Advanced Test Equipment Corp.
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Model 2555A
AC/DC Current Calibrator

Operation Manual

VALHALLA SCIENTIFIC

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CERTIFICATION

Valhalla Scientific, Inc. certifies that this instrument was thoroughly tested and inspected and found to meet published specifications when shipped from the factory. Valhalla Scientific, Inc. further certifies that its calibration measurements are traceable to the National Institute of Standards and Technology to the extent allowed by NIST's calibration facility.

WARRANTY

The warranty period for this instrument is stated on your invoice and packing list. Please refer to these to determine appropriate warranty dates. We will repair or replace the instrument during the warranty period provided it is returned to Valhalla Scientific, Inc. freight prepaid. No other warranty is expressed or implied. We are not liable for consequential damages. Permission and a return authorization number must be obtained directly from the factory for warranty repairs. No liability will be accepted if returned without such permission. In the interest of continuing product refinement and due to possible parts manufacturer changes we reserve the right to change any or all specifications without notice.

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SECTION I
UNPACKING AND INSTALLATION

1-1. Unpacking

If the shipping carton is damaged, request that the carrier's agent be present when the instrument is unpacked. If the 2555A appears damaged when unpacked, notify the carrier's agent immediately. Even if the instrument appears undamaged it may have suffered internal damage in transit that may not be evident until the instrument is operated or tested to verify performance. If the instrument fails to meet the performance specifications in Section II, notify the carrier's agent and Valhalla Scientific. Retain the shipping carton for the carrier's inspection.

Do not return equipment without obtaining prior authorization from Valhalla Scientific.

1-2. Initial Adjustments

Before operating the 2555A, verify that the correct local power source voltage is selected. The supply voltages and circuit breaker values are listed below:

105 to 125VAC 50/60 Hz	20 Amp Circuit Breaker
210 to 250VAC 50/60 Hz	10 Amp Circuit Breaker

NOTE: **Line voltage selection is internal and requires rewiring of the main transformer. It is recommended that this procedure be performed at the factory. All units are wired for 105-125VAC unless a placard attached to the unit indicates otherwise.**

1-3. Bench Use

The 2555A is delivered ready for operation in bench use. Before connecting the 2555A to the AC power source, the user should verify that the power cord is equipped with a three-terminal connector (see the Safety Precautions, Section 1-5).

1-4. Rack Mounting

Optional rack mounting brackets are available for mounting the 2555A in a standard 19" equipment rack. These are listed in Section III of this manual. The size and weight of the 2555A require that the unit be supported on both sides along its entire length by the use of trays or slides. When transporting while mounted in a rack, support the unit to prevent vertical movement.

It is recommended that sufficient room be allowed for airflow around the 2555A since performance is diminished at temperatures above 50°C. This may be accomplished by placing at least 1.75" blank panels above and below the 2555A in the rack and ensuring that there are no obstructions within 5" of either the air inlet or outlet on the rear panel of the 2555A.

Under no circumstances should the air temperature surrounding the 2555A be allowed to exceed 50°C in operation or 70°C in storage.

1-5. Safety Precautions

A three-contact power connector and grounded outlet is required for safe operation of the 2555A. If an extension cable is used, it must be a heavy-duty three-contact type capable of carrying at least 15 amps. It must also provide a continuous ground. Unsuitable extension cords will essentially "choke" the 2555A and may cause clipping at high output currents.

CAUTION!

Operation of the 2555A without proper grounding can be hazardous to personnel and equipment.

SECTION II
SPECIFICATIONS & OPTIONS

2-1. Description

The Valhalla Scientific Model 2555A AC-DC Current Calibrator is a wide-range voltage-to-current converter that produces an output current directly proportional to the input AC or DC voltage. AC voltage produces an output current of the same frequency and phase that is directly proportional in magnitude.

2-2. Performance Specifications

Ranges:	2mA, 20mA, 200mA, 2A, 20A, 100A
DC Accuracy:	(360 days 23EC " 5EC) 20 Amp range and below: " 0.015% of range " 0.03% of output 100 Amp Range: " 0.03% of range " 0.03% of output
AC Accuracy:	(360 days 23EC " 5EC) 20 Amp range and below: " 0.15% of range " 0.1% of output to 100Hz " 0.2% of range " 0.2% of output to 400Hz " 0.3% of range " 0.3% of output to 1000Hz 100 Amp range: " 0.3% of range " 0.1% of output to 100Hz " 0.4% of range " 0.2% of output to 400Hz " 0.6% of range " 0.3% of output to 1000Hz
Input Impedance:	100kÙ
Compliance Voltage:	(At nominal line voltage and frequency) 100 ampere range typically 3V; 20 amperes and below 5V
Input/Output Ratio:	2.0000V input produces full scale output. (1.0000V input maximum on 100A range)
Maximum Input:	3VDC or Peak AC
Input Common Mode:	60dB at DC linearly decreasing to 40dB at maximum frequency
Temperature Coefficient:	".0002% of output ".004% of range/EC for DC below 20EC and above 30EC (double above figures for AC Temperature Coefficient)
Upper Frequency Limit	1kHz

2-3. Environmental Specifications

Temperature Range:
Operating: 0EC to 50EC
Storage: -25EC to +75EC

2-4. Physical Specifications

Size:	10.5" H x 17" W x 23" D (Fan included)
Weight:	100 lbs. net, 140 lbs. shipping 45 Kg. net, 66 Kg. shipping

2-5. Accessories

The Model 2555A is shipped from the factory with mating 100 ampere outlet connectors and an instruction manual.

2-6. Rack Mount Option R3

This option allows the 2555A to be mounted in a standard 19" equipment rack enclosure.

2-7. Cable Option BBL

Option BBL provides dual banana leads on 48" cable, shielded to provide low leakage.

2-8. 100A Cable Option HMF

Option HMF provides 4-gauge copper welding cable terminated in 100A plugs and Option Jaws heavy duty 2" Kelvin clips.

2-9. 100A Cable Option HC

Option HC provides a 6-foot cable set terminated on one end in copper ring lugs and on the other end with banana plugs that mate with the 2555A's 100A terminals. Recommended for use with the Valhalla 2575A Current Shunt.

2-10. Buffer Amplifier Model 2009

Model 2009 Buffer Amplifier provides high impedance circuit measurement. This is used to eliminate voltmeter loading effects. The 2009 is a battery operated precision buffer amplifier with a gain of 1.0000. The input impedance is greater than $1 \times 10^{10}\Omega$ and the output impedance is 1Ω maximum (0.1Ω typical).

2-11. Option RV

Option "RV" provides a rear-mounted BNC connector wired in parallel with the front panel Voltage Input Terminals. This becomes useful when rack mounting or for other custom applications.

2-12. Option R-100

Option "R-100" provides rear-mounted cables wired in parallel with the 100 Amp Output Terminals. This becomes useful when rack mounting or for other custom applications.

2-13. Spare 100-ampere Connectors

Spare mating plugs are available for making connections to the 100A terminals of the 2555A. Red plugs may be ordered as Valhalla Stock Number 05-10106. White plugs may be ordered as Stock Number 05-10105.

SECTION III
OPERATION

3-1. Input Voltage

The polarity and level of the input voltage determines the polarity and level of the output current. If the input voltage is zero, the output current will be zero. As the input voltage is increased, the output current will increase linearly within the selected range (i.e for the selected range of 1mA an input voltage of 1.0000 volts DC will produce an output current of 1.0000mA. If the input is increased to 1.5000 volts DC, the output current will increase to 1.5000mA.

If the 10mA range is selected, the output currents will be 10.000mA and 15.000mA for inputs of 1.0000 volts DC and 1.5000 volts DC, respectively. Positive polarity input will produce positive polarity output, and vice-versa.

AC voltage input will produce output current with the same amplitude, frequency and phase characteristics. The maximum input voltage is 2 volts RMS or DC on all ranges except the 100 ampere range. The 100 ampere range is limited to 1 volt RMS or DC.

3-2. Range Selection

To select a different range, move the cable connections to the set of jacks with the required range. Only a single range may be used at any one time. The instrument ranges are defined in decade increments of 2mA, 20mA, 200mA, 2A, 20A, and 100A. For example, if the 2mA range is selected and 1 volt is applied, the output current will be 1 milliampere. If 1 volt AC RMS is applied, the output will be 1 milliampere AC RMS. Heavy duty connectors are provided for the 100 ampere range. Plugs of the same current rating are supplied for insertion. Wire size AWG #4 or larger should be used to minimize the voltage drop in the connecting leads for the 100 ampere range.

3-3. Output Current

The output current is proportional to the input voltage. A 2-volt input will produce an output .current that is 100% of the selected range. For example, if the 2mA range is selected, the output current is 2mA. The 100 Amp range is limited to a 1 volt maximum input; therefore, 1 volt produces 100% of range on the 100 Amp range.

The effective output impedance of the current calibrator approaches infinity; therefore, the output current generating circuit attempts to deliver the requested current into any load impedance applied to the output terminals. A 1mA current output applied to a 1 kohm load impedance produces 1 volt across that load impedance. A 1mA input current applied to a 2 kohm load impedance produces 2 volts.

The maximum output compliance voltage for the 20A range and below is ± 7 volts DC or peak AC. The 7 volt DC maximum compliance voltage corresponds to 4.95 volts RMS maximum compliance voltage for sine wave output currents. The 100A range has a compliance voltage of ± 3 volts DC or peak AC. This requires the use of the highest quality connections and cables to reduce any resistance in the leads.

3-4. Range Limit Indicators

Three LED indicators provide the operator with indication of range limit conditions. The green LED indicates the output voltage is within compliance limits. The yellow LED indicates the output voltage is greater than 5 volts. The red LED indicates the output voltage is 7 volts or out of compliance.

3-5. Standby/Operate Switch

The Standby/Operate switch disables the instrument in the "standby" mode preventing current from being supplied to the load. The "operate" position restores normal operation. The input impedance = ∞ in the standby mode. Do not open the input terminals unless the unit is in standby mode.

CAUTION!

In high current systems using more than one 2555A in parallel, reduce input signal to zero volts before selecting STANDBY.

3-6. Error Sources

Input Impedance: There are potential error sources associated with current calibration. One possible source of error is caused when the impedance of the input voltage source, demonstrated as R_s in Figure 3-1, forms a resistor divider with the 100 kohm input impedance of the current calibrator, R_1. To reduce the error to 0.01% or less, the ratio of R_1/R_s must be maintained at 10,000/1 or greater. Since R1 is 100 kohms, the maximum impedance for R_s must be less than 10 ohms.

Output Impedance: The second potential for error occurs at the current output of the AC-DC current calibrator when the input impedance of the DVM, R_z in Figure 3-1, acts in parallel with the load impedance, R_L. To reduce this error to 0.01% or less the ratio of R_z/R_L must be maintained at 10,000/1 or greater. If the input impedance to the DVM is 10 megohms, the maximum shunt impedance should not exceed 1 kohm. For a shunt impedance of 1 megohm the input impedance of the DVM must be at least 10,000 megohms. To eliminate this problem we offer an optional high impedance buffer, Model 2009. The 2009 is a precision buffer amplifier with an AC/DC gain of 1.0000. See section 2-10 for details.

Inductance In Series: Another potential error source is inductance in series with the load resistor, shown as R_L in Figure 3-2. If the load resistance is 0.001 ohm and the series inductance is 100 nanohenries, the effective load impedance at 1kHz is:

$$Z = \sqrt{0.001\Omega^2 + [2\pi\,(1\text{kHz})\,(100 \times 10^{-9}\ \text{Henries})]^2}$$

$$Z = \sqrt{0.000001 + 0.0000003}$$

$$Z = 0.001181\Omega$$

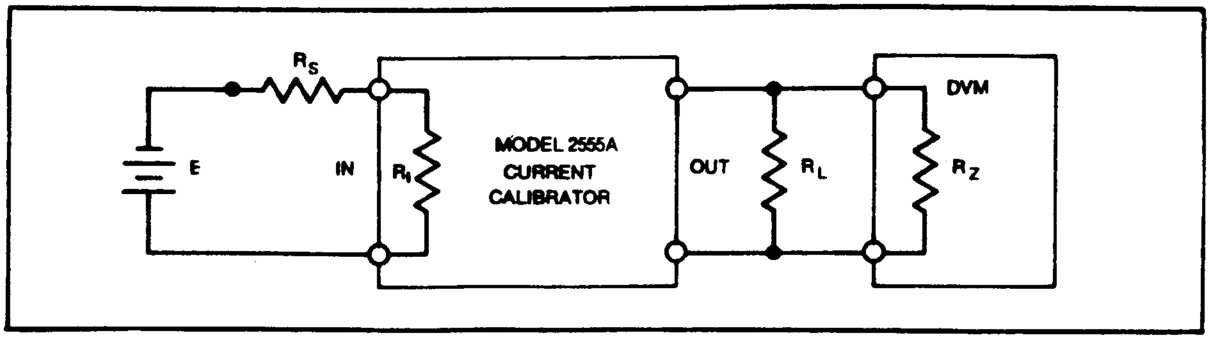

Figure 3-1. Block Diagram, DC Error Sources.

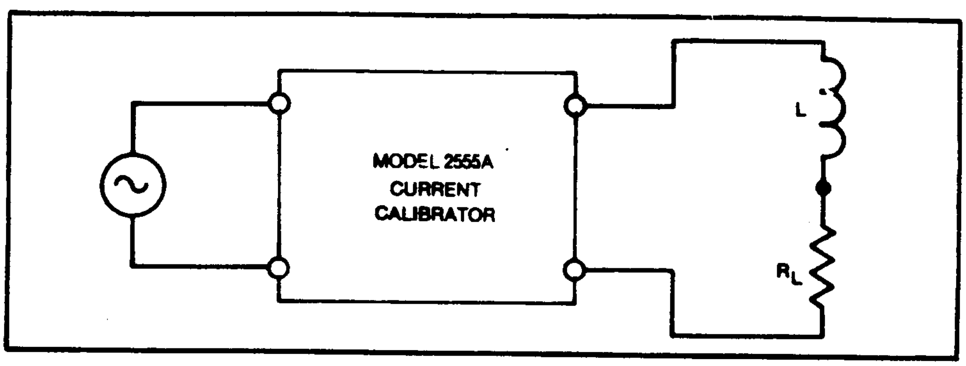

Figure 3-2. Block Diagram, AC Error Sources.

SECTION IV
THEORY OF OPERATION

4-1. General

This section of the manual provides a description of the circuits of the 2555A Current Calibrator. The circuit descriptions are referenced to the schematic diagrams at the end of the manual.

4-2. Power Supply

The circuits of the 2555A require two dual power sources. One circuit provides nominal positive and negative 15 volts DC and the other nominal positive and negative 10 volts DC. T1 and diodes CR10 through CR13 generate positive and negative potentials in the range of 20 volts DC. These are regulated to ± 15 volts DC by IC8 and IC9. The positive and negative 10 volt DC sources are obtained from a separate winding on T1 and diodes CR14 through CR17. These sources do not require regulation and are the collector supplies for Q3, Q5-Q44 and Q46.

4-3. Voltage to Current Converter Transconductance Amplifier (U.S. Patent 4,091,333)

A simplified diagram of the voltage-to-current converter is shown in Figure 4-1. The first amplifier, IC1, operates with a gain of 1 due to the operational feedback loop provided by R3. The output of the first amplifier drives the inverting input of the second amplifier, which operates open loop and at very high gain.

The output of the second amplifier, IC2, provides a potentiometric feedback to the non-inverting input of the first amplifier. The system operates to maintain the output of the first amplifier, and the inverting input of the second amplifier, at approximately the same potential as that applied to the non-inverting input of the second amplifier. Very small differences between the inputs of the second amplifier are sufficient to drive it to full scale output.

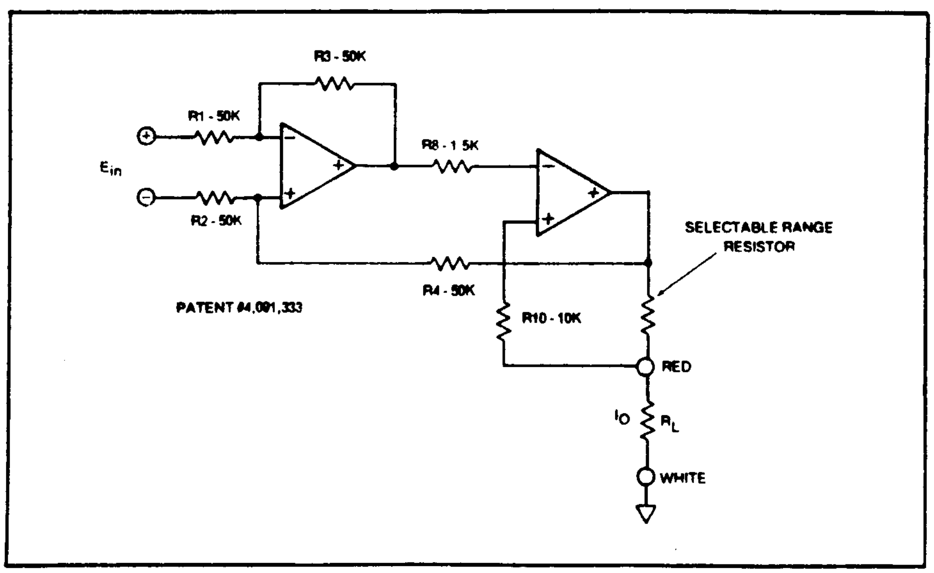

Figure 4-1. Simplified Diagram, Transconductance Amplifier.

Assume the output terminals are shorted and 1 volt DC is applied to the input terminals with the RED input terminal positive. To equalize the inputs of the second amplifier, IC1 must be driven to zero. This is accomplished when the voltage drops across R1 and R2 and those across R3 and R4 are equal.

This condition will be obtained when the output of the second amplifier is at 1 volt. The currents through R1, R2, R3, and R4 are the same. Since the output of IC1 must be zero, the drop across R3 must be 0.5 volts, making the non-inverting input of IC1 +0.5 volts. R4 will have the same drop, making the inverting input +0.5 volts. The drop across R1 and R2 will be the same. Since the inputs of IC1 are essentially equal, the output of IC1 is zero (offset by the few microvolts necessary to drive the output of the second amplifier to 1 volt.) The sum of the voltages across the four resistors, R1 through R4, equal the sum of the input voltage and second amplifier output voltage.

When the short circuit is removed from the output terminals and 100 ohm resistor is connected across them, the reference level to the non-inverting input of the second amplifier is now above ground due to the current through the load resistor, R_L. This drives the output of the second amplifier in a positive direction and a point of stability is reached when the output of the first amplifier is equal to the level applied to the non-inverting input of the second amplifier.

Again, this condition exists when the voltage drops across R1 and R2 are equal and those across R3 and R4 are equal. This occurs when the output of the second amplifier is at 2 volts. The drop across the range resistor, R_s is 1 volt, as it was when the output terminals were shorted. The current through the load is 10 milliamperes. Although the resistance across the input terminals has been increased from zero to 100 ohms, the current flowing across the output terminals remains at 10 milliamperes. The voltage difference between the output of the first amplifier and the second amplifier is always equal to the voltage applied to the input terminals.

When the input signal is increased to 2.0 volts DC, the potential difference between the output of the first amplifier and the output of the second amplifier increases to 2.0 volts. The drops across resistors R1 and R2 are one volt and the drops across resistors R3 and R4 are one volt.

The current through the 100 ohm resistor is increased to 20 milliamperes, proportional to the input voltage increase. If a 200 ohm resistor is connected across the output terminals, the output of the second amplifier increases to 2.2 volts and the current through the combination of range and load resistors remains at 20 milliamperes.

The system maintains a voltage across the range resistor proportional to the input voltage. Selecting different values for the range resistor results in different current levels through those resistors to maintain a 1 volt DC drop with 1 volt DC at the input terminals.

The second amplifier, shown as a single operational amplifier in the simplified diagram of Figure 4-1, is actually a current amplifier comprised of IC2 and 46 transistors, Q1 through Q46. The transistors are connected in four groups, in series parallel to form a "totem pole" configuration. The complete circuit is shown in the schematic diagram 2555-070 at the end of this manual. Q2 and Q3 operate as constant current sources to bias the parallel connected sets of output transistors. R7 and R9 provide adjustment of the operational amplifier offsets.

4-4. Range Selection

The current output range is selected by manually inserting the load connector into the appropriate range jacks. This inserts resistors of different values in series with the load, effectively changing the value of the range resistor of Figure 4-1. This is best illustrated by reference to the complete schematic diagram 2555-070. Calibration potentiometers in the resistor matrix permit precise adjustments of the proportion between input voltage and output current. The adjustments of these potentiometers are covered in Section V.

4-5. Range Indicators

Refer to schematic 2555-070. Level sensors of IC3 and IC4 provide the drive for the three range indicator LED's, DS1 through DS3. Those of IC3 are compared to the output of IC1, which is proportional to the output voltage levels developed in the voltage divider comprised of R12 through R21. This divider is connected across the +15 and -15 volts supply lines. The inputs to IC3-1 and IC3-7 from the divider are positive with respect to ground and those to IC3-8 and IC3-14 are negative. When the output of IC1 is between 0 and +5 volts, all of IC3's outputs are at -15V and the junction of R22, R23 and R28 is at -10V. Thus, the output of IC4-1 and IC4-7 are also at -15V which forces the output of IC4-8 to +15V to light DS3 (GRN). As the output transitions above +5V, the output of IC7-3 goes to +15V, forcing the output of IC4-1 to +15V, turning on DS2 (YEL), forcing the output of IC4-8 to -15V which extinguishes DS3. As the voltage transitions to +7 volts, the output of IC3-1 goes to +15V. This forces the output of IC4-7 to 15V, turning on DS1. The output of IC4-1 is forced low, turning off DS2. The output of IC4-7 holds IC4-8 at -15V, keeping DS3 turned off.

When the output is forced in the negative direction, a similar sequence occurs. However, IC3-8 and IC3-14 outputs will transition rather than those of IC3-7 and IC3-1.

4-6. Standby/Operate Switch

The Standby/Operate switch, when in the "standby" position, connects the non-inverting input of IC2 directly to 0 volts DC. This removes any drive signal from the output power transistor circuits, preventing current from being supplied to the load. The Voltage Input Terminals are disconnected from the circuitry in the "Standby" mode.

4-7. Power Supplies (Detail)

The ± 20 volt power supplies are formed by diodes CR14, CR15, CR16 and CR17. These supplies are unregulated and voltage varies from 18.5 to 21.5 volts, depending on the line voltage and load.

The ± 15 volt power supplies are formed by integrated circuit voltage regulators IC8 and IC9. Their voltages will vary slightly from unit to unit due to component tolerances and will typically be near 14.8-15.2 volts.

The 5 volt supplies for the current shunt amplifier are comprised of CR1 through CR4 and integrated circuit amplifiers IC5 and IC6. These voltages will vary slightly from unit to unit and are typically 4.95 volts.

SECTION V
MAINTENANCE

5-1. Required Test Equipment

The test equipment required for the calibration procedures are:

1) DC Voltage Standard:
   0-2VDC, ±0.0003% Accuracy
   (Valhalla 2701C or equivalent)

2) 5-Digit DVM:
   ±0.0003% Accuracy, 10 Megohms Input Impedance

3) AC Voltage Standard:
   0-2V, ±0.03% Accuracy
   (Valhalla 2703 or equivalent)

4) External Shunt System:
   ± 0.01% Accuracy
   (Valhalla 2575A or equivalent)

5) 4KΩ 1% 1/4 W metal-film resistor

5-2. Calibration Procedure

5-2-1. Output Impedance Adjustment

1) Connect the equipment as shown in Figure 5-1 using a Valhalla 2575A Current Shunt, 2mA range, (or equivalent) for RL and a 4 kohm 1% resistor in series for RS.

Set the Valhalla 2701C DC Voltage Standard (or equivalent) output to zero volts DC. Connect the 2mA output range of the 2555A directly to RL with RS shorted.

Adjust R7 for an indication of zero volts DC ± 30 microvolts or less on the DVM.

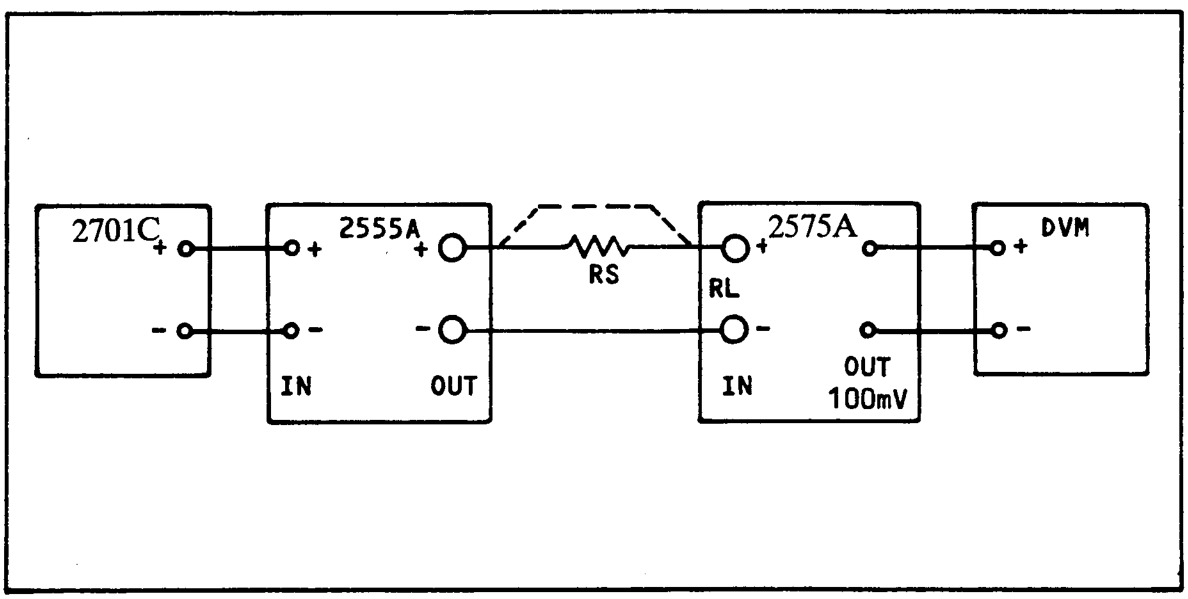

Figure 5-1. Output Impedance Test Equipment Set-Up

2) Set the DC Voltage Standard (2701C) to 1VDC and adjust R96 for a reading of 100.00 mV on the DVM.

3) Remove the Current Hi lead of the 2555A from the current shunt (Valhalla 2575A) and connect a 4KΩ 1% resistor between the 2555A and the current shunt (RS). Observe the direction and magnitude of change on the DVM. Adjust R110 for 100.00 ±75 microvolts on the DVM.

4) Repeat steps 2 and 3 adjusting R96 and R110 for the least amount of change on the DVM.

5) Connect the equipment as shown in Figure 5-2.

6) Calibrate the 2555A according to Table 5-1, checking the DC zero at the beginning of each step by reducing the voltage input to the 2555A to zero and adjusting R7 to zero volts DC ±30 microvolts, if necessary.

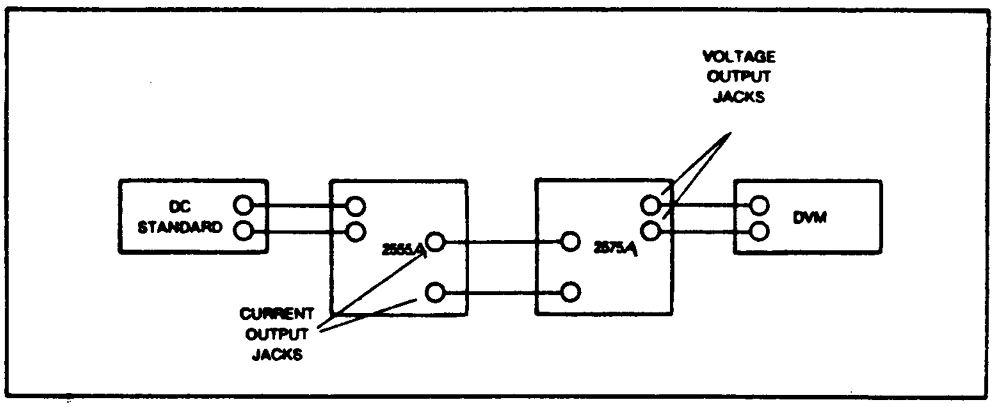

Figure 5-2. DC Calibration Test Equipment Set-Up

Voltage Input	2555A Range	2575A Range	2555A Adjustment	DVM Indication
1 VDC	100 Amp	100 Amp	See Note*	100 mV ± 60 μV
1 VDC	20 Amp	20 Amp	R108	100 mV ± 60 μV
1 VDC	2 Amp	2 Amp	R105	100 mV ± 60 μV
1 VDC	200 mA	200 mA	R102	100 mV ± 60 μV
1 VDC	20 mA	20 mA	R99	100 mV ± 60 μV
1 VDC	2 mA	2 mA	R96	100 mV ± 60 μV

Note: **If the specified DVM indications are not obtained, it will be necessary to either file or shunt R107B, as required.**

Table 5-1. Calibration Equipment Settings

5-2-2. Frequency Response

The frequency response test need not be performed on a routine basis. When required, use Figure 5-3 and check each range to 1kHz. Before attempting to perform this test, Section 3-6 Error Sources should be reviewed.

The frequency response test has no adjustments. If any range fails to meet specifications, the DC calibration in both polarities and zero will need to be checked.

5-2-3. Range Indicator Adjustment

Connect the DC Standard plus (+) output to the plus (RED) input terminal of the Model 2555A and the minus (-) output to the minus (BLACK) input of the Model 2555A. Connect a 5K kohm 1% resistor across the 2 mA output jack of the Model 2555A and connect the DVM across the resistor. Increase the DC Standard output until the DVM reads +5 volts. Adjust the +YEL potentiometer to just turn on the yellow panel indicator. The green indicator will be turned off. Increase the DC Standard output for a +7 volt reading on the DVM. Adjust the +RED potentiometer to just turn on the red indicator. The yellow indicator will be turned off. Reverse polarity of the input to the Model 2555A and repeat the procedure, but adjust the -YEL and -RED potentiometers instead.

5-3. Troubleshooting

Difficulties with precision equipment often occur from misinterpretation of the specifications. Make a careful check to determine that the equipment is truly malfunctioning before initiating repair procedures.

5-4. Amplifier Servicing

Note: If IC1, IC2, Q6 through Q14, Q16 through Q24, Q26 through Q34, Q36 through Q44 or R44 through R110 are replaced, the AC frequency response test must be performed.

Before attempting to service the amplifiers of the 2555A, it is recommended that the technician review the Theory of Operation in Section IV. The following procedure is only an aid to isolate a catastrophic malfunction to a local area.

Short the input terminals and short the output terminals. With the differential DC voltmeter, measure the voltage between the common connections of the power transistor emitter resistors and pin 6 of IC1. This voltage must be less than 15 millivolts. If it is greater than 15 millivolts, IC1 is most likely defective. If it is less than 15 millivolts, the malfunction is somewhere in the second amplifier (and/or the current amplifiers) or the feedback network.

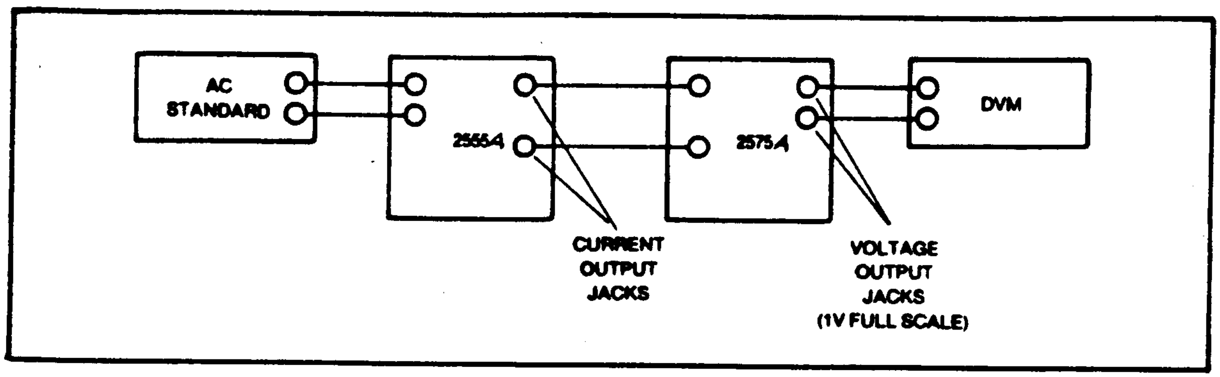

Figure 5-3. AC Frequency Response Test Equipment Set-Up