2010       !
```

```
2020  ! --- AMPS - Subroutine to program a Fluke Mfg Co., Inc. Model 5101 Meter
2030  !            Calibrator for ac and dc current output.
2040  !
2050  ! --- Parameters
2060  !            AMPS     - the current to be output
2070  !                       expressed in amperes                - INPUT
2080  !            FREQ     - the frequency of the output current
2090  !                       if FREQ = 0 then output is dc
2100  !                       if FREQ <>0 then output is ac
2110  !                       frequency is expressed in Hz
2120  !                       50. <=  FREQ  <= 50000.              - INPUT
2130  !            ADDR     - IEEE-488 address of JF 5101 calibrator
2140  !                       0 <= ADDR <= 31                      - INPUT
2150  !            MESS     - the command output string provided
2160  !                       by this subroutine - normally sent
2170  !                       to the 5101 via the IEEE-488 bus.    - OUTPUT
2180  !            ERRORS   - an error message for error conditions
2190  !                       (such as out-of-range, overload, etc)
2200  !                       generated by the 5101               - OUTPUT
2210  !            ERRFLG   - a flag = 0 if no error condition
2220  !                              = 1 if error condition       - OUTPUT
2230  !
2240  !----------------------------------------------------------------------
2250  !
2260  Checkout=0      ! FOR DEBUG SET=1
2270  !
2280  DIM ErrorcodeS(10)[80]
2290  DIM ErrorS[80]
2300  DIM MesS[80]
2310  Addr=Addr+0                           ! Get HP address from IEEE address
2320  Errflg=0
2330  ErrorS="No  Error Mesage"
2340  !
2350  RESTORE 2370
2360  !
2370  DATA "No Error Message (status message only)",
2380  DATA "Invalid character or sequence",
2390  DATA "Invalid frequency or resistance entry",
2400  DATA "Programmed output exceeds entry limits or instrument capabilities",
2410  DATA "Invalid frequency/output combination",
2420  DATA "Overload or overcompliance voltage",
2430  DATA "Module accessed inoperative or not installed",
2440  DATA "String command exceeds 32 characters",
2450  DATA "Tape load/feed problem or write protected",
2460  DATA "Unable to read tape"
2470  FOR N=0 TO 9
2480    READ ErrorcodeS(N)                  ! Read the Error Codes in form of
2490  NEXT N                                ! Table 2-10.
2500  !
2510  IF Amps=0 THEN OUTPUT Addr;"CC"       ! Remove current source
2520  IF Amps=0 THEN RETURN
2530  !
2540  OUTPUT Addr;"CC"                      ! Reset - stay in remote
2550  WAIT .5
2560  IF Freq<>0 THEN 2900                   ! Go to ac current section
2570  IF ABS(Amps)<.0000001 OR ABS(Amps)>1.99999 THEN ErrorS="Programmed dc CURRENT limit exceeded"
2580  IF ABS(Amps)<.0000001 OR ABS(Amps)>1.99999 THEN Errflg=1
2590  AS=VALS(Amps)
2600  OUTPUT Addr;AS                        ! Append the CURRENT value
2610  OUTPUT Addr;"A"                       ! Add the A
2620  WAIT .5
2630  OUTPUT Addr;","                       ! Add the terminator
2640  WAIT .5
2650  OUTPUT Addr;"N"                       ! Go to operate condition
2660  !
2670  ! Check for abnormal condition from 5101
2680  !
```

```
2690  WAIT 1.0                                ! Allow 5101 to settle to error
2700  OUTPUT Addr;"!?"                        ! Request central display message
2710  ENTER Addr;Stat$                        ! Store message in Stat$
2720  !
2730  IF Checkout=1 THEN PRINT "STATUS = ";Stat$
2740  !
2750  Error_num=VAL(Stat$[1,1])
2760  IF VAL(Stat$[1,1])>0 THEN Error$=Errorcode$(Error_num)
2770  IF VAL(Stat$[1,1])>0 THEN Errflg=1
2780  !
2790  IF Checkout=1 THEN PRINT Error$
2800  IF Checkout=1 THEN PRINT "Errflg = ";Errflg
2810  !
2820  IF Errflg=1 THEN OUTPUT Addr;"CC"      ! It's an error - shut it off
2830  IF Retest$="Y" OR Retest$="y" THEN GOSUB Entry
2840  RETURN
2850  !
2860  !  ---------------------------------------------------------------------
2870  !       End of the dc section    ---   Start of the ac section
2880  !  ---------------------------------------------------------------------
2890  !
2900  OUTPUT Addr;"CC"                        ! Reset - stay in remote
2910  WAIT .5
2920  IF Amps<.0000001 OR Amps>1.99999 THEN Error$="Programmed ac CURRENT limit exceeded"
2930  IF Amps<.0000001 OR Amps>1.99999 THEN Errflg=1
2940  A$=VAL$(Amps)
2950  OUTPUT Addr;A$                          ! Appedd the CURRENT value
2960  OUTPUT Addr;"A"                         ! Add the A
2970  WAIT .5
2980  OUTPUT Addr;","                         ! Add the terminator
2990  F$=VAL$(Freq)
3000  OUTPUT Addr;F$                          ! Append the frequency
3010  OUTPUT Addr;"H"
3020  WAIT .5
3030  OUTPUT Addr;","                         ! Append the terminator
3040  WAIT .5
3050  OUTPUT Addr;"N"                         ! Go to operate condition
3060  !
3070  !*******************************************
3080  !
3090  ! Check for abnormal condition from 5101
3100  !
3110  !*******************************************
3120  !
3130  WAIT 1.0                                ! Allow 5101 to settle to error
3140  OUTPUT Addr;"!?"                        ! Request central display message
3150  ENTER Addr;Stat$                        ! Store message in Stat$
3160  IF Checkout=1 THEN PRINT Stat$
3170  Error_num=VAL(Stat$[1,1])
3180  IF VAL(Stat$[1,1])>0 THEN Error$=Errorcode$(Error_num)
3190  IF VAL(Stat$[1,1])>0 THEN Errflg=1      ! Check error codes 4,5,6,8, & 9
3200  IF VAL(Stat$[2,4])=41 THEN Error$=Errorcode$(2)
3210  IF VAL(Stat$[2,4])=41 THEN Errflg=1     ! Check for invalid frequency
3220  IF VAL(Stat$[2,4])=141 THEN Error$=Errorcode$(2)
3230  IF VAL(Stat$[2,4])=141 THEN Errflg=1    ! Check for invalid frequency
3240  IF VAL(Stat$[3,5])=412 THEN Error$=Errorcode$(3)
3250  IF VAL(Stat$[3,5])=412 THEN Errflg=1    ! Check for invalid voltage
3260  IF Checkout=1 THEN PRINT Error$
3270  IF Checkout=1 THEN PRINT "Errflg = ";Errflg
3280  IF Errflg=1 THEN OUTPUT Addr;"CC"      ! It's an error - shut it off
3290  IF Retest$="Y" OR Retest$="y" THEN GOSUB Entry
3300  RETURN
3310  !
3320  !*******************************************
3330  !
3340 Entry:  !
3350  !
```

```
3360  !  This subroutine records the operator's entry of the UUT reading
3370  !  and checks for the validity of response.  In addition, it uses the
3380  !  numerical entry to determine the range the meter is set to, i.e.
3390  !  amps, milliamps, etc.
3400  !
3410  !
3420  PRINT
3430  PRINT
3440  BEEP
3450  Meter_readingS=""
3460  PRINT "  ENTER THE READING DISPLAYED ON THE DMM!"
3470  PRINT
3480  INPUT Meter_readingS                   ! The operator's entry of reading
3490  ValidS=""                              ! Clear the flag for bad entry
3500  IF Meter_readingS="" THEN 3440
3510  !
3520  IF Meter_readingS="OL" THEN Meter_readingS="100000"
3530  IF Meter_readingS="-OL" THEN Meter_readingS="-10000"
3540  !
3550  !
3560  !*****************************************
3570  !
3580 Convert:   !   Convert Meter_readingS to AMPS
3590  !
3600  FOR D=-6 TO +6                         ! Go through the ranges to determine
3610    Reading=VAL(Meter_readingS)*(10^D)!  the meter's range
3620    IF ABS(Reading/Amps-1)<.3 THEN Decade=D
3630  NEXT D
3640  !
3650 Range_check:  !Check to assure that a reasonable range has been entered
3660  !
3670  IF Decade=-6 THEN PRINT "        Meter reading  = ";Meter_readingS;"  microamps"
3680  IF Decade=-5 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
3690  IF Decade=-4 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
3700  IF Decade=-3 THEN PRINT "        Meter reading  = ";Meter_readingS;"  milliamps"
3710  IF Decade=-2 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
3720  IF Decade=-1 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
3730  IF Decade=0 THEN PRINT "         Meter reading  = ";Meter_readingS;"  amps"
3740  IF Decade=+1 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
3750  IF Decade=+2 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
3760  IF Decade=+3 THEN PRINT "        Meter reading  = ";Meter_readingS;"  kiloamps"
3770  !
3780  !  If the operator's entry is more than 30 percent in error, question it.
3790  !
3800  IF ABS(((VAL(Meter_readingS)*(10^Decade))/Amps)-1)>.3 THEN
3810    BEEP 500,1.1
3820    PRINT "RECHECK THE READING THAT WAS ENTERED!"
3830    BEEP 400,1.5
3840  END IF
3850  PRINT
3860  BEEP
3870  ValidS=""
3880  PRINT "IS THE READING ENTERED CORRECTLY?   Yes= <ENTER>;  No = <N>"
3890  INPUT ValidS                               !  Check for valid entry
3900  IF ValidS="n" OR ValidS="N" THEN 3430      !  Re-enter data
3910  IF RetestS="Y" OR RetestS="y" THEN GOSUB Retest
3920  RETURN
3930  !
3940  !*******************************************
3950  !
3960 Retest:  !    REPEAT A TEST POINT?
3970  !
3980  PRINT
3990  BEEP
4000  RetestS=""
4010  PRINT "DO YOU WISH TO RE-TEST THIS POINT? NO = <ENTER>;   YES = <Y>"
4020  INPUT RetestS
```

```
4030  IF Retest$="" THEN RETURN
4040  GOSUB Range
4050  RETURN
4060  !
4070  !*****************************************
4080  !
4090 Record: !
4100  !
4110  IF Decade=-6 THEN Meter_reading$=Meter_reading$&" uA"     ! APPEND THE UNITS TO THE METER RDG.
4120  IF Decade=-3 THEN Meter_reading$=Meter_reading$&" mA"     ! APPEND THE UNITS TO THE METER RDG.
4130  IF Decade=0 THEN Meter_reading$=Meter_reading$&" A"       ! APPEND UNITS
4140  IF Decade=+3 THEN Meter_reading$=Meter_reading$&" kA"     ! APPEND UNITS
4150  PRINTER IS CRT
4160  BEEP
4170  IF T=1 THEN Record1
4180  PRINTER IS Printer
4190  PRINT USING "16X,2D,11X,2D.6D,12X,9A";T,Amps,Meter_reading$
4200  !
4210  !*****************************************
4220  !
4230 Return:   !
4240  !
4250  PRINTER IS CRT
4260  RETURN
4270  !
4280  !*****************************************
4290  !
4300 Record1:    !
4310  !
4320  PRINTER IS Printer
4330  IF Freq=0 THEN
4340    PRINT USING "24X,24A";"DC CURRENT ACCURACY TEST"
4350    PRINT USING "24X,24A";"------------------------"
4360  ELSE
4370    PRINT
4380    IF Freq=500 THEN PRINT CHR$(12)
4390    PRINT USING "20X,28A,K,3A";"AC CURRENT ACCURACY TEST AT";Freq;" Hz."
4400    PRINT USING "20X,35A,K,3A";"-----------------------------------"
4410  END IF
4420  PRINT USING "15X,4A,10X,10A,10X,9A";"TEST","PROGRAMMED","  METER "
4430  PRINT USING "14X,6A,10X,7A,12X,9A";"NUMBER","CURRENT"," READING"
4440  PRINT USING "14X,6A,9X,10A,11X,7A";"------","----------","----------"
4450  PRINT USING "16X,2D,11X,2D.6D,12X,11A";T,Amps,Meter_reading$
4460  PRINTER IS CRT
4470  GOTO Return
4480  !
4490  !*****************************************
4500  !
4510 Initialize:       !
4520  !
4530  ON KEY 0 LABEL "TO" GOTO Abort
4540  ON KEY 1 LABEL "SAFELY" GOTO Abort
4550  ON KEY 2 LABEL "ABORT" GOTO Abort
4560  ON KEY 3 LABEL "THE" GOTO Abort
4570  ON KEY 4 LABEL "RUNNING" GOTO Abort
4580  ON KEY 5 LABEL "PROGRAM" GOTO Abort
4590  ON KEY 6 LABEL "PRESS" GOTO Abort
4600  ON KEY 7 LABEL "ANY" GOTO Abort
4610  ON KEY 8 LABEL "SOFT-" GOTO Abort
4620  ON KEY 9 LABEL "KEY!" GOTO Abort
4630  Addr=702
4640  Printer=701
4650  REMOTE Addr
4660  RETURN
4670  !
4680  !*****************************************
4690  !
```

```
4700 Abort:     !
4710  !
4720  CLEAR 7
4730  PRINT
4740  BEEP 500,.4
4750  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4760  PRINT
4770  WAIT 3
4780  PRINTER IS Printer
4790  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4800  PRINT
4810  PRINTER IS CRT
4820  GOTO Restart
4830   !
4840   !*********************************************
4850 Abort1:      !
4860  !
4870  CLEAR 7
4880  PRINT
4890  BEEP 500,.4
4900  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4910  PRINT
4920  WAIT 3
4930  PRINTER IS 701
4940  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
4950  PRINT
4960  PRINTER IS CRT
4970  GOTO Start
4980  !
4990  !*********************************************
5000  !
5010 Range:    !
5020  !
5030  BEEP
5040  PRINT
5050  OUTPUT Addr;"CC"
5060  IF Retest$="Y" OR Retest$="y" THEN PRINT CHR$(12)
5070  Valid$=""
5080  PRINT "IS THE DMM SET TO CORRECT RANGE?   Yes= <ENTER>;  No = <N>"
5090  INPUT Valid$
5100  IF Valid$="n" OR Valid$="N" THEN 5030      !  Re-enter data
5110  PRINT
5120  BEEP
5130  PRINT " TEST IN PROGRESS! WAIT FOR FURTHER INSTRUCTIONS!"
5140  ! PRINT
5150  IF Retest$="Y" OR Retest$="y" THEN GOSUB Amps
5160  RETURN
5170  !
5180  !*********************************************
5190  !
5200  END
```

```
10    !************* OHMS *************************
20    !
30    !
40    ! Routine to test resistance.
50    ! PRG = OHMS. KJL.
60    ! DISC VOLUME = TMDE3A. VERSION 1.1
70    !
80    !
90    !*******************************************
100   !
110 Start: !
120   !
130   CLEAR 7
140   DIM Ohms(50)                          ! Vector that contains RESISTANCE
150   DIM Meter_reading$[20]
160   PRINTER IS CRT
170   PRINT CHR$(12)                        ! Roll screen to clear it
180   Addr=702                                ! IEEE Address of JF 5101 Calibrator
190   Printer=701                 ! IEEE ADDRESS OF  EXTERNAL PRINTER
200   !
210   ! ------------------------------------------------------------------
220   !          Test  Data Definition Section
230   ! ------------------------------------------------------------------
240   !
250   ! RESISTANCE TEST DATA
260   !
270   Ohmstest_length=8                       ! Number of RESISTANCE Tests
280   !
290   !  Values
300   !
310   DATA 1.0      , 10     , 100    ,1000 ,10000,       100000,
320   DATA 1000000, 10000000
330   !
340   FOR N=1 TO Ohmstest_length              ! Loop number of RESISTANCE Tests
350     READ Ohms(N)                          ! Read sequence into Ohms(*)
360   NEXT N
370   !
380   ! -------------------------------------------------------------------
390   !                End of Test Data Definition Section
400   ! -------------------------------------------------------------------
410   !
420   !  Clear the screen and query operator for type of test to be performed
430   !
440 Restart:        !
450   !
460   PRINT CHR$(12)
470   CLEAR 7
480   !
490 Choice:       !
500   !
510   BEEP
520   PRINT "          DO YOU WISH TO PERFORM A RESISTANCE ACCURACY TEST?"
530   PRINT
540   PRINT "                  (1)  YES                                        "
550   PRINT "                  (2)  RETURN TO MAIN MENU                               "
560   PRINT
570   PRINT "         ENTER    1 or 2                                         "
580   PRINT
590   INPUT Response
600   PRINT CHR$(12)
610   IF Response<1 OR Response>2 THEN Choice
620   IF Response=2 THEN LOAD "MENU"
630   !
640   ! ---------------------------------------------------------------
650   !               Start of resistance test sequence
660   ! ---------------------------------------------------------------
670   !
```

```
680 Ohmstests:     !
690   !
700   BEEP
710   PRINT
720   PRINT "SET METER TO RESPOND TO RESISTANCE!"
730   PRINT
740   PRINT "PRESS <CONTINUE> WHEN READY!"
750   PRINT
760   PAUSE
770   !
780   FOR T=1 TO Ohmstest_length
790     PRINT CHRS(12)                          ! Clear the screen
800     BEEP
810     PRINT "Resistance test number ";T;" of ";Ohmstest_length! Displays test sequ
820     Res=Ohms(T)
830     PRINT "PROGRAMMED RESISTANCE = ";Res
840     GOSUB Res
850     GOSUB Entry
860     GOSUB Record
870   NEXT T
880   !
890   CLEAR 7
900   PRINT
910   BEEP 500,.5
920   PRINTER IS Printer
930   PRINT
940   PRINT TAB(25);"ALL RESISTANCE TESTS COMPLETED!"
950   PRINT
960   PRINTER IS CRT
970   PRINT "ALL RESISTANCE TESTS COMPLETED! WAIT 5 SECONDS."
980   WAIT 5
990   GOTO Restart
1000  !
1010  !
1020  ! ********************************************************************
1030  !              Start of Subroutines
1040  ! ********************************************************************
1050  !
1060 Res: !
1070     !
1080  ! --- OHMS - Subroutine to program a Fluke Mfg Co., Inc. Model 5101 Meter
1090  !              Calibrator for resistance output.
1100  !
1110  ! --- Parameters
1120  !              OHMS    - the resistance to be output
1130  !                        expressed in ohms              - INPUT
1140  !              ADDR    - IEEE-488 address of JF 5101 calibrator
1150  !                        0 <= ADDR <= 31                      - INPUT
1160  !              MESS    - the command output string provided
1170  !                        by this subroutine - normally sent
1180  !                        to the 5101 via the IEEE-488 bus.   - OUTPUT
1190  !              ERRORS  - an error message for error conditions
1200  !                        (such as out-of-range, overload, etc)
1210  !                        generated by the 5101              - OUTPUT
1220  !              ERRFLG  - a flag = 0 if no error condition
1230  !                               = 1 if error condition      - OUTPUT
1240  !
1250  !--------------------------------------------------------------------
1260  !
1270  Checkout=0     ! FOR DEBUG SET=1
1280  !
1290  DIM ErrorcodeS(10)[80]
1300  DIM ErrorS[80]
1310  DIM MesS[80]
1320  Addr=Addr+0                          ! Get HP address from IEEE address
1330  Errflg=0
1340  ErrorS="NO ERROR MESSAGE"
```

```
1350  !
1360  RESTORE 1380
1370  !
1380  DATA "No Error Message (status message only)",
1390  DATA "Invalid character or sequence",
1400  DATA "Invalid frequency or resistance entry",
1410  DATA "Programmed output exceeds entry limits or instrument capabilities",
1420  DATA "Invalid frequency/output combination",
1430  DATA "Overload or overcompliance voltage",
1440  DATA "Module accessed inoperative or not installed",
1450  DATA "String command exceeds 32 characters",
1460  DATA "Tape load/feed problem or write protected",
1470  DATA "Unable to read tape"
1480  !
1490  FOR N=0 TO 9
1500    READ ErrorcodeS(N)                  ! Read the Error Codes in form of
1510  NEXT N                                ! Table 2-10.
1520  !
1530  IF Res=0 THEN OUTPUT Addr,"CC"       ! Remove RESISTANCE source
1540  IF Res=0 THEN RETURN
1550  !
1560  OUTPUT Addr;"CC"                      ! Reset - stay in remote
1570  WAIT .5
1580  IF Res<1.0 OR Res>1.0E+7 THEN ErrorS="Programmed RESISTANCE limit exceeded"
1590  IF Res<1.0 OR Res>1.0E+7 THEN Errflg=1
1600  RS=VALS(Res)
1610  OUTPUT Addr;RS                        ! Append the RESISTANCE value
1620  OUTPUT Addr;"Z"                       ! Add the Z
1630  WAIT .5
1640  OUTPUT Addr;","                       ! Add the terminator
1650  WAIT .5
1660  OUTPUT Addr;"N"                       ! Go to operate condition
1670  !
1680  !******************************************
1690  !
1700  ! Check for abnormal condition from 5101
1710  !
1720  !******************************************
1730  !
1740  WAIT 1.0                              ! Allow 5101 to settle to error
1750  OUTPUT Addr;"!?"                      ! Request central display message
1760  ENTER Addr;StatS                      ! Store message in StatS
1770  IF Checkout=1 THEN PRINT "StatS=";StatS
1780  Error_num=VAL(StatS[1,1])
1790  IF VAL(StatS[1,1])>0 THEN ErrorS=ErrorcodeS(Error_num)
1800  IF VAL(StatS[1,1])>0 THEN Errflg=1      ! Check error codes 4,5,6,8, & 9
1810  IF VAL(StatS[2,4])=41 THEN ErrorS=ErrorcodeS(2)
1820  IF VAL(StatS[2,4])=41 THEN Errflg=1     ! Check for invalid frequency
1830  IF VAL(StatS[2,4])=141 THEN ErrorS=ErrorcodeS(2)
1840  IF VAL(StatS[2,4])=141 THEN Errflg=1    ! Check for invalid frequency
1850  IF VAL(StatS[3,5])=412 THEN ErrorS=ErrorcodeS(3)
1860  IF VAL(StatS[3,5])=412 THEN Errflg=1    ! Check for invalid voltage
1870  IF Checkout=1 THEN PRINT "ErrorS=";ErrorS
1880  IF Checkout=1 THEN PRINT "Errflg = ";Errflg
1890  IF Errflg=1 THEN OUTPUT Addr;"CC"      ! It's an error - shut it off
1900  RETURN
1910  !
1920  !******************************************
1930  !
1940 Entry:  !
1950  !
1960  !  This subroutine records the operator's entry of the UUT reading
1970  !  and check for the validity of response.  In addition, it uses the
1980  !  numerical entry to determine the range the meter is set to, i.e.
1990  !  Ohms, kiloOhms, etc.
2000  !
2010  PRINT
```

```
2020  PRINT
2030  BEEP
2040  Meter_readingS=""
2050  PRINT "  Enter the Reading Displayed on the Digital Multimeter:"
2060  PRINT
2070  INPUT Meter_readingS                  ! The operator's entry of reading
2080  IF Meter_readingS="" THEN 2030
2090  ValidS=""                             ! Clear the flag for bad entry
2100  !
2110 Convert:   !   Convert Meter_readingS to Resistance in Ohms
2120  !
2130  FOR D=-6 TO +6                        ! Go through the ranges to determine
2140    Reading=VAL(Meter_readingS)*(10^D)!  the meter's range
2150    IF ABS(Reading/Res-1)<.3 THEN Decade=D
2160  NEXT D
2170  !
2180 Range_check:  !Check to assure that a reasonable range has been entered
2190  !
2200  IF Decade=-6 THEN PRINT "        Meter reading  = ";Meter_readingS;"  microohms"
2210  IF Decade=-5 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
2220  IF Decade=-4 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
2230  IF Decade=-3 THEN PRINT "        Meter reading  = ";Meter_readingS;"  milliohms"
2240  IF Decade=-2 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
2250  IF Decade=-1 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
2260  IF Decade=0 THEN PRINT "         Meter reading  = ";Meter_readingS;"  ohms"
2270  IF Decade=+1 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
2280  IF Decade=+2 THEN PRINT "        Data entered   = ";Meter_readingS;"  CHECK IT!"
2290  IF Decade=+3 THEN PRINT "        Meter reading  = ";Meter_readingS;"  kiloohms"
2300  IF Decade=+4 THEN PRINT "        Meter reading  = ";Meter_readingS;"  CHECK IT"
2310  IF Decade=+5 THEN PRINT "        Meter reading  = ";Meter_readingS;"  CHECK IT"
2320  IF Decade=+6 THEN PRINT "        Meter reading  = ";Meter_readingS;"  megohms"
2330  !
2340  !  If the operator's entry is more than 30 percent in error, question it.
2350  !
2360  IF ABS(((VAL(Meter_readingS)*(10^Decade))/Res)-1)>.3 THEN
2370    BEEP 500,1.1
2380    PRINT "RECHECK THE READING THAT WAS ENTERED!"
2390    BEEP 400,1.5
22400  END IF
2410  PRINT
2420  BEEP
2430  ValidS=""
2440  PRINT "IS THE READING ENTERED CORRECTLY?   Yes= <ENTER>;  No = <N>"
2450  INPUT ValidS                          !  Check for valid entry
2460  IF ValidS="n" OR ValidS="N" THEN 2020 !  Re-enter data
2470  RETURN
2480  !
2490  !*******************************************
2500  !
2510 Record: !
2520  !
2530  IF Decade=-6 THEN Meter_readingS=Meter_readingS&" uOhms"
2540  IF Decade=-3 THEN Meter_readingS=Meter_readingS&" mOhms"
2550  IF Decade=0 THEN Meter_readingS=Meter_readingS&" Ohms"
2560  IF Decade=3 THEN Meter_readingS=Meter_readingS&" kOhms"
2570  IF Decade=6 THEN Meter_readingS=Meter_readingS&" MOhms"
2580  PRINTER IS CRT
2590  BEEP
2600  IF T=1 THEN Record1
2610  PRINTER IS Printer
2620  PRINT USING "16X,2D,11X,8D,12X,11A";T,Res,Meter_readingS
2630  !
2640  !*******************************************
2650  !
2660 Return:   !
2670  !
2680  PRINTER IS CRT
```

```
2690  RETURN
2700  !
2710  !*****************************************
2720  !
2730 Record1:     !
2740  !
2750  PRINTER IS Printer
2760  PRINT
2770  PRINT
2780  PRINT TAB(25);"RESISTANCE ACCURACY TEST"
2790  PRINT TAB(25);"------------------------"
2800  PRINT
2810  PRINT
2820  PRINT USING "15X,4A,11X,10A,10X,7A";"TEST","PROGRAMMED"," METER "
2830  PRINT USING "14X,6A,10X,10A,11X,7A";"NUMBER","RESISTANCE","READING"
2840  PRINT USING "14X,6A,10X,10A,9X,9A";"------","----------"," ----------"
2850  PRINT USING "16X,2D,11X,8D,12X,11A";T,Res,Meter_reading$
2860  PRINTER IS CRT
2870  GOTO Return
2880  !
2890  !*****************************************
2900  !
2910 Abort:     !
2920  !
2930  CLEAR 7
2940  PRINT
2950  BEEP 500,.4
2960  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
2970  PRINT
2980  WAIT 3
2990  PRINTER IS Printer
3000  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3010  PRINT
3020  PRINTER IS CRT
3030  GOTO Restart
3040  !
3050  !*****************************************
3060 Abort1:     !
3070  !
3080  CLEAR 7
3090  PRINT
3100  BEEP 500,.4
3110  PRINT "RUN ABORTED! WAIT!",TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3120  PRINT
3130  WAIT 3
3140  PRINTER IS 701
3150  PRINT "     RUN ABORTED! ";TIME$(TIMEDATE)&" "&DATE$(TIMEDATE)
3160  PRINT
3170  PRINTER IS CRT
3180  GOTO Start
3190  !
3200  !*****************************************
3210  !
3220  END
```

```
10    !*************** RESP *********************
20    !
30    !
40    !  Program to test AC and DC response time for meters in both
50    !  the voltage and current modes, and resistance.
60    !
70    !  PRG=RESP. VOL=TMDE3A. VERSION 1.2
80    !  KJL.
90    !
100   !*******************************************
110   !
120 Start:        !
121   !
123   Addr=702
130   DIM Pass$[1]
140   Printer=701
150   PRINTER IS CRT
160   PRINT CHR$(12)                        ! Roll the screen to clear it
170   BEEP
180   PRINT "    ENTER THE TYPE OF TEST DESIRED:"
190   PRINT "  "
200   PRINT "           (1)  DC VOLTAGE RESPONSE TIME"
201   PRINT
210   PRINT "           (2)  AC VOLTAGE RESPONSE TIME"
211   PRINT
220   PRINT "           (3)  DC CURRENT RESPONSE TIME"
221   PRINT
230   PRINT "           (4)  AC CURRENT RESPONSE TIME"
231   PRINT
240   PRINT "           (5)  RESISTANCE RESPONSE TIME"
241   PRINT
250   PRINT "           (6)  RETURN TO MAIN MENU."
260   PRINT
261   Choice=0
270   PRINT "    ENTER 1, 2, 3, 4, 5, OR 6"
280   INPUT Choice
290   IF Choice=1 THEN 420
300   IF Choice=2 THEN 1150
310   IF Choice=3 THEN 1880
320   IF Choice=4 THEN 2610
330   IF Choice=5 THEN 3350
340   IF Choice=6 THEN LOAD "MENU"
350   PRINT
360   PRINT "  IMPROPER  CHOICE  !!             Try Again!"
370   BEEP
380   WAIT 2.0
390   GOTO Start
400   !
410   !
420   ! -------------------  Start of the DC Voltage Section  ----------------
430   !
440   OUTPUT Addr;"CC"                      ! Clear 5101B
450   PRINT CHR$(12)                        ! Roll Screen to Clear
460   !
470   Time=1.0     ! PROGRAMMED RESPONSE TIME INTERVAL IN SECONDS
480   Numberoftests=6                       ! Number of tests to be performed
490   !
500   RESTORE 510
501   !
510   DATA     .005,    .05,      .5,        5.,       50.,        500.
520   !
530   FOR N=1 TO Numberoftests              ! Loop each test
540     READ D(N)                           ! Read output level
550   NEXT N
560   !
570   BEEP 3000,.6
580   PRINT "********** ENSURE THAT METER IS SET TO RESPOND TO DC VOLTAGE **********"
```

```
590   PRINT
591   PRINT
592   PRINT "   CONNECT TEST METER TO FLUKE 5101B CALIBRATOR!"
593   PRINT
600   PRINT "    At the sound of the tone, mentally note the voltage reading on the meter."
610   PRINT
620   PRINT "    This test will consist of";Numberoftests;"tests."
630   PRINT
640   PRINT "********** PRESS <CONTINUE> WHEN READY! **********"
650   PAUSE
660   PRINT CHR$(12)
670   FOR Test=1 TO Numberoftests
671     IF Test=1 THEN OUTPUT Printer;"                    DC VOLTAGE RESPONSE TIME TESTS"
672     IF Test=1 THEN OUTPUT Printer;"                    ------------------------------"
673     !
680 Dc_volts:         !
681     !
683     OUTPUT Addr;D(Test);"V"
690     OUTPUT Addr;","
700     PRINT CHR$(12)
710     PRINT
720     PRINT "----------------- Test ",Test," of ";Numberoftests;"----------------------------"
730     PRINT
740     BEEP
750     PRINT "     PROGRAMMED VOLTAGE WILL BE =";D(Test);"volts"
760     PRINT
770     PRINT "               PRESS <ENTER> WHEN READY"
780     PRINT
790     PRINT "                WATCH THE METER NOW!!!"
800     INPUT A$
810     PRINT
820     PRINT "                  DC VOLTAGE TESTS"
840     OUTPUT Addr;"N"
850     WAIT Time
851     !
860 Enter_dcvolts:       !
861     !
863     BEEP 3000,.15
870     PRINT
871     Meter_reading$=""
880     PRINT "ENTER THE READING OBSERVED AT THE TIME OF THE TONE"
890     INPUT Meter_reading$
900     PRINT
901     IF Meter_reading$="" THEN Enter_dcvolts
910     PRINT "               READING ENTERED =";Meter_reading$
920     PRINT
930     BEEP
931     Yes_no$=""
940     PRINT "IS THE READING ENTERED CORRECTLY?  (Y/N)"
950     INPUT Yes_no$
951     IF Yes_no$="" THEN 930
960     IF Yes_no$="N" OR Yes_no$="n" THEN Enter_dcvolts
970     OUTPUT Addr;"CC"
980     PRINT
990     BEEP
991     Yes_no$=""
1000    PRINT "DO YOU WISH TO RETEST THIS VOLTAGE? (Y/N)"
1010    INPUT Yes_no$
1011    IF Yes_no$="" THEN 990
1020    IF Yes_no$="Y" OR Yes_no$="y" THEN Dc_volts
1030    GOSUB Record
1040  NEXT Test
1041  Freq$="DC"
1042  GOSUB Record1
1140  !
1150  ! ------------------  Start of the AC Voltage Section  ----------------
1160  !
```

```
1170  OUTPUT Addr;"CC"
1180  PRINT CHR$(12)                          ! Roll Screen to Clear
1190  !
1200  Time=5.0
1210  Numberoftests=4                         ! Number of tests to be performed
1220  !
1230  RESTORE 1240
1231  !
1240  DATA     0.10,    1.0,    10.0,      100.
1250  !
1260  FOR N=1 TO Numberoftests                ! Loop each test
1270    READ D(N)                             ! Read output level
1280  NEXT N
1290  !
1300  BEEP 3000,.6
1310  PRINT "********** ENSURE THAT METER IS SET TO RESPOND TO AC VOLTAGE **********"
1320  PRINT
1321  PRINT
1322  PRINT "    CONNECT TEST METER TO FLUKE 5101B CALIBRATOR!"
1323  PRINT
1330  PRINT "    At the sound of the tone, mentally note the voltage reading on the meter."
1340  PRINT
1350  PRINT "    This test will consist of ";Numberoftests;" tests."
1360  PRINT
1370  PRINT "********** PRESS <CONTINUE> WHEN READY! **********"
1380  PAUSE
1390  PRINT CHR$(12)
1400  FOR Test=1 TO Numberoftests
1401    IF Test=1 THEN OUTPUT Printer;"                    AC VOLTAGE RESPONSE TIME TESTS"
1402    IF Test=1 THEN OUTPUT Printer;"                    ------------------------------"
1403    !
1410 Ac_volts:OUTPUT Addr;D(Test);"V"
1411    !
1420    OUTPUT Addr;","
1430    OUTPUT Addr;"1000H,"
1440    PRINT CHR$(12)
1450    PRINT
1460    PRINT "------------------ Test ";Test;" of ";Numberoftests;"----------------------------"
1470    PRINT
1480    BEEP
1490    PRINT "     PROGRAMMED VOLTAGE WILL BE =";D(Test);"volts"
1500    PRINT
1510    PRINT "              PRESS <ENTER> WHEN READY"
1520    PRINT
1530    PRINT "               WATCH THE METER NOW!!!"
1540    INPUT A$
1550    PRINT
1560    PRINT "                     AC VOLTAGE TESTS"
1580    OUTPUT Addr;"N"
1590    WAIT Time
1591    !
1600 Enter_acvolts:BEEP 3000,.15
1601    !
1610    PRINT
1611    Meter_reading$=""
1620    PRINT "ENTER THE READING OBSERVED AT THE TIME OF THE TONE"
1630    INPUT Meter_reading$
1631    IF Meter_reading$="" THEN Enter_acvolts
1640    PRINT
1650    PRINT "              READING ENTERED =";Meter_reading$
1660    PRINT
1670    BEEP
1671    Yes_no$=""
1680    PRINT "IS THE READING ENTERED CORRECTLY?  (Y/N)"
1690    INPUT Yes_no$
1691    IF Yes_no$="" THEN 1670
1700    IF Yes_no$="N" OR Yes_no$="n" THEN Enter_acvolts
```

```
1710    OUTPUT Addr;"CC"
1720    PRINT
1730    BEEP
1731    Yes_no$=""
1740    PRINT "DO YOU WISH TO RETEST THIS VOLTAGE? (Y/N)"
1750    INPUT Yes_no$
1751    IF Yes_no$="" THEN 1730
1760    IF Yes_no$="Y" OR Yes_no$="y" THEN Ac_volts
1770    GOSUB Record
1780  NEXT Test
1790  Freq$="1000 Hz"
1800  GOSUB Record1
1870  !
1880  ! -------------------  Start of the DC Current Section  ----------------
1890  !
1900  OUTPUT Addr;"CC"                          ! Clear 5101B
1910  PRINT CHR$(12)                            ! Roll Screen to Clear
1920  !
1930  Time=1.0
1940  Numberoftests=4                           ! Number of tests to be performed
1950  !
1960  RESTORE 1970
1961  !
1970  DATA     .0001,    .001,     .01,       .1
1980  !
1990  FOR N=1 TO Numberoftests                  ! Loop each test
2000    READ D(N)                               ! Read output level
2010  NEXT N
2020  !
2030  BEEP 3000,.6
2040  PRINT "********** ENSURE THAT METER IS SET TO RESPOND TO DC CURRENT **********"
2050  PRINT
2051  PRINT "     CONNECT TEST METER TO FLUKE 5101B CALIBRATOR!"
2052  PRINT
2060  PRINT "    At the sound of the tone, mentally note the current reading on the meter."
2070  PRINT
2080  PRINT "    This test will consist of ";Numberoftests;" tests."
2090  PRINT
2100  PRINT "********** PRESS <CONTINUE> WHEN READY! **********"
2110  PAUSE
2120  PRINT CHR$(12)
2130  FOR Test=1 TO Numberoftests
2131    IF Test=1 THEN OUTPUT Printer,"                    DC CURRENT RESPONSE TIME TESTS"
2132    IF Test=1 THEN OUTPUT Printer;"                    ------------------------------"
2133    !
2140 Dc_amps:OUTPUT Addr;D(Test);"A"
2141    !
2150    OUTPUT Addr;","
2160    PRINT CHR$(12)
2170    PRINT
2180    PRINT "------------------ Test ";Test;" of ";Numberoftests;"----------------------------"
2190    PRINT
2200    BEEP
2210    PRINT "      PROGRAMMED CURRENT WILL BE =";D(Test);"amps"
2220    PRINT
2230    PRINT "               PRESS <ENTER> WHEN READY"
2240    PRINT
2250    PRINT "                WATCH THE METER NOW!!!"
2260    INPUT A$
2270    PRINT
2280    PRINT "                     DC CURRENT TESTS"
2300    OUTPUT Addr;"N"
2310    WAIT Time
2320 Enter_dcamps:BEEP 3000,.15
2330    PRINT
2331    Meter_reading$=""
2340    PRINT "ENTER THE READING OBSERVED AT THE TIME OF THE TONE"
```

```
2350     INPUT Meter_readingS
2351     IF Meter_readingS="" THEN Enter_dcamps
2360     PRINT
2370     PRINT "              READING ENTERED =";Meter_readingS
2380     PRINT
2390     BEEP
2391     Yes_noS=""
2400     PRINT "IS THE READING ENTERED CORRECTLY?  (Y/N)"
2410     INPUT Yes_noS
2411     IF Yes_noS="" THEN 2390
2420     IF Yes_noS="N" OR Yes_noS="n" THEN Enter_dcamps
2430     OUTPUT Addr;"CC"
2440     PRINT
2450     BEEP
2451     Yes_noS=""
2460     PRINT "DO YOU WISH TO RETEST THIS CURRENT? (Y/N)"
2470     INPUT Yes_noS
2471     IF Yes_noS="" THEN 2450
2480     IF Yes_noS="Y" OR Yes_noS="y" THEN Dc_amps
2490     GOSUB Record
2500   NEXT Test
2510   FreqS="DC"
2520   GOSUB Record1
2600   !
2610   ! -------------------  Start of the AC Current Section  ----------------
2620   !
2630   OUTPUT Addr;"CC"                        ! Clear 5101B
2640   PRINT CHRS(12)                          ! Roll Screen to Clear
2650   !
2660   Time=5.0
2670   Numberoftests=4                         ! Number of tests to be performed
2680   !
2690   RESTORE 2700
2691   !
2700   DATA     .0001,    .001,     .01,       .1
2710   !
2720   FOR N=1 TO Numberoftests                ! Loop each test
2730     READ D(N)                             ! Read output level
2740   NEXT N
2750   !
2760   BEEP 3000,.6
2770   PRINT "********** ENSURE THAT METER IS SET TO RESPOND TO AC CURRENT **********"
2780   PRINT
2781   PRINT "     CONNECT TEST METER TO FLUKE 5101B CALIBRATOR!"
2782   PRINT
2790   PRINT "    At the sound of the tone, mentally note the current reading on the meter "
2800   PRINT
2810   PRINT "    This test will consist of ";Numberoftests;" tests."
2820   PRINT
2830   PRINT "********** PRESS <CONTINUE> WHEN READY! **********"
2840   PAUSE
2850   PRINT CHRS(12)
2860   FOR Test=1 TO Numberoftests
2861     IF Test=1 THEN OUTPUT Printer;"                   AC CURRENT RESPONSE TIME TESTS"
2862     IF Test=1 THEN OUTPUT Printer;"                   ------------------------------"
2863     !
2870 Ac_amps:OUTPUT Addr;D(Test);"A"
2871     !
2880     OUTPUT Addr;","
2890     OUTPUT Addr;"1000H,"
2900     PRINT CHRS(12)
2910     PRINT
2920     PRINT "------------------ Test ";Test;" of ";Numberoftests;"----------------------------"
2930     PRINT
2940     BEEP
2950     PRINT "      PROGRAMMED CURRENT WILL BE =";D(Test);"amps"
2960     PRINT
```

```
2970    PRINT "              PRESS <ENTER> WHEN READY"
2980    PRINT
2990    PRINT "               WATCH THE METER NOW!!!"
3000    INPUT A$
3010    PRINT
3020    PRINT "                      AC CURRENT TESTS"
3040    OUTPUT Addr;"N"
3050    WAIT Time
3051    !
3060 Enter_acamps:BEEP 3000,.15
3061    !
3070    PRINT
3080    PRINT "ENTER THE READING OBSERVED AT THE TIME OF THE TONE"
3081    Meter_reading$=""
3090    INPUT Meter_reading$
3091    IF Meter_reading$="" THEN Enter_acamps
3100    PRINT
3110    PRINT "              READING ENTERED =";Meter_reading$
3120    PRINT
3130    BEEP
3131    Yes_no$=""
3140    PRINT "IS THE READING ENTERED CORRECTLY?  (Y/N)"
3150    INPUT Yes_no$
3151    IF Yes_no$="" THEN 3130
3160    IF Yes_no$="N" OR Yes_no$="n" THEN Enter_acamps
3170    OUTPUT Addr;"CC"
3180    PRINT
3190    BEEP
3191    Yes_no$=""
3200    PRINT "DO YOU WISH TO RETEST THIS CURRENT? (Y/N)"
3210    INPUT Yes_no$
3211    IF Yes_no$="" THEN 3190
3220    IF Yes_no$="Y" OR Yes_no$="y" THEN Ac_amps
3230    GOSUB Record
3240  NEXT Test
3250  Freq$="1000 Hz"
3260  GOSUB Record1
3330  ! GOTO Start
3340  !
3350  ! -------------------  Start of the RESISTANCE Section  ---------------
3360  !
3370  OUTPUT Addr;"CC"                       ! Clear 5101B
3380  PRINT CHR$(12)                         ! Roll Screen to Clear
3390  !
3400  Time=8
3410  Numberoftests=4
3420  !
3430  RESTORE 3440
3431  !
3440  DATA      100,   1000,   100E3,    10E6
3450  !
3460  FOR N=1 TO Numberoftests
3470    READ D(N)
3480  NEXT N
3490  !
3500  BEEP 3000,.6
3510  PRINT "********** ENSURE THAT METER IS SET TO RESPOND TO RESISTANCE *********"
3520  PRINT
3521  PRINT "     CONNECT TEST METER TO FLUKE 5101B CALIBRATOR!"
3522  PRINT
3530  PRINT "    At the sound of the tone, mentally note the resistance reading on the meter."
3540  PRINT
3550  PRINT "    This test will consist of ";Numberoftests;" tests."
3560  PRINT
3570  PRINT "********** PRESS <CONTINUE> WHEN READY! **********"
3580  PAUSE
3590  PRINT CHR$(12)
```

```
3600  FOR Test=1 TO Numberoftests
3601    IF Test=1 THEN OUTPUT Printer;"                        RESISITANCE RESPONSE TIME TESTS"
3602    IF Test=1 THEN OUTPUT Printer;"                        --------------------------------"
3603    !
3610 Resistance:OUTPUT Addr;D(Test);"Z"
3611    !
3620    OUTPUT Addr;","
3630    PRINT CHRS(12)
3640    PRINT
3650    PRINT "----------------- Test ";Test;" of ";Numberoftests;"----------------------------"
3660    PRINT
3670    BEEP
3680    PRINT "     PROGRAMMED RESISTANCE WILL BE =";D(Test);"ohms"
3690    PRINT
3700    PRINT "              PRESS <ENTER> WHEN READY"
3710    PRINT
3720    PRINT "               WATCH THE METER NOW!!!"
3730    INPUT AS
3740    PRINT
3750    PRINT "                       RESISTANCE TESTS"
3770    OUTPUT Addr;"N"
3780    WAIT Time
3781    !
3790 Enter_resist:BEEP 3000,.15
3791    !
3800    PRINT
3801    Meter_readingS=""
3810    PRINT "ENTER THE READING OBSERVED AT THE TIME OF THE TONE"
3820    INPUT Meter_readingS
3821    IF Meter_readingS="" THEN Enter_resist
3830    PRINT
3840    PRINT "              READING ENTERED =";Meter_readingS
3850    PRINT
3860    BEEP
3861    Yes_noS=""
3870    PRINT "IS THE READING ENTERED CORRECTLY?  (Y/N)"
3880    INPUT Yes_noS
3881    IF Yes_noS="" THEN 3860
3890    IF Yes_noS="N" OR Yes_noS="n" THEN Enter_resist
3900    OUTPUT Addr;"CC"
3910    PRINT
3920    BEEP
3921    Yes_noS=""
3930    PRINT "DO YOU WISH TO RETEST THIS RESISTANCE? (Y/N)"
3940    INPUT Yes_noS
3941    IF Yes_noS="" THEN 3920
3950    IF Yes_noS="Y" OR Yes_noS="y" THEN Resistance
3960    GOSUB Record
3970  NEXT Test
3980  FreqS="DC"
3990  GOSUB Record1
4050  GOTO Start
4060  !
4070  ! *******PRINT ROUTINE HERE**************
4080  !
4090 Record:  !
4091  !
4100  PRINTER IS CRT
4110  PRINT
4120  PRINT " ENTERED READING =",Meter_readingS
4170  PRINTER IS Printer
4190  PRINT TAB(10),"PROGRAMMED VALUE = ";D(Test),"    METER READING =",Meter_readingS
4200  PRINTER IS CRT
4210  RETURN
4211  !
4212  !*****************************************
4213  !
```

```
4215 Record1:      !
4216  !
4217  OUTPUT Addr;"CC"
4218  PRINT
4219  BEEP 500,.4
4220  PRINT "ALL";Numberoftests;"TESTS COMPLETED!"
4221  PRINT
4222  PRINTER IS Printer
4223  PRINT
4224  PRINT TAB(25),"ALL";Numberoftests;"TESTS COMPLETED!"
4225  PRINT
4226  PRINT TAB(10),"TIME INTERVAL =";Time;"seconds"
4228  PRINT TAB(10),"TEST FREQUENCY = ";Freq$
4229  PRINT
4230  PRINTER IS CRT
4231  PRINT "WAIT 5 SECONDS!"
4232  WAIT 5
4233  GOTO Start
4234  !
4235  !*******************************************
4238  END
```

APPENDIX D

SPECIAL FIXTURES USED IN TEST PROCEDURES FOR THE AN/PSM-51 DIGITAL MULTIMETER

Table D-1
Special Fixtures Used in Test Procedures for
AN/PSM-51 Digital Multimeter

Item

1. Aluminum Sheet
2. Attenuator, Variable
3. Banana Connector to Test Probe Adapter
4. Binding Post to Binding Post Adapter
5. Capacitor, 0.1μF ±10%, Film
6. Continuity Test Fixture
7. Crest Factor Generator, 3:1
8. Current Loop, Single Turn
9. Current Loop, 30 Turns
10. Diode Test Fixture
11. Incremental Resistance Source
12. Microphone to BNC Adapter
13. Power Supply for 3:1 Crest Factor Generator
14. Resistor Fixture for CMRR Test, 1 kΩ
15. Resistor Summing Network, 3 kΩ

Each of the items above are illustrated on the following pages. Numbers enclosed in circles are index number for each component contained in the item. A complete description of the components is contained in the parts list at the end of this Appendix.

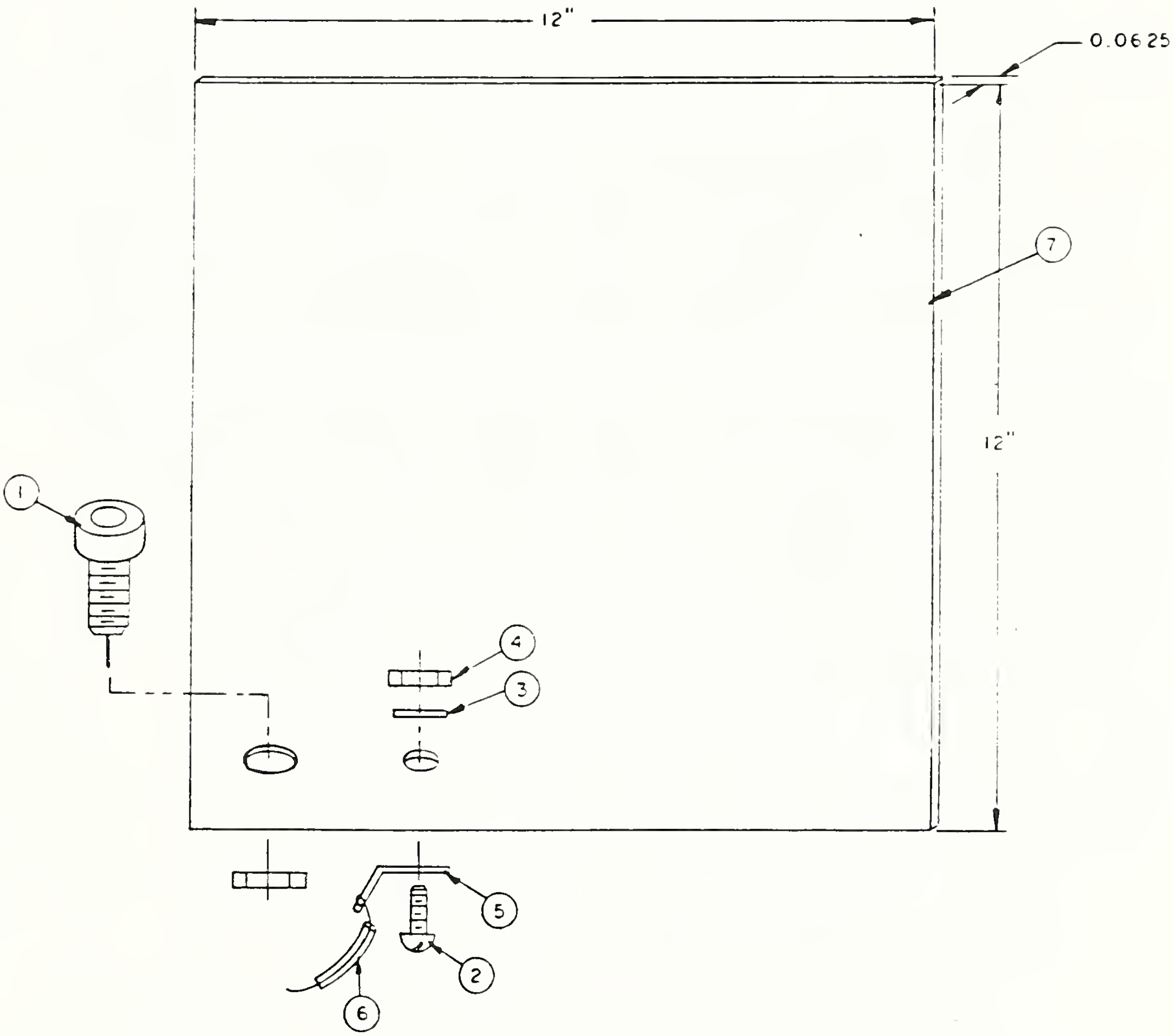

Figure D-1 Aluminum Sheet, Assembly Drawing

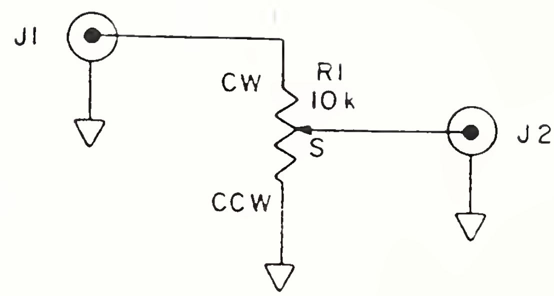

Figure D-2a Attenuator, Variable, Schematic Diagram

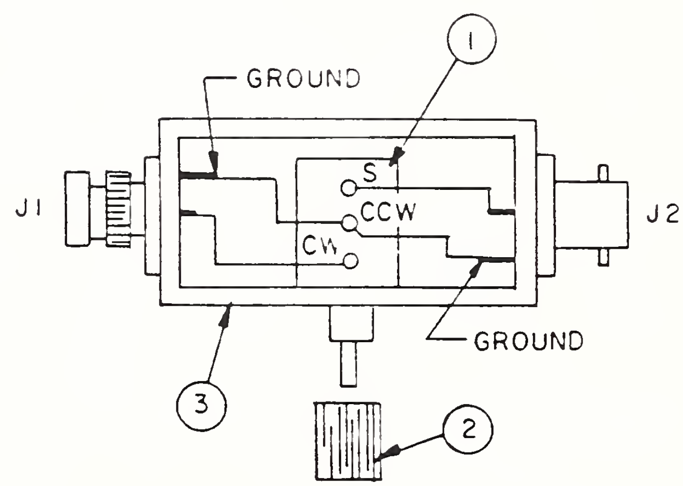

Figure D-2b Attenuator, Variable, Assembly Drawing

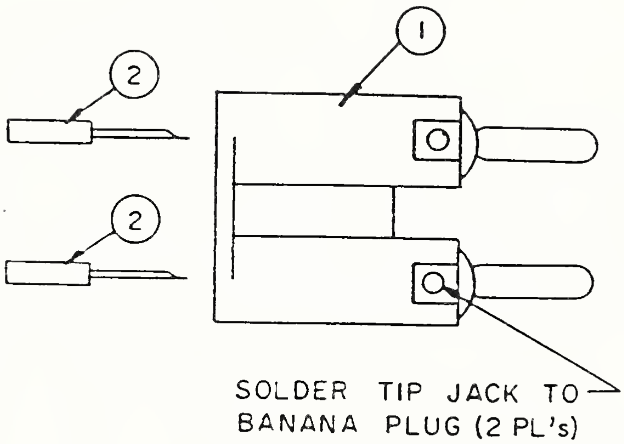

Figure D-3 Banana Connector to Test Probe Adapter, Assembly Drawing

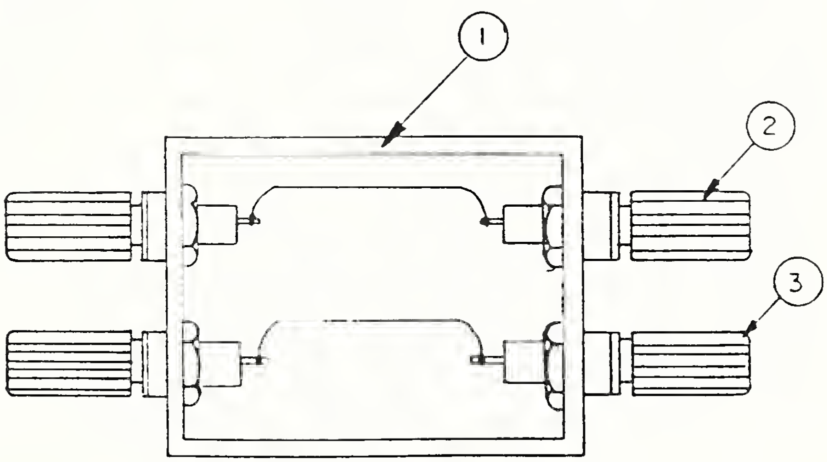

Figure D-4 Binding Post to Binding Post Adapter, Assembly Drawing

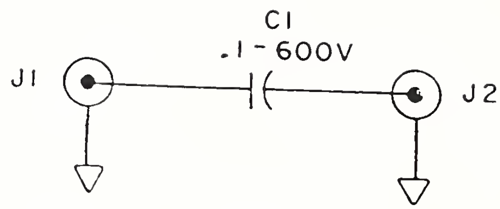

Figure D-5a Capacitor, 0.1μF ±10%, Film, Schematic Diagram

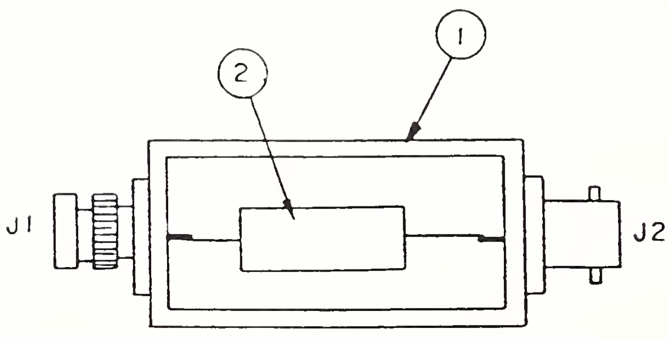

Figure D-5b Capacitor, 0.1μF ±10%, Film, Assembly Drawing

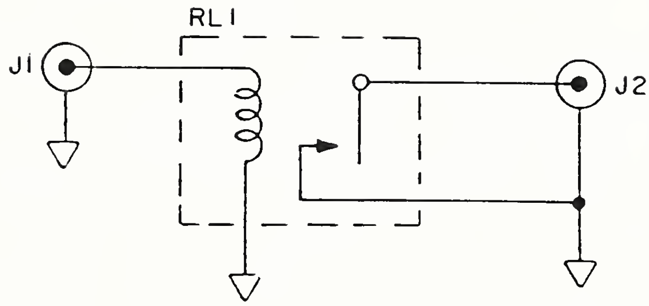

Figure D-6a Continuity Test Fixture, Schematic Diagram

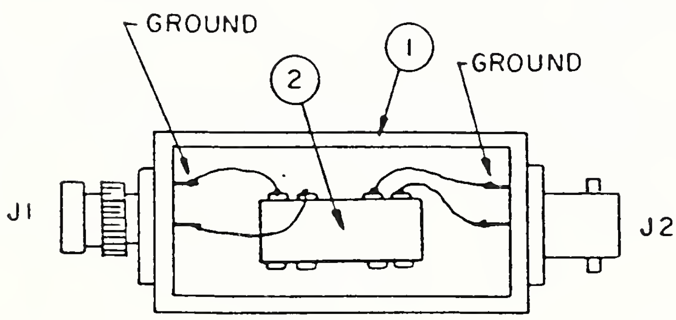

Figure D-6b Continuity Test Fixture, Assembly Drawing

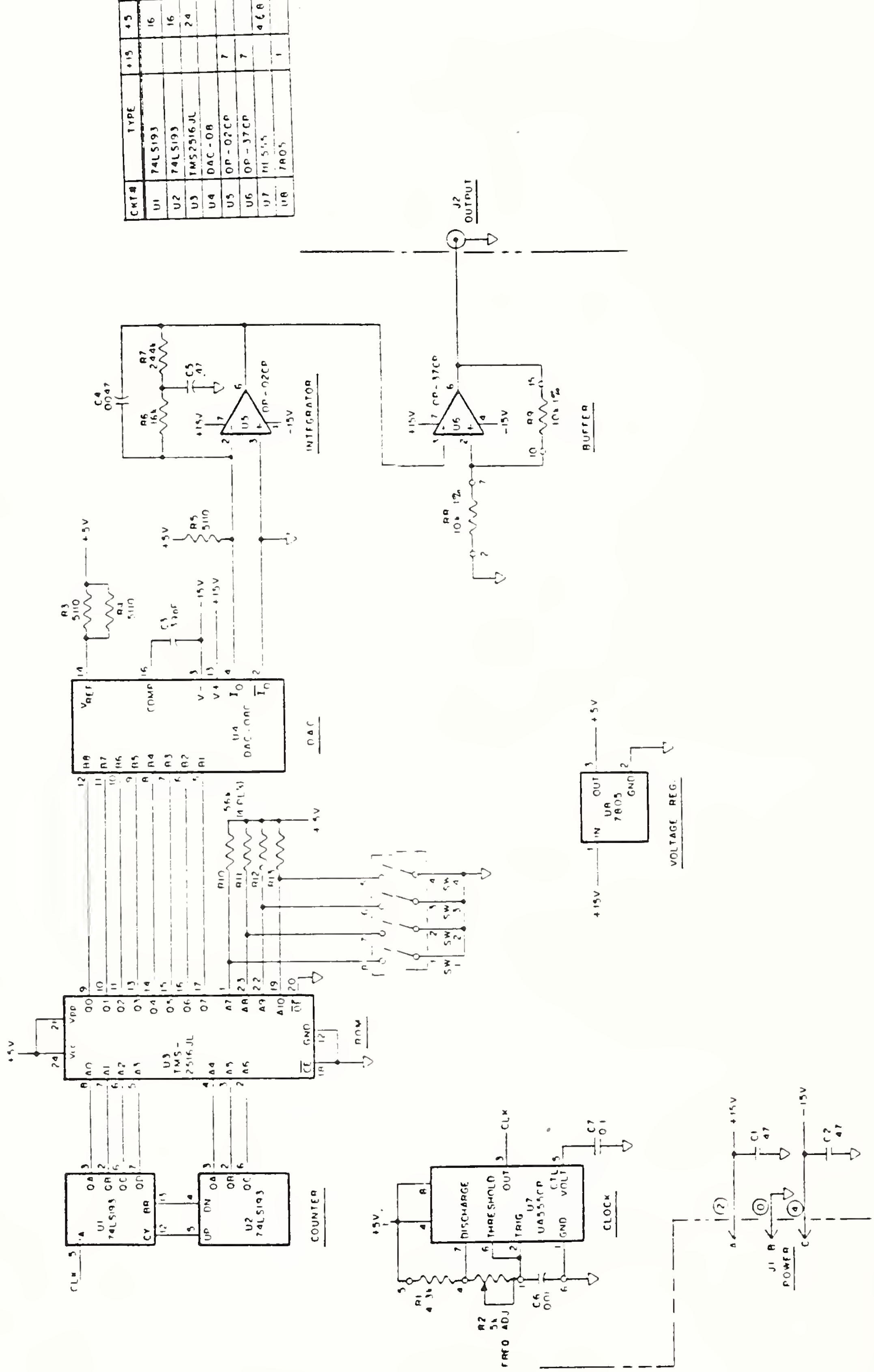

Figure D-7a Crest Factor Generator, 3:1, Schematic Diagram

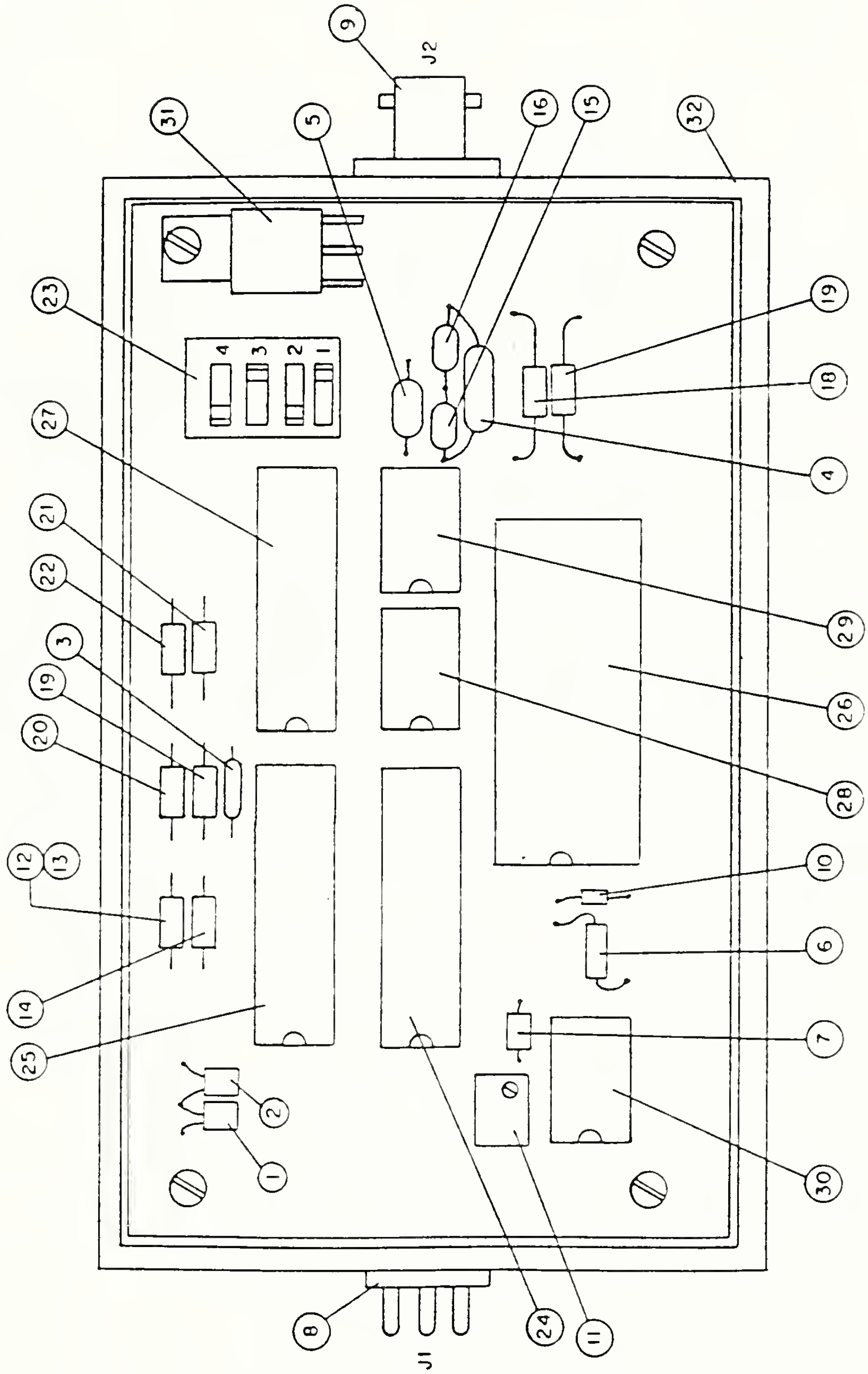

Figure D-7b Crest Factor Generator, 3:1, Assembly Drawing

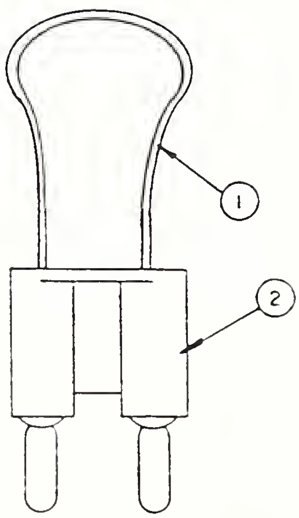

Figure D-8 Current Loop, Single Turn, Assembly Drawing

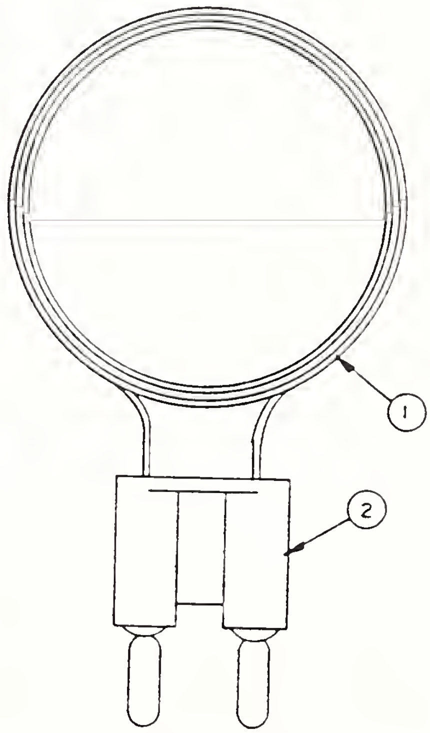

Figure D-9 Current Loop, 30 Turns, Assembly Drawing

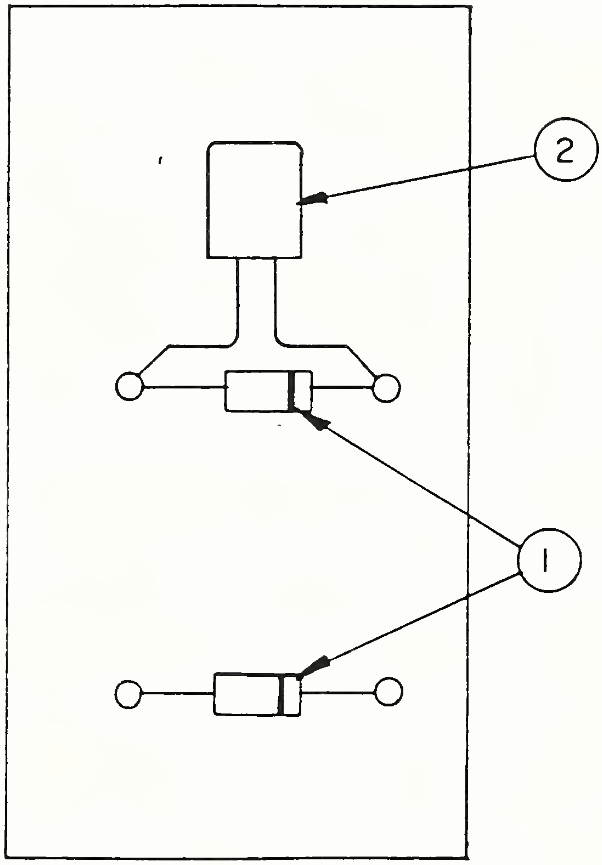

Figure D-10 Diode Test Fixture, Assembly Drawing

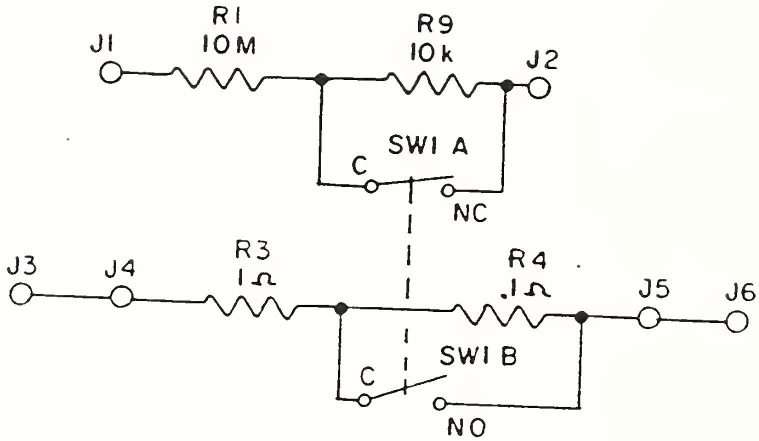

Figure D-11a Incremental Resistance Source, Schematic Diagram

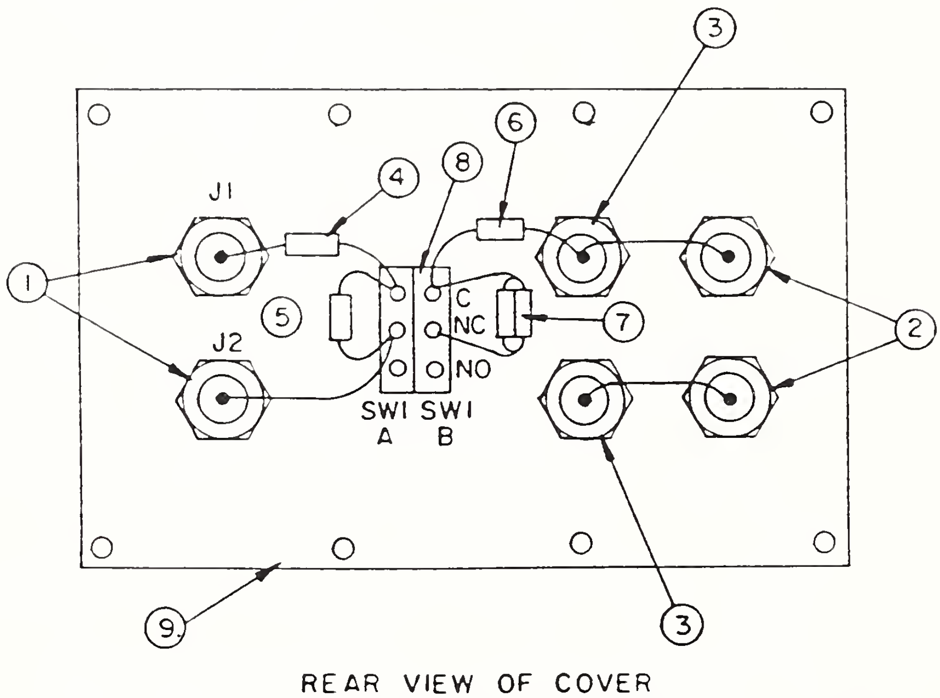

Figure D-11b Incremental Resistance Source, Assembly Drawing

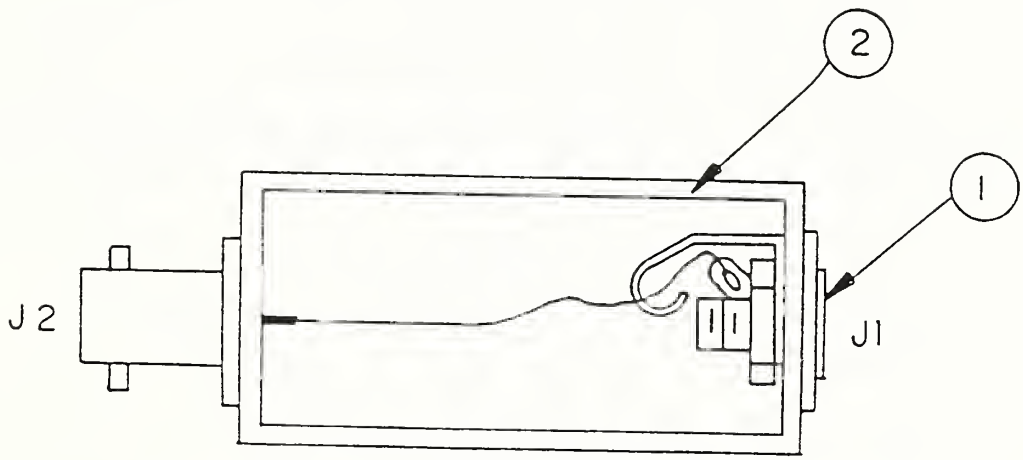

Figure D-12 Microphone to BNC Adapter, Assembly Drawing

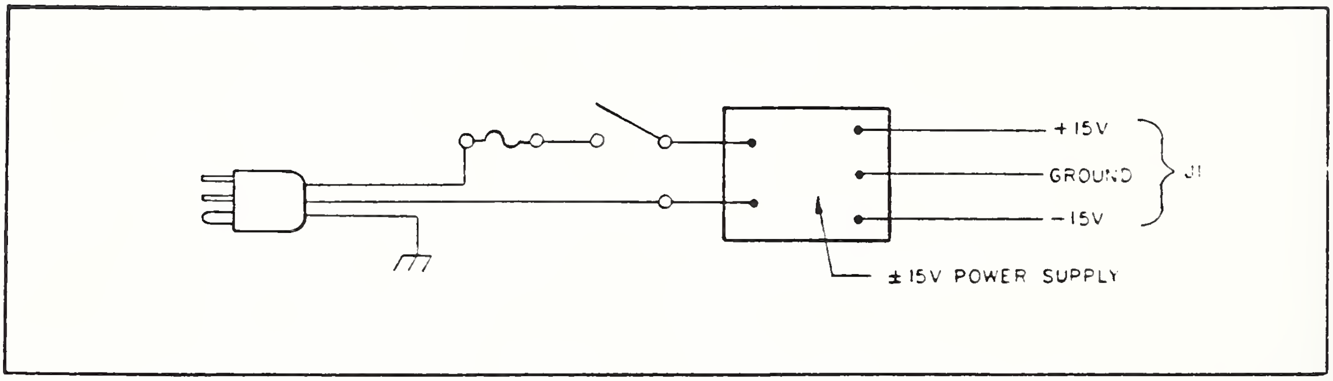

Figure D-13a Power Supply for 3:1 Crest Factor Generator, Schematic Diagram

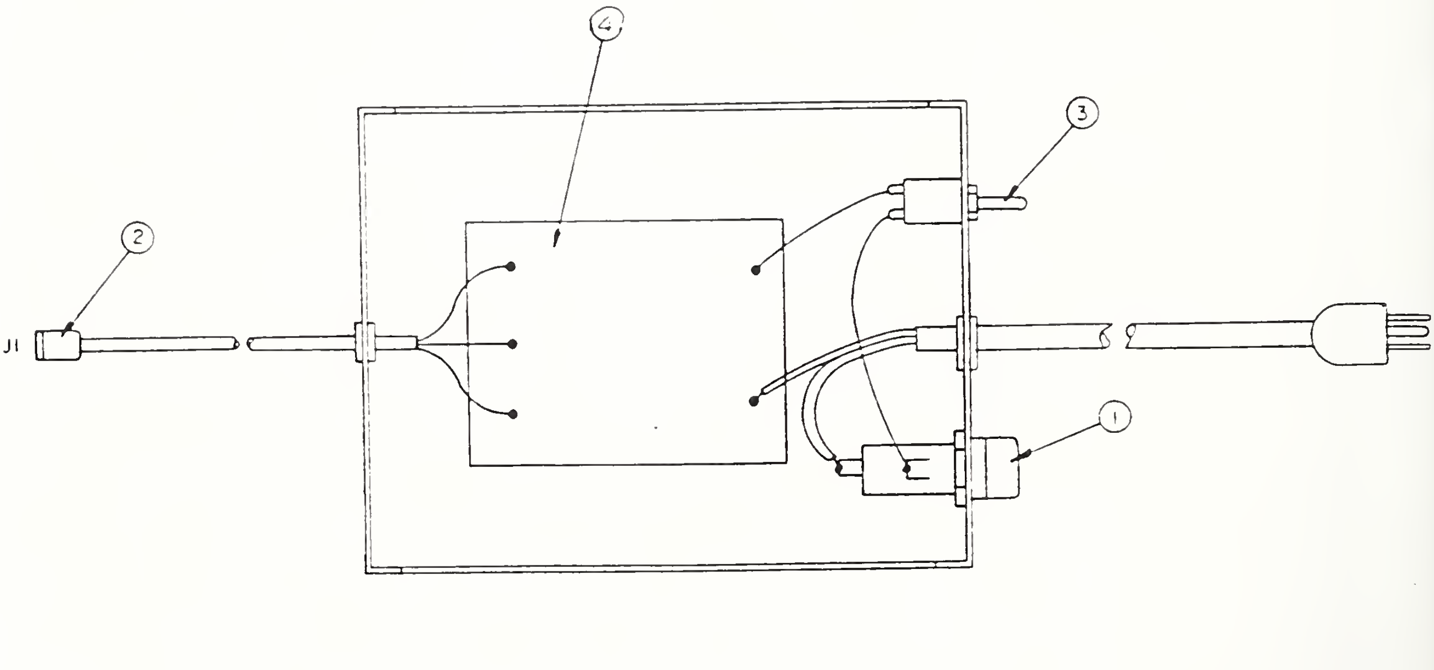

Figure D-13b Power Supply for 3:1 Crest Factor Generator, Assembly Drawing

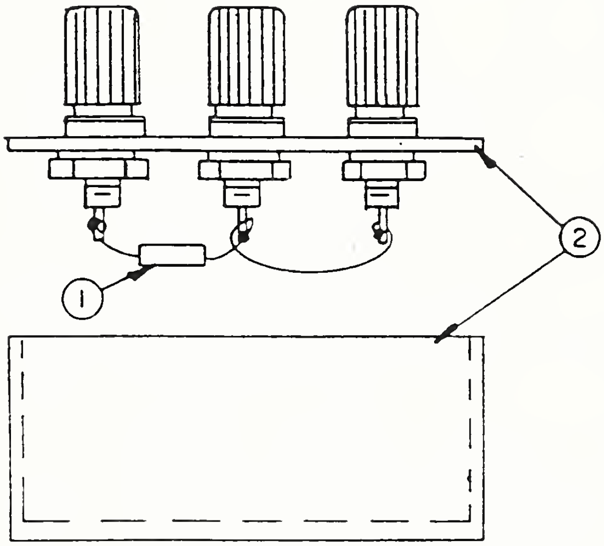

Figure D-14a Resistor Fixture for CMRR Test, 1 kΩ, Schematic Diagram

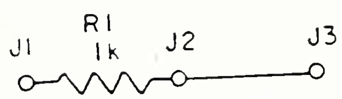

Figure D-14b Resistor Fixture for CMRR Test, 1 kΩ, Assembly Drawing

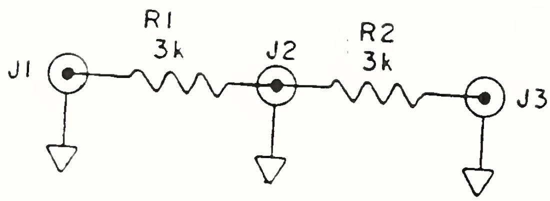

Figure D-15a Resistor Summing Network, 3 kΩ, Schematic Diagram

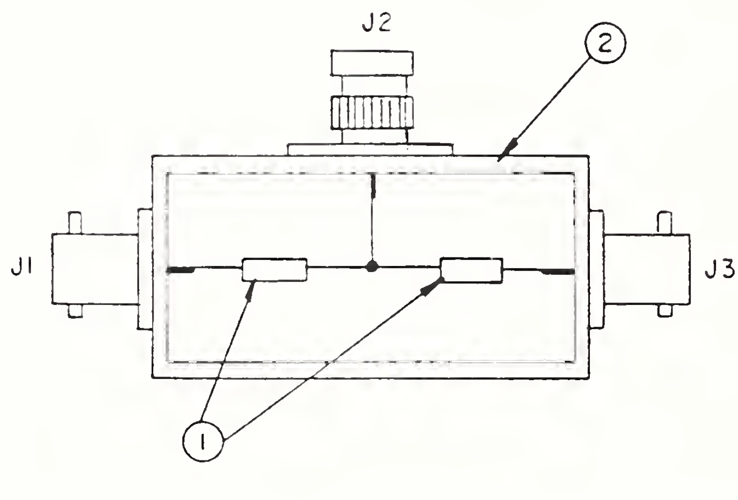

Figure D-15b Resistor Summing Network, 3 kΩ, Assembly Drawing

Table D-2 Parts List for Special Fixtures

Figure & Index No.	Reference	Description	Part No.
1-		ALUMINUM SHEET FOR CMRR TEST	REF
-1		CONNECTOR, BANNANA, Pomona Electronics	37600
-2		SCREW, 6-32 x 1/4	
-3		WASHER, #6	
-4		NUT, #6	
-5		LUG, #6, H.H. Smith	1414-6
-6		WIRE, #20 AWG, 1"	
-7		ALUMINUM SHEET, 12"x12"x0.0625	
2-		ATTENUATOR, VARIABLE	REF
-1	R1	RESISTOR, VARIABLE, 10-TURN, 10 KΩ, Beckman Instr., Helipot	7221-R10K-L.25
-2		KNOB, Alco Electronics Products	KN-500
-3	J1 J2	ENCLOSURE, with BNC Female and BNC Male Connectors, Pomona Electronics	3303
3-		BANANA CONNECTOR TO TEST PROBE ADAPTER	REF
-1		DOUBLE BANANA PLUG, Pomona	MDP-2
-2		JACK, Modified Press-in Tip Jack, E. F. Johnson (2/Ass'y)	105-1040-001
4-		BINDING POST TO BINDING POST ADAPTER	
-1		CONNECTOR, BANANA, Pomona Electronics (2 req'd)	40980
-1		CONNECTOR, BANANA, Pomona Electronics (2 req'd)	40982
-2		ENCLOSURE, PHENOLIC, Pomona Electronics	2104
5-		CAPACITOR, 0.1 μF ±10%, FILM	REF
-1	C1	CAPACITOR, 0.1 μF ±10%, 600 V, FILM, Southern Electronics,	MMPPII
-2	J1 J2	ENCLOSURE, with BNC Female and BNC Male Connectors, Pomona Electronics	3231
6-		CONTINUITY TEST FIXTURE	REF
-1	RL1	RELAY, Sigma	191TE2A1-5G
-2		ENCLOSURE, with BNC Female and BNC Male Connectors, Pomona Electronics	3231

Table D-2 Parts List for Special Fixtures, Continued

Figure & Index No.	Reference	Description	Part No.
7-		CREST FACTOR GENERATOR, 3:1	REF
-1	C1	CAPACITOR, FIXED, .47μF, 50V Ceramic, Sprague	3CZ5U474D8500C5
-2	C2	CAPACITOR, FIXED, .47μF, 50V Ceramic, Sprague	3CZ5U474D8500C5
-3	C3	CAPACITOR, FIXED, 39pF, 500V Mica, Cornell-Dubilier	CMR05E390GODR
-4	C4	CAPACITOR, FIXED, .0047, 80V Film, Sprague	192P4729R8
-5	C5	CAPACITOR, FIXED, .47μF, 50V Ceramic, Sprague	3CZ5U474D8500C5
-6	C6	CAPACITOR, FIXED, .001μF, 200V Film, Sprague	192P10292
-7	C7	CAPACITOR, FIXED, .1μF, 80V Ceramic, Sprague	8121-050-651 -104M
-8	J1	CONNECTOR, POWER, Male, 4 pins Continental Connector	4-20P
-9	J2	CONNECTOR, OUTPUT, BNC, FEMALE Part of Enclosure, Pomona	2451
-10	R1	RESISTOR, FIXED, 4320 Ω, 1%, 1/3 Watt, Mepco/Electra	5063J4K32
-11	R2	RESISTOR, VARIABLE, 5k Ω, 5% Beckman Instrument, Helipot	63WR5K
-12	R3	RESISTOR, FIXED, 5110 Ω, 1%, 1/3 Watt, Mepco/Electra	5063J5K11
-13	R4	RESISTOR, FIXED, 5110 Ω, 1%, 1/3 Watt, Mepco/Electra	5063J5K11
-14	R5	RESISTOR, FIXED, 5110 Ω, 1%, 1/3 Watt, Mepco/Electra	5063J5K11
-15	R6	RESISTOR, FIXED, 16.2 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J16K2
-16	R7	RESISTOR, FIXED, 243 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J243K
-17	R8	RESISTOR, FIXED, 10 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J10K0
-18	R9	RESISTOR, FIXED, 10 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J10K0
-19	R10	RESISTOR, FIXED, 56.2 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J56K2

Table D-2 Parts List for Special Fixtures, Continued

Figure & Index No.	Reference	Description	Part No.
7-		CREST FACTOR GENERATOR, (con't)	
-20	R11	RESISTOR, FIXED, 56.2 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J56K2
-21	R12	RESISTOR, FIXED, 56.2 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J56K2
-22	R13	RESISTOR, FIXED, 56.2 kΩ, 1%, 1/3 Watt, Mepco/Electra	5063J56K2
-23	SW1	SWITCH, DIP, FOUR POSITION SPST, CTS Inc.	341804
-24	U1	INTEGRATED CIRCUIT, Binary Counter, 4-Bits, Texas Instru.	SN74LS193J
-25	U2	INTEGRATED CIRCUIT, Binary Counter, 4-Bits Texas Instru.	SN74LS193J
-26	U3	INTEGRATED CIRCUIT, Read-Only Memory, 2K x 8 Bits (EPROM) (Encoded data is given at end of this parts list)	TMS2516JL
-27	U4	INTEGRATED CIRCUIT, Digital-to-Analog Converter, Signetics	DAC-08C
-28	U5	INTEGRATED CIRCUIT, Operational Amplifier, PMI	OP-02CP
-29	U6	INTEGRATED CIRCUIT, Operational Amplifier, PMI	OP-37CP
-30	U7	INTEGRATED CIRCUIT, Timer Fairchild	UA555TC
-31	U8	INTEGRATED CIRCUIT, Voltage Regulator, 5 Volts, Fairchild	µA7805UC
-32		ENCLOSURE, with BNC Female, modified to accept 4-pin power connector, Pomona Electronics	3303

Table D-2 Parts List for Special Fixtures, Continued

Figure & Index No.	Reference	Description	Part No.
8-		CURRENT LOOP, SINGLE TURN	REF
-1		WIRE, 24 AWG, 12"	
-2		CONNECTOR, BANANA, Pomona Electronics	40982
9-		CURRENT LOOP, 30 TURNS	REF
-1		WIRE, 22 AWG, approx 100" wrapped in 30 turns	
-2		CONNECTOR, BANANA, Pomona Electronics	40982
10-		DIODE TEST FIXTURE	REF
-1		DIODE, Silicon, Texas Instru. (2 per Ass'y)	1N914B
-2		RESISTOR, FIXED, 5 kΩ, 1/4W, 0.005%, Vishay	HP202
11-		INCREMENTAL RESISTANCE SOURCE	REF
-1		CONNECTOR, BANANA, Pomona Electronics	40984
-2		CONNECTOR, BANANA, Pomona Electronics	40989
-3		CONNECTOR, BANANA, Pomona Electronics	40985
-4		RESISTOR, FIXED, 10 Meg., 1/4W, 1%, Allen-Bradley	RN55D1005F
-5		RESISTOR, FIXED, 10 kΩ, 1%, Mepco-Electra	5063J10K0
-6		RESISTOR, FIXED, 1 Ω, 1%, Mepco-Electra	5063J1R00
-7		RESISTOR, FIXED, .1 Ω, 1%, consists of 10, 1Ω resistors in parallel, (10 req'd) Mepco-Electra	5063J1R00
-8		SWITCH, PUSH-BUTTON, DPDT, Microswitch, Inc.	2PB11-T2
-9		ENCLOSURE, No connectors Pomona Electronics	3311

Table D-2 Parts List for Special Fixtures, Continued

Figure & Index No.	Reference	Description	Part No.
12-		MICROPHONE TO BNC ADAPTER	REF
-1	J1	MICROPHONE JACK, FEMALE Switchcraft	43
-2	J2	CONNECTOR, OUTPUT, BNC, FEMALE Part of Enclosure, Pomona Electronics	
		ENCLOSURE, With BNC Female and BNC Male Connectors, (BNC Male removed) Pomona Electronics	3231
13-		POWER SUPPLY FOR 3:1 CREST FACTOR GENERATOR	
-1	F1	FUSE, 1A, 250 V, 3AG Littlefuse	312001
-2	SW1	SWITCH, TOGGLE, DPDT Alco Electronic Products	MST-205N
-3	J1	CONNECTOR, OUTPUT, Female, 4 Pins, Continental Electric	M4S
-4	U1	POWER SUPPLY, MODULAR, ±15V, 300 mA, Cardon Corp.	D-15-300
		CORD, POWER LINE, Belden	17236S
		FUSE HOLDER, Littlefuse	342004
		ENCLOSURE, Bud	CU-3007A
14-		RESISTOR FIXTURE FOR CMRR TEST	REF
-1	R1	RESISTOR, FIXED, 1000 Ω, 1%, 1/3 Watt, Mepco/Electra	5063J1K00
-2		ENCLOSURE, with three Binding Posts, Pomona Electronics	4745
15-		RESISTOR SUMMING NETWORK, 3010 Ω,	REF
-1	R1, R2	RESISTOR FIXED, 3000 Ω, 1%, 1/3 Watt, Mepco/Electra	5063J3K01
-2		ENCLOSURE, TWO BNC FEMALES TO BNC MALE, Pomona Electronics	2401

Table D-3

Code Contained in EPROM, U7, Crest Factor Generator, 3:1

```
Addr. ------------------Data------------------------

0000: C0 C0 C0 C0 C0 C0 40 40 40 40 40 40 80 80 80 80
0010: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0020: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0030: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0040: 40 40 40 40 40 40 C0 C0 C0 C0 C0 C0 80 80 80 80
0050: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0060: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0070: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0080: C0 C0 C0 C0 C0 C0 40 40 40 40 40 40 40 40 40 40
0090: 40 40 C0 C0 C0 C0 C0 C0 80 80 80 80 80 80 80 80
00A0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
00B0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
00C0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
00D0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
00E0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
00F0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
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0110: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0120: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0130: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0140: 40 40 40 40 40 40 40 C0 C0 C0 C0 C0 C0 C0 80 80
0150: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0160: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0170: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0180: C0 C0 C0 C0 C0 C0 C0 40 40 40 40 40 40 40 40 40
0190: 40 40 40 40 40 C0 C0 C0 C0 C0 C0 C0 80 80 80 80
01A0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
01B0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
01C0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
01D0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
01E0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
01F0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0200: C0 C0 C0 C0 C0 C0 C0 C0 40 40 40 40 40 40 40 40
0210: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0220: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0230: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0240: 40 40 40 40 40 40 40 40 C0 C0 C0 C0 C0 C0 C0 C0
0250: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0260: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0270: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
0280: C0 C0 C0 C0 C0 C0 C0 C0 40 40 40 40 40 40 40 40
0290: 40 40 40 40 40 40 40 40 C0 C0 C0 C0 C0 C0 C0 C0
02A0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
02B0: 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80
```

Addr.	Data															
02C0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
02D0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
02E0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
02F0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0300:	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40	40	40	40
0310:	40	40	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0320:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0330:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0340:	40	40	40	40	40	40	40	40	40	C0	C0	C0	C0	C0	C0	C0
0350:	C0	C0	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0360:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0370:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0380:	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40	40	40	40
0390:	40	40	40	40	40	40	40	40	40	40	40	C0	C0	C0	C0	C0
03A0:	C0	C0	C0	C0	80	80	80	80	80	80	80	80	80	80	80	80
03B0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
03C0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
03D0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
03E0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
03F0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
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0410:	40	40	40	40	80	80	80	80	80	80	80	80	80	80	80	80
0420:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0430:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0440:	40	40	40	40	40	40	40	40	40	40	C0	C0	C0	C0	C0	C0
0450:	C0	C0	C0	C0	80	80	80	80	80	80	80	80	80	80	80	80
0460:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0470:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0480:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40	40	40
0490:	40	40	40	40	40	40	40	40	40	40	40	40	40	40	C0	C0
04A0:	C0	C0	C0	C0	C0	C0	C0	C0	80	80	80	80	80	80	80	80
04B0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
04C0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
04D0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
04E0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
04F0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0500:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40	40
0510:	40	40	40	40	40	40	80	80	80	80	80	80	80	80	80	80
0520:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0530:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0540:	40	40	40	40	40	40	40	40	40	40	40	C0	C0	C0	C0	C0
0550:	C0	C0	C0	C0	C0	C0	80	80	80	80	80	80	80	80	80	80
0560:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0570:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0580:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40	40
0590:	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
05A0:	40	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	80	80	80	80
05B0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
05C0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
05D0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80

Addr.	Data															
05E0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
05F0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0600:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40
0610:	40	40	40	40	40	40	40	40	80	80	80	80	80	80	80	80
0620:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0630:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0640:	40	40	40	40	40	40	40	40	40	40	40	40	C0	C0	C0	C0
0650:	C0	C0	C0	C0	C0	C0	C0	C0	80	80	80	80	80	80	80	80
0660:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0670:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0680:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40	40
0690:	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
06A0:	40	40	40	40	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
06B0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
06C0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
06D0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
06E0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
06F0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0700:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40
0710:	40	40	40	40	40	40	40	40	40	40	80	80	80	80	80	80
0720:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0730:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0740:	40	40	40	40	40	40	40	40	40	40	40	40	40	C0	C0	C0
0750:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	80	80	80	80	80	80
0760:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0770:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
0780:	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	40	40	40
0790:	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
07A0:	40	40	40	40	40	40	40	C0	C0	C0	C0	C0	C0	C0	C0	C0
07B0:	C0	C0	C0	C0	80	80	80	80	80	80	80	80	80	80	80	80
07C0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
07D0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
07E0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
07F0:	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80

Table D-4
Switch Settings of Crest Factor Generator, 3:1

SW1 Switch Setting #4	#3	#2	ROM Starting Address (Hex)	τ	T	Crest Factor
On	On	On	0	12	64	4.000
On	On	Off	100	14	64	3.703
On	Off	On	200	16	64	3.464
On	Off	Off	300	18	64	3.266
Off	On	On	400	20	64	3.098
Off	On	Off	500	22	64	2.954
Off	Off	On	600	24	64	2.828
Off	Off	Off	700	26	64	2.717

Note: Switch 1 controls the waveform of the output. If Switch 1 is On, the waveform is a positive-going triangle output immediately followed by a negative-going output. If Switch 1 is Off, the waveform is a positive-going output and the negative-going output are spaced equally in time.

APPENDIX E

UNCERTAINITIES OF SOURCES AND SPECIFICATION LIMITS FOR THE AN/PSM-51 DIGITAL MULTIMETER

Table E-1 DC VOLTAGE UNCERTAINTIES

Applied DC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.02	5.0E-06	0.0050	0.001	±0.00000545	0.01999	1.0E-05	±0.0000150	0.00498	0.00502	2.75
0.010	0.02	5.0E-06	0.0050	0.001	±0.00000570	0.01999	1.0E-05	±0.0000200	0.00998	0.01002	3.51
0.018	0.02	5.0E-06	0.0050	0.001	±0.00000610	0.01999	1.0E-05	±0.0000280	0.01797	0.01803	4.59
0.050	0.20	5.0E-06	0.0050	0.001	±0.00000950	0.1999	1.0E-04	±0.0001500	0.0499	0.0502	15.79
0.100	0.20	5.0E-06	0.0050	0.001	±0.00001200	0.1999	1.0E-04	±0.0002000	0.0998	0.1002	16.67
0.180	0.20	5.0E-06	0.0050	0.001	±0.00001600	0.1999	1.0E-04	±0.0002800	0.1797	0.1803	17.50
0.500	2.00	5.0E-06	0.0050	0.001	±0.00005000	1.999	1.0E-03	±0.0015000	0.498	0.502	30.00
1.000	2.00	5.0E-06	0.0050	0.001	±0.00007500	1.999	1.0E-03	±0.0020000	0.998	1.002	26.67
1.800	2.00	5.0E-06	0.0050	0.001	±0.00011500	1.999	1.0E-03	±0.0028000	1.797	1.803	24.35
5.000	20.00	5.0E-06	0.0050	0.001	±0.00045500	19.99	1.0E-02	±0.0150000	4.98	5.01	32.97
10.000	20.00	5.0E-06	0.0050	0.001	±0.00070500	19.99	1.0E-02	±0.0200000	9.98	10.02	28.37
18.000	20.00	5.0E-06	0.0050	0.001	±0.00110500	19.99	1.0E-02	±0.0280000	17.97	18.03	25.34
50.000	200.00	5.0E-06	0.0050	0.001	±0.00450500	199.9	1.0E-01	±0.1500000	49.8	50.2	33.30
100.000	200.00	5.0E-06	0.0050	0.001	±0.00700500	199.9	1.0E-01	±0.2000000	99.8	100.2	28.55
180.000	200.00	5.0E-06	0.0050	0.001	±0.01100500	199.9	1.0E-01	±0.2800000	179.7	180.3	25.44
500.000	1100.00	5.0E-06	0.0050	0.001	±0.03600500	1000.	1.0E+00	±1.5000000	498.	502.	41.66
800.000	1100.00	5.0E-06	0.0050	0.001	±0.05100500	1000.	1.0E+00	±1.8000000	798.	802.	35.29

Notes:
[1] Fluke Model 5101B published specifications for dc voltage.
[2] Assumed meter characteristics for dc voltage, see Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-2 AC VOLTAGE UNCERTAINTIES (20 Hz - 30 Hz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.01	1.0E-05	0.1000	0.0000	±0.000015	0.01999	1.0E-05	±0.00012	0.00487	0.00513	8.33
0.010	0.01	1.0E-05	0.1000	0.0000	±0.000020	0.01999	1.0E-05	±0.00020	0.00980	0.01020	10.00
0.018	0.10	1.0E-05	0.1000	0.0000	±0.000028	0.01999	1.0E-05	±0.00032	0.01768	0.01832	11.43
0.050	0.10	1.0E-05	0.1000	0.0000	±0.000060	0.1999	1.0E-04	±0.00125	0.0487	0.0513	20.83
0.100	0.10	1.0E-05	0.1000	0.0000	±0.000110	0.1999	1.0E-04	±0.00200	0.0980	0.1020	18.18
0.180	1.00	0.0E+00	0.1000	0.0050	±0.000230	0.1999	1.0E-04	±0.00320	0.1768	0.1832	13.91
0.500	1.00	0.0E+00	0.1000	0.0050	±0.000550	1.999	1.0E-03	±0.01250	0.487	0.513	22.73
1.000	1.00	0.0E+00	0.1000	0.0050	±0.001050	1.999	1.0E-03	±0.02000	0.980	1.020	19.05
1.800	10.00	0.0E+00	0.1000	0.0050	±0.002300	1.999	1.0E-03	±0.03200	1.768	1.832	13.91
5.000	10.00	0.0E+00	0.1000	0.0050	±0.005500	19.99	1.0E-02	±0.12500	4.87	5.13	22.73
10.000	10.00	0.0E+00	0.1000	0.0050	±0.010500	19.99	1.0E-02	±0.20000	9.80	10.20	19.05
18.000	100.00	0.0E+00	0.1000	0.0050	±0.023000	19.99	1.0E-02	±0.32000	17.68	18.32	13.91
50.000	100.00	0.0E+00	0.1000	0.0050	±0.055000	199.9	1.0E-01	±1.25000	48.7	51.3	22.73
100.000	100.00	0.0E+00	0.1000	0.0050	±0.105000	199.9	1.0E-01	±2.00000	98.0	102.0	19.05
180.000	1000.00	0.0E+00	0.1200	0.0050	±0.266000	199.9	1.0E-01	±3.20000	176.8	183.2	12.03
500.000	1000.00	0.0E+00	0.1200	0.0050	±0.650000	1000.	1.0E+00	±12.50000	487.	513.	19.23
730.000	1000.00	0.0E+00	0.1200	0.0050	±0.926000	1000	1.0E+00	±15.95000	714.	746.	17.22

Notes:
1 Fluke Model 5200/5205 published specifications over the frequency range of 30 Hz to 20 kHz.
2 Assumed meter characteristics over the frequency range of 30 Hz to 39 Hz; see Notes in Appendix B.
3 The Estimated Uncertainty is for the applied voltage shown in the first column.
4 This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
5 The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-3 AC VOLTAGE UNCERTAINTIES (30 Hz - 40 Hz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resol-ution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.01	1.0E-05	0.0200	0.0000	±0.000011	0.01999	1.0E-05	±0.00005	0.00494	0.00506	5.00
0.010	0.01	1.0E-05	0.0200	0.0000	±0.000012	0.01999	1.0E-05	±0.00008	0.00992	0.01008	6.67
0.018	0.10	1.0E-05	0.0200	0.0000	±0.000014	0.01999	1.0E-05	±0.00012	0.01788	0.01812	8.82
0.050	0.10	1.0E-05	0.0200	0.0000	±0.000020	0.1999	1.0E-04	±0.00055	0.0494	0.0506	27.50
0.100	0.10	1.0E-05	0.0200	0.0000	±0.000030	0.1999	1.0E-04	±0.00080	0.0992	0.1008	26.67
0.180	1.00	0.0E+00	0.0200	0.0020	±0.000056	0.1999	1.0E-04	±0.00120	0.1788	0.1812	21.43
0.500	1.00	0.0E+00	0.0200	0.0020	±0.000120	1.999	1.0E-03	±0.00550	0.494	0.506	45.83
1.000	1.00	0.0E+00	0.0200	0.0020	±0.000220	1.999	1.0E-03	±0.00800	0.992	1.008	36.36
1.800	10.00	0.0E+00	0.0200	0.0020	±0.000560	1.999	1.0E-03	±0.01200	1.788	1.812	21.43
5.000	10.00	0.0E+00	0.0200	0.0020	±0.001200	19.99	1.0E-02	±0.05500	4.94	5.06	45.83
10.000	10.00	0.0E+00	0.0200	0.0020	±0.002200	19.99	1.0E-02	±0.08000	9.92	10.08	36.36
18.000	100.00	0.0E+00	0.0200	0.0020	±0.005600	19.99	1.0E-02	±0.12000	17.88	18.12	21.43
50.000	100.00	0.0E+00	0.0200	0.0020	±0.012000	199.9	1.0E-01	±0.55000	49.4	50.6	45.83
100.000	100.00	0.0E+00	0.0200	0.0020	±0.022000	199.9	1.0E-01	±0.80000	99.2	100.8	36.36
180.000	1000.00	0.0E+00	0.0400	0.0020	±0.092000	199.9	1.0E-01	±1.20000	178.8	181.2	13.04
500.000	1000.00	0.0E+00	0.0400	0.0020	±0.220000	1000.	1.0E+00	±5.50000	494.	506.	25.00
730.000	1000.00	0.0E+00	0.0400	0.0020	±0.312000	1000.	1.0E+00	±6.65000	723.	737.	21.31

Notes:
[1] Fluke Model 5200A/5205A published specifications over the frequency range of 30 Hz to 20 kHz.
[2] Assumed meter characteristics over the frequency range of 30 Hz to 40 Hz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-4 AC VOLTAGE UNCERTAINTIES (40 Hz to 1 kHz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resol-ution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.01	1.0E-05	0.0200	0.0000	±0.000011	0.01999	1.0E-05	±0.00007	0.00492	0.00506	6.82
0.010	0.01	1.0E-05	0.0200	0.0000	±0.000012	0.01999	1.0E-05	±0.00010	0.00990	0.01010	8.33
0.018	0.10	1.0E-05	0.0200	0.0000	±0.000014	0.01999	1.0E-05	±0.00014	0.01786	0.01814	10.29
0.050	0.10	1.0E-05	0.0200	0.0000	±0.000020	0.1999	1.0E-04	±0.00075	0.0492	0.0508	37.50
0.100	0.10	1.0E-05	0.0200	0.0000	±0.000030	0.1999	1.0E-04	±0.00100	0.0990	0.1010	33.33
0.180	1.00	0.0E+00	0.0200	0.0020	±0.000056	0.1999	1.0E-04	±0.00140	0.1786	0.1814	25.00
0.500	1.00	0.0E+00	0.0200	0.0020	±0.000120	1.999	1.0E-03	±0.00750	0.492	0.507	62.50
1.000	1.00	0.0E+00	0.0200	0.0020	±0.000220	1.999	1.0E-03	±0.01000	0.990	1.010	45.45
1.800	10.00	0.0E+00	0.0200	0.0020	±0.000560	1.999	1.0E-03	±0.01400	1.786	1.814	25.00
5.000	10.00	0.0E+00	0.0200	0.0020	±0.001200	19.99	1.0E-02	±0.07500	4.92	5.08	62.50
10.000	10.00	0.0E+00	0.0200	0.0020	±0.002200	19.99	1.0E-02	±0.10000	9.90	10.10	45.45
18.000	100.00	0.0E+00	0.0200	0.0020	±0.005600	19.99	1.0E-02	±0.14000	17.86	18.14	25.00
50.000	100.00	0.0E+00	0.0200	0.0020	±0.012000	199.9	1.0E-01	±0.75000	49.2	50.8	62.50
100.000	100.00	0.0E+00	0.0200	0.0020	±0.022000	199.9	1.0E-01	±1.00000	99.0	101.0	45.45
180.000	1000.00	0.0E+00	0.0400	0.0020	±0.092000	199.9	1.0E-01	±1.40000	178.6	181.4	15.22
500.000	1000.00	0.0E+00	0.0400	0.0020	±0.220000	1000.	1.0E+00	±7.50000	492.	508.	34.09
730.000	1000.00	0.0E+00	0.0400	0.0020	±0.312000	1000.	1.0E+00	±8.65000	721.	739.	27.72

Notes:
[1] Fluke Model 5200A/5205 published specifications over the frequency range of 30 Hz to 20 kHz.
[2] Assumed meter characteristics over the frequency range of 40 Hz to 1 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-5 AC VOLTAGE UNCERTAINTIES (1kHz - 10 kHz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.01	1.0E-05	0.0200	0.0000	±0.000011	0.01999	1.0E-05	±0.00007	0.00493	0.00508	6.82
0.010	0.01	1.0E-05	0.0200	0.0000	±0.000012	0.01999	1.0E-05	±0.00010	0.00990	0.01010	8.33
0.018	0.10	1.0E-05	0.0200	0.0000	±0.000014	0.01999	1.0E-05	±0.00014	0.01786	0.01814	10.29
0.050	0.10	±1.0E-05	0.0200	0.0000	±0.000020	0.1999	1.0E-04	±0.00075	0.0493	0.0508	37.50
0.100	0.10	1.0E-05	0.0200	0.0000	±0.000030	0.1999	1.0E-04	±0.00100	0.0990	0.1010	33.33
0.180	1.00	0.0E+00	0.0200	0.0020	±0.000056	0.1999	1.0E-04	±0.00140	0.1786	0.1814	25.00
0.500	1.00	0.0E+00	0.0200	0.0020	±0.000120	1.999	1.0E-03	±0.00750	0.493	0.508	62.50
1.000	1.00	0.0E+00	0.0200	0.0020	±0.000220	1.999	1.0E-03	±0.01000	0.990	1.010	45.45
1.800	10.00	0.0E+00	0.0200	0.0020	±0.000560	1.999	1.0E-03	±0.01400	1.786	1.814	25.00
5.000	10.00	0.0E+00	0.0200	0.0020	±0.001200	19.99	1.0E-02	±0.07500	4.93	5.08	62.50
10.000	10.00	0.0E+00	0.0200	0.0020	±0.002200	19.99	1.0E-02	±0.10000	9.90	10.10	45.45
18.000	100.00	0.0E+00	0.0200	0.0020	±0.005600	19.99	1.0E-02	±0.14000	17.86	18.14	25.00
50.000	100.00	0.0E+00	0.0200	0.0020	±0.012000	199.9	1.0E-01	±0.75000	49.3	50.8	62.50
100.000	100.00	0.0E+00	0.0200	0.0020	±0.022000	199.9	1.0E-01	±1.00000	99.0	101.0	45.45
180.000	1000.00	0.0E+00	0.0400	0.0020	±0.092000	199.9	1.0E-01	±1.40000	178.6	181.4	15.22
500.000	1000.00	0.0E+00	0.0400	0.0020	±0.220000	1000.	1.0E+00	±7.50000	493.	508.	34.09
730.000	1000.00	0.0E+00	0.0400	0.0020	±0.312000	1000.	1.0E+00	±8.65000	721.	739.	27.72

Notes:
[1] Fluke Model 5200A/5205A published specifications over the frequency range of 30 Hz to 20 kHz.
[2] Assumed meter characteristics over the frequency range of 1 kHz to 10 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-6 AC VOLTAGE UNCERTAINTIES (10 kHz to 20 kHz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[6]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.01	1.0E-05	0.0200	0.0000	±0.000011	0.01999	1.0E-05	±0.00045	0.00455	0.00545	40.91
0.010	0.01	1.0E-05	0.0200	0.0000	±0.000012	0.01999	1.0E-05	±0.00050	0.00950	0.01050	41.67
0.018	0.10	1.0E-05	0.0200	0.0000	±0.000014	0.01999	1.0E-05	±0.00058	0.01742	0.01858	42.65
0.050	0.10	1.0E-05	0.0200	0.0000	±0.000020	0.1999	1.0E-04	±0.00450	0.0455	0.0545	225.00
0.100	0.10	1.0E-05	0.0200	0.0000	±0.000030	0.1999	1.0E-04	±0.00500	0.0950	0.1050	166.67
0.180	1.00	0.0E+00	0.0200	0.0020	±0.000056	0.1999	1.0E-04	±0.00580	0.1742	0.1858	103.57
0.500	1.00	0.0E+00	0.0200	0.0020	±0.000120	1.999	1.0E-03	±0.04500	0.455	0.545	375.00
1.000	1.00	0.0E+00	0.0200	0.0020	±0.000220	1.999	1.0E-03	±0.05000	0.950	1.050	227.27
1.800	10.00	0.0E+00	0.0200	0.0020	±0.000560	1.999	1.0E-03	±0.05800	1.742	1.858	103.57
5.000	10.00	0.0E+00	0.0200	0.0020	±0.001200	19.99	1.0E-02	±0.45000	4.55	5.45	375.00
10.000	10.00	0.0E+00	0.0200	0.0020	±0.002200	19.99	1.0E-02	±0.50000	9.50	10.50	227.27
18.000	100.00	0.0E+00	0.0200	0.0020	±0.005600	19.99	1.0E-02	±0.58000	17.42	18.58	103.57
50.000	100.00	0.0E+00	0.0200	0.0020	±0.012000	199.9	1.0E-01	±4.50000	45.5	54.5	375.00
100.000	100.00	0.0E+00	0.0200	0.0020	±0.022000	199.9	1.0E-01	±5.00000	95.0	105.0	227.27
180.000	1000.00	0.0E+00	0.0400	0.0020	±0.092000	199.9	1.0E-01	±5.80000	174.2	185.8	63.04
500.000	1000.00	0.0E+00	0.0400	0.0020	±0.220000	1000.	1.0E+00	±45.00000	455.	545.	204.55
730.000	1000.00	0.0E+00	0.0400	0.0020	±0.312000	1000.	1.0E+00	±47.30000	682.	777.	151.60

Notes:
[1] Fluke Model 5200A/5205A published specifications over the frequency range of 30 Hz to 20 kHz.
[2] Assumed meter characteristics over the frequency range of 10 kHz to 20 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[6] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-7 AC VOLTAGE UNCERTAINTIES (50 Hz - 1 kHz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[6]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.02	5.0E-05	0.0500	0 0050	±0.000053	0.01999	1.0E-05	±0.00005	0.00494	0.005055	1.03
0.010	0.02	5.0E-05	0.0500	0.0050	±0.000056	0.01999	1.0E-05	±0.00008	0.00992	0.010080	1.43
0.018	0.02	5.0E-05	0.0500	0.0050	±0.000060	0.01999	1.0E-05	±0.00012	0.01788	0.018120	2.00
0.050	0.20	5.0E-05	0.0500	0.0050	±0.000085	0.1999	1.0E-04	±0.00055	0.0494	0.050550	6.47
0.100	0.20	5.0E-05	0.0500	0.0050	±0.000110	0.1999	1.0E-04	±0.00080	0.0992	0.100800	7.27
0.180	0.20	5.0E-05	0.0500	0.0050	±0.000150	0.1999	1.0E-04	±0.00120	0.1788	0.181200	8.00
0.500	2.00	5.0E-05	0.0500	0.0050	±0.000400	1.999	1.0E-03	±0.00550	0.494	0.505500	13.75
1.000	2.00	5.0E-05	0.0500	0.0050	±0.000650	1.999	1.0E-03	±0.00800	0.992	1.008000	12.31
1.800	2.00	5.0E-05	0.0500	0.0050	±0.001050	1.999	1.0E-03	±0.01200	1.788	1.812000	11.43
5.000	20.00	5.0E-05	0.0500	0.0050	±0.003550	19.99	1.0E-02	±0.05500	4.94	5.055000	15.49
10 000	20.00	5.0E-05	0.0500	0.0050	±0.006050	19.99	1.0E-02	±0.08000	9.92	10.080000	13.22
18.000	20.00	5.0E-05	0.0500	0.0050	±0.010050	19.99	1.0E-02	±0.12000	17.88	18.120000	11.94
50.000	200.00	5.0E-05	0.0500	0.0050	±0.035050	199.9	1 0E-01	±0.55000	49.4	50.550000	15.69
100.000	200.00	5.0E-05	0.0500	0.0050	±0.060050	199.9	1.0E-01	±0.80000	99.2	100.800000	13.32
180.000	200.00	5.0E-05	0.0500	0.0050	±0.100050	199.9	1.0E-01	±1.20000	178.8	181.200000	11.99
500.000	1100.00	5.0E-05	0.0500	0.0050	±0.305050	1000.	1.0E+00	±5.50000	494.	505.500000	18.03
730.000	1100.00	5.0E-05	0.0500	0.0050	±0.420050	1000.	1.0E+00	±6.65000	723.	736.650000	15.83

Notes:
[1] Fluke Model 5101B published specifications over the frequency range of 50 Hz to 10 kHz.
[2] Assumed meter characteristics over the frequency range of 50 Hz to 1 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[6] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-8 AC VOLTAGE UNCERTAINTIES (1 kHz - 10 kHz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1] Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Digital Multimeter Specifications[2] Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	Uncertainty Ratio[5]
0.005	0.02	5.0E-05	0.0500	0.0050	±0.000053	0.01999	1.0E-05	±0.00007	0.00492	0.00508	1.40
0.010	0.02	5.0E-05	0.0500	0.0050	±0.000056	0.01999	1.0E-05	±0.00010	0.00990	0.01010	1.79
0.018	0.02	5.0E-05	0.0500	0.0050	±0.000060	0.01999	1.0E-05	±0.00014	0.01786	0.01814	2.33
0.050	0.20	5.0E-05	0.0500	0.0050	±0.000085	0.1999	1.0E-04	±0.00075	0.0492	0.0508	8.82
0.100	0.20	5.0E-05	0.0500	0.0050	±0.000110	0.1999	1.0E-04	±0.00100	0.0990	0.1010	9.09
0.180	0.20	5.0E-05	0.0500	0.0050	±0.000150	0.1999	1.0E-04	±0.00140	0.1786	0.1814	9.33
0.500	2.00	5.0E-05	0.0500	0.0050	±0.000400	1.999	1.0E-03	±0.00750	0.492	0.508	18.75
1.000	2.00	5.0E-05	0.0500	0.0050	±0.000650	1.999	1.0E-03	±0.01000	0.990	1.010	15.38
1.800	2.00	5.0E-05	0.0500	0.0050	±0.001050	1.999	1.0E-03	±0.01400	1.786	1.814	13.33
5.000	20.00	5.0E-05	0.0500	0.0050	±0.003550	19.99	1.0E-02	±0.07500	4.92	5.08	21.13
10.000	20.00	5.0E-05	0.0500	0.0050	±0.006050	19.99	1.0E-02	±0.10000	9.90	10.10	16.53
18.000	20.00	5.0E-05	0.0500	0.0050	±0.010050	19.99	1.0E-02	±0.14000	17.8	18.14	13.93
50.000	200.00	5.0E-05	0.0500	0.0050	±0.035050	199.9	1.0E-01	±0.75000	49.2	50.8	21.40
100.000	200.00	5.0E-05	0.0500	0.0050	±0.060050	199.9	1.0E-01	±1.00000	99.0	101.0	16.65
180.000	200.00	5.0E-05	0.0500	0.0050	±0.100050	199.9	1.0E-01	±1.40000	178.	181.4	13.99
500.000	1100.00	5.0E-05	0.0500	0.0050	±0.305050	1000.	1.0E+00	±7.50000	492.	508.	24.59
730.000	1100.00	5.0E-05	0.0500	0.0050	±0.420050	1000.	1.0E+00	±8.65000	721.	739.	20.59

Notes:
[1] Fluke Model 5101B published specifications over the frequency range of 50 Hz to 10 kHz.
[2] Assumed meter characteristics over the frequency range of 1 kHz to 10 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-9 AC VOLTAGE UNCERTAINTIES (10 kHz - 20 kHz)

Applied AC Voltage	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (V)	Offset (V)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (V)	Maximum Reading[4] (V)	Resolution (V)	Estimated Meter Uncertainty[3] (V)	Acceptable Meter Reading Min. (V)	Acceptable Meter Reading Max. (V)	
0.005	0.02	1.0E-05	0.0800	0.0080	±0.000016	0.01999	1.0E-05	±0.00045	0.00455	0.00545	28.85
0.010	0.02	1.0E-05	0.0800	0.0080	±0.000020	0.01999	1.0E-05	±0.00050	0.00950	0.01050	25.51
0.018	0.02	1.0E-05	0.0800	0.0080	±0.000026	0.01999	1.0E-05	±0.00058	0.01742	0.01858	22.31
0.050	0.20	1.0E-05	0.0800	0.0080	±0.000066	0.1999	1.0E-04	±0.00450	0.0455	0.0545	68.18
0.100	0.20	1.0E-05	0.0800	0.0080	±0.000106	0.1999	1.0E-04	±0.00500	0.0950	0.1050	47.17
0.180	0.20	1.0E-05	0.0800	0.0080	±0.000170	0.1999	1.0E-04	±0.00580	0.1742	0.1858	34.12
0.500	2.00	1.0E-05	0.0800	0.0080	±0.000570	1.999	1.0E-03	±0.04500	0.455	0.545	78.95
1.000	2.00	1.0E-05	0.0800	0.0080	±0.000970	1.999	1.0E-03	±0.05000	0.950	1.050	51.55
1.800	2.00	1.0E-05	0.0800	0.0080	±0.001610	1.999	1.0E-03	±0.05800	1.742	1.858	36.02
5.000	20.00	1.0E-05	0.0800	0.0080	±0.005610	19.99	1.0E-02	±0.45000	4.55	5.45	80.21
10.000	20.00	1.0E-05	0.0800	0.0080	±0.009610	19.99	1.0E-02	±0.50000	9.50	10.50	52.03
18.000	20.00	1.0E-05	0.0800	0.0080	±0.016010	19.99	1.0E-02	±0.58000	17.42	18.58	36.23
50.000	200.00	1.0E-05	0.0800	0.0080	±0.056010	199.9	1.0E-01	±4.50000	45.5	54.5	80.34
100.000	200.00	1.0E-05	0.0800	0.0080	±0.096010	199.9	1.0E-01	±5.00000	95.0	105.0	52.08
180.000	200.00	1.0E-05	0.0800	0.0080	±0.160010	199.9	1.0E-01	±5.80000	174.2	185.8	36.25
500.000	1100.00	1.0E-05	0.0800	0.0080	±0.488010	1000.	1.0E+00	±45.00000	455.	545.	92.21
730.000	1100.00	1.0E-05	0.0800	0.0080	±0.672010	1000.	1.0E+00	±47.30000	682.	777.	70.39

Notes:
[1] Fluke Model 5101B published specifications over the frequncy range of 10 kHz to 50 kHz.
[2] Assumed meter characteristics over the frequency rnage of 10 kHz to 20 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied voltage shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-10 DC CURRENT UNCERTAINTIES

Applied DC Current	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (A)	Offset (A)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (A)	Maximum Reading[4] (A)	Resolution (V)	Estimated Meter Uncertainty[3] (A)	Acceptable Meter Reading Min. (A)	Acceptable Meter Reading Max. (A)	
0.000010	0.0002	1.0E-08	0.0250	0.0025	±1.75E-08	0.00002	1.0E-07	±1.5E-07	0.00000985	0.00001015	8.57
0.000018	0.0002	1.0E-08	0.0250	0.0025	±1.95E-08	0.00002	1.0E-07	±1.9E-07	0.00001781	0.00001819	9.74
0.000050	0.0002	1.0E-08	0.0250	0.0025	±2.75E-08	0.00020	1.0E-06	±1.2E-06	0.0000487	0.0000513	45.45
0.000100	0.0002	1.0E-08	0.0250	0.0025	±4.00E-08	0.00020	1.0E-06	±1.5E-06	0.0000985	0.0001015	37.50
0.000180	0.0002	1.0E-08	0.0250	0.0025	±6.00E-08	0.00020	1.0E-06	±1.9E-06	0.0001781	0.0001819	31.67
0.000500	0.0020	1.0E-08	0.0250	0.0025	±1.85E-07	0.00200	1.0E-05	±1.2E-05	0.000487	0.000513	67.57
0.001000	0.0020	1.0E-08	0.0250	0.0025	±3.10E-07	0.00200	1.0E-05	±1.5E-05	0.000985	0.001015	48.39
0.001800	0.0020	1.0E-08	0.0250	0.0025	±5.10E-07	0.00200	1.0E-05	±1.9E-05	0.001781	0.001819	37.25
0.005000	0.0200	1.0E-08	0.0250	0.0025	±1.76E-06	0.0200	1.0E-04	±1.3E-04	0.00487	0.00513	71.02
0.010000	0.0200	1.0E-08	0.0250	0.0025	±3.01E-06	0.0200	1.0E-04	±1.5E-04	0.00985	0.01015	49.83
0.018000	0.0200	1.0E-08	0.0250	0.0025	±5.01E-06	0.0200	1.0E-04	±1.9E-04	0.01781	0.01819	37.92
0.050000	0.2000	1.0E-08	0.0250	0.0025	±1.75E-05	0.200	1.0E-03	±1.4E-03	0.0486	0.0514	78.53
0.010000	0.2000	1.0E-08	0.0250	0.0025	±7.51E-06	0.200	1.0E-03	±1.1E-03	0.00892	0.01108	143.14
0.180000	0.2000	1.0E-08	0.0250	0.0025	±5.00E-05	0.200	1.0E-03	±2.3E-03	0.1776	0.1824	46.99
0.500000	2.0000	1.0E-08	0.0250	0.0025	±1.75E-04	2.00	1.0E-02	±1.4E-02	0.486	0.514	78.57
1.000000	2.0000	1.0E-08	0.0250	0.0025	±3.00E-04	2.00	1.0E-02	±1.7E-02	0.9825	1.018	58.33
1.800000	2.0000	1.0E-08	0.0250	0.0025	±5.00E-04	2.00	1.0E-02	±2.3E-02	1.777	1.824	47.00

Notes:
[1] Fluke Model 5101B published specifications for dc current.
[2] Assumed meter characteristics for dc current; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied current shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

Table E-11 AC CURRENT UNCERTAINTIES (50 Hz - 1 kHz)

Applied AC Current	Calibrator 6 Mo. Accuracy[1]					Digital Multimeter Specifications[2]					Uncertainty Ratio[5]
	Range (A)	Offset (A)	Percent of Setting	Percent of Range	Estimated Uncertainty[3] (A)	Maximum Reading[4] (A)	Resol-ution (A)	Estimated Meter Uncertainty[3] (A)	Acceptable Meter Reading Min. (A)	Acceptable Meter Reading Max. (A)	
0.000010	0.000200	2.0E-08	0.0700	0.0100	±0.000000047	0.000020	1.0E-07	±6.50E-07	0.00000935	0.00001065	13.83
0.000018	0.000200	2.0E-08	0.0700	0.0100	±0.000000053	0.000020	1.0E-07	±7.70E-07	0.00001723	0.00001877	14.64
0.000050	0.000200	2.0E-08	0.0700	0.0100	±0.000000075	0.000200	1.0E-07	±1.25E-06	0.0000487	0.0000513	16.67
0.000100	0.000200	2.0E-08	0.0700	0.0100	±0.000000110	0.000200	1.0E-07	±2.00E-06	0.0000980	0.0001020	18.18
0.000180	0.000200	2.0E-08	0.0700	0.0100	±0.000000166	0.000200	1.0E-07	±3.20E-06	0.0001768	0.0001832	19.28
0.000500	0.002000	2.0E-08	0.0700	0.0100	±0.000000570	0.00200	1.0E-06	±1.25E-05	0.000487	0.000513	21.93
0.001000	0.002000	2.0E-08	0.0700	0.0100	±0.000000920	0.00200	1.0E-06	±2.00E-05	0.000980	0.001020	21.74
0.001800	0.002000	2.0E-08	0.0700	0.0100	±0.000001480	0.00200	1.0E-06	±3.20E-05	0.001768	0.001832	21.62
0.005000	0.020000	2.0E-08	0.0700	0.0100	±0.000005520	0.0200	1.0E-05	±1.25E-04	0.00487	0.00513	22.64
0.010000	0.020000	2.0E-08	0.0700	0.0100	±0.000009020	0.0200	1.0E-05	±2.00E-04	0.00980	0.01020	22.17
0.018000	0.020000	2.0E-08	0.0700	0.0100	±0.000014620	0.0200	1.0E-05	±3.20E-04	0.01768	0.01832	21.89
0.050000	0.200000	2.0E-08	0.0700	0.0100	±0.000055020	0.200	1.0E-04	±1.25E-03	0.0487	0.0513	22.72
0.100000	0.200000	2.0E-08	0.0700	0.0100	±0.000090020	0.200	1.0E-04	±2.00E-03	0.0980	0.1020	22.22
0.180000	0.200000	2.0E-08	0.0700	0.0100	±0.000146020	0.200	1.0E-04	±3.20E-03	0.1768	0.1832	21.91
0.500000	2.000000	2.0E-08	0.0700	0.0100	±0.000550020	2.00	1.0E-02	±5.75E-02	0.442	0.558	104.54
1.000000	2.000000	2.0E-08	0.0700	0.0100	±0.000900020	2.00	1.0E-02	±6.50E-02	0.935	1.065	72.22
1.800000	2.000000	2.0E-08	0.0700	0.0100	±0.001460020	2.00	1.0E-02	±7.70E-02	1.723	1.877	52.74

Notes:
[1] Fluke Model 5101B published specifications over the frequency range of 50 Hz to 1 kHz.
[2] Assumed meter characteristics over the frequency range 40 Hz to 1 kHz; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied current shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[5] The ratio of the uncertainity of the meter divided by the uncertainty of the calibrator.

Table E-12 RESISTANCE UNCERTAINTIES

Applied Ressistance Ω	Calibrator 6 Mo. Accuracy[1] Range (Ω)	Two or Four Wire	Percent Accuracy	Estimated Uncertainty[3] (Ω)	Digital Multimeter Specifications[2] Maximum Reading[4]	Resol-ution (Ω)	Estimated Meter Uncertainty[3] Percent	(Ω)	Acceptable Meter Reading Min. (Ω)	Max. (Ω)	Uncertainty Ratio[6]
1.00E+00	1.0E+00	4	0.020	±0.00020	20Ω	1.0E-01	±0.30	±0.2030	7.97E-01	1.203E+00	1015.00
1.00E+01	1.0E+01	4	0.010	±0.00100	20Ω	1.0E-01	±0.30	±0.2300	9.77E+00	1.023E+01	230.00
1.00E+02	1.0E+02	4	0.005	±0.00500	200Ω	1.0E-01	±0.30	±0.5000	9.95E+01	1.005E+02	100.00
1.00E+03	1.0E+03	4	0.005	±0.0500	2000Ω	1.0E+00	±0.25	±3.5000	9.97E+02	1.004E+03	70.00
1.00E+04	1.0E+04	4	0.005	±0.500	20.00kΩ	1.0E+01	±0.25	±35.000	9.97E+03	1.004E+04	70.00
1.00E+05	1.0E+05	2	0.005	±5.00	200.0kΩ	1.0E+02	±0.25	±350.00	9.97E+04	1.004E+05	70.00
1.00E+06	1.0E+06	2	0.010	±100.0	2000kΩ	1.0E+03	±0.25	±3500.00	9.97E+05	1.004E+06	35.00
1.00E+07	1.0E+07	2	0.050	±5000.	20.00MΩ	1.0E+04	±1.00	±110000.	9.89E+06	1.011E+07	22.00

Notes:
[1] Fluke Model 5101B published specifications for resistance.
[2] Assumed meter characteristics for resistance; see Notes in Appendix B.
[3] The Estimated Uncertainty is for the applied resistance shown in the first column.
[4] This number represents the maximum reading possible for the assumed meter characteristics in order to determine the magnitude of ±1 count of the digital multimeter.
[6] The ratio of the uncertainity of the meter divided by the uncertainity of the calibrator.

For the lowest two resistance tests, the UUT was assumed to have a 0.1 ohm resolution, rather than a 0.01 ohm resolution, characteristic of a 3.5 digit meter.

APPENDIX F

TEST EQUIPMENT
FOR THE AN/PSM-51 DIGITAL MULTIMETER

Test Equipment for the AN/PSM-51 Digital Multimeter

488 Controller	HP 9836 or equivalent
Aluminum Sheet	See Appendix D, Item 1
Arbitrary Waveform Generator	Wavetek 275 or equivalent
Attenuator, Variable	See Appendix D, Item 2
Audio Analyzer	HP 8903B or equivalent
Banana Connector to Test Probe Adapter	See Appendix D, Item 3
Beaker, 800 mL	Corning, Pyrex, Model 1000, or equivalent
Binding Post to Binding Post Adapter	See Appendix D, Item 4
BNC "T" Adapter (Female-Male-Female)	Pomona 3285 or equivalent
BNC Female to Banana Adapter	Pomona 1269 or equivalent
BNC Male to Binding Post Adapter	Pomoma 1296 or equivalent
BNC Male to BNC Male Patch Cord, 24 inches	Pomona BNC-C-24 or equivalent
Calibrated Current Shunt, 0.1Ω	Fluke 80J-10 or equivalent
Capacitor, 0.1μF	See Appendix D, Item 5
Clip Leads	Pomona Electronics AL-B-12 or equivalent
Clock	General Electric 2908 or equivalent
Continuity Test Fixture	See Appendix D, Item 6
Crest Factor Generator, 3:1	See Appendix D, Item 7
Current Loop, 30 Turns	See Appendix D, Item 8
Current Loop, Single Turn	See Appendix D, Item 9
Digital Frequency Counter	HP 5316A or equivalent
Digital LCR meter	HP 4262A or equivalent
Digital Multimeter	Fluke 8506 or equivalent
Diode Test Fixture	See Appendix D, Item 10
Function Generator	HP 3325A or equivalent
Hot Plate	Corning Model PC-35 or
Incremental Resistance Source	See Appendix D, Item 11
Manufacturer's manual for temperature probe	
Manufacturer's manual for the UUT	
Meter Calibrator	Fluke 5101B or equivalent
Meter Calibrator	Fluke 5200A or equivalent
Microphone, Dynamic	Radio Shack P/N 33-1054 or equivalent
Microphone to BNC Adapter	See Appendix D, Item 12
Oscilloscope	Tektronix 465 or equivalent
Patch Cord, Stack-up Banana Plugs Both Ends	Pomona B-120 or equivalent
Power Amplifier	Fluke 5205A or equivalent
Power Supply for 3:1 Crest Factor Generator	See Appendix D, Item 13
Printer for 488 Controller	HP 2871G or equivalent
Resistor Fixture for CMRR Test, 1 k	See Appendix D, Item 14
Resistor Summing Network, 3 k	See Appendix D, Item 15
Thermometer Reading Lens	Parr Model 3003 or equivalent
Thermometer, Immersion, -20°C to +150°C, 76 mm scale length, ±0.5°C accuracy	S-W Type 12C or equivalent
Transconductance Amplifier	Fluke 5220A or equivalent

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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 battery-powered, hand-held digital multimeters were developed for the purpose of evaluating samples submitted by electronic instrument manufacturers in response to specifications issued by the U.S. Army Communications-Electronics Command. The detailed, step-by-step test procedures are based on the specifications by the Army and include sample data sheets and tables for the recording of interim data and final test results.

This report discusses the measurement principles and techniques underlying each of the procedures. In addition, the sources of measurement uncertainty are discussed.

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

ammeter; digital multimeter; ohmmeter; test procedures; voltmeter

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