KEITHLEY

Instruction Manual

Model 155

Null Detector/Microvoltmeter

Keithley Instruments, Inc.
28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400

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Keithley Instruments, Inc./28775 Aurora Road/Cleveland, Ohio 44139/(216) 248-0400/Telex: 98-5469
Keithley Instruments GmbH/Heiglhofstrasse 5/D-8000 Munchen 70/(089) 714-40-65/Telex: 521 21 60
Keithley Instruments, Ltd./1, Boulton Road/GB-Reading, Berkshire RG2 ONL/(0734) 86 12 87
Keithley Instruments SARL/44, Rue Anatole France/F-91121 Palaiseau Cedex/01-014-22-06/Telex: (842) 204188

INSTRUCTION MANUAL

Model 155

Null Detector

Microvoltmeter

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SPECIFICATIONS

RANGE: ±1 microvolt full scale to ±1000 volts.

ACCURACY: ±1% of full scale at recorder output, ±2% of full scale at meter, exclusive of noise and drift.

ZERO DRIFT: Less than 0.5 microvolt per 24 hours, typically less than 0.1 microvolt per °C. Long-term drift is non-cumulative.

METER NOISE: Less than 0.03 microvolt rms (0.15 microvolt peak-to-peak) on most sensitive range with input shorted.

INPUT RESISTANCE:
100 megohms – 3-volt to 1-kilovolt ranges;
10 megohms – 300-millivolt to 1-volt ranges;
1 megohm – 1-microvolt to 100-millivolt ranges.

NORMAL MODE REJECTION: An applied 50-60 Hz signal which is 80 dB greater than full scale peak-to-peak will not affect reading on most sensitive range (equivalent to 100 dB NMRR).

COMMON MODE REJECTION: Common mode voltage – dc or 50-60 Hz – 120 dB greater than full scale up to 1200 volts peak will not affect reading (equivalent to 140 dB CMRR).

ISOLATION: Greater than 10^{12} ohms shunted by 0.01 microfarad between chassis ground (case) and input low.

RISE TIME (10%-90%): Less than 1 second on 10-microvolt range and above, increasing to 5 seconds on 1-microvolt range.

ZERO SUPPRESSION: ±25 microvolts.

RECORDER OUTPUT: ±1 volt at up to 1 milliampere.

OVERLOAD: Up to 1200 volts peak may be applied on any range. Recovery from overload 10^6 times full scale for 1 second with 10-kilohm source is within 5 seconds on the 30-microvolt and higher ranges.

CONNECTORS: Output: Barrier Strip. Input: Binding Posts.

POWER: Four internally mounted zinc-carbon batteries (2N6) provide more than 1000 hours continuous operation. Barrier strip provided for external power supply (+ and –15 volts unregulated).

DIMENSIONS, WEIGHT: 5¼" high x 8¼" wide x 6¾" deep; net weight, 6 pounds.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL. The Keithley Model 155 is a completely solid state, rugged, battery-operated combination Null Detector-Microvoltmeter. It measures from 1 microvolt full scale to 1000 volts in 19 1x and 3x steps and has 150 nanovolts resolution. The recorder output, accurate to 1% of full scale exclusive of noise and drift, extends the versatility of the instrument.

1-2. FEATURES.

a. Excellent immunity to ac interference allows the Model 155 to detect dc signals in the presence of large ac voltages. The Microvoltmeter-Null Detector has greater than 140 dB CMRR and 100 dB NMRR (refer to specifications in Table 1). Also, hook up to source is simple and quick. Unshielded leads may generally be used without degrading performance.

b. The Model 155 Null Detector can recover from 100-volt overloads within 5 seconds on the 30-microvolt range. Up to 1200 volts peak may be applied momentarily on any range without damaging the instrument.

c. Stability is better than 0.5 microvolt per 24 hours after warm-up with a reasonably constant ambient temperature. The long-term drift is non-cumulative.

d. The ten-turn ZERO Control permits easy adjustment of instrument zero. It also provides up to at least ±25 microvolts suppression, which allows measuring submicrovolt changes in signals up to the limit of the suppression.

e. Zero Check position on the Power Switch allows convenient zeroing of the instrument by shorting the input. This means the measuring circuit need not be disturbed by disconnecting and shorting the input cables.

f. High input resistance of 1 to 100 megohms coupled with less than 10^{-11} volt per ohm zero shift with source resistance permits measurement accuracy even with high resistance sources.

g. The Model 155 is designed for battery operation to minimize ground loop and high frequency pick-up problems in sensitive voltage measurements. Four internally mounted zinc-carbon batteries provide greater than 1000 hours operation. The Model 155 may also be operated from external supplies. These may be connected to the barrier strip on the rear panel. Power requirement is ±15 to ±25 volts at 2 milliamperes.

h. For line operation, the Model 1554 Power Supply is a convenient accessory. It attaches to the rear panel of the instrument and its output may be connected to the barrier strip provided also on the rear panel. A switch on the supply provided selectable line or battery operation. Line operation with the Model 1554 maintains excellent floating characteristics and negligible coupling to line.

i. Four binding posts on the front panel provide fast and convenient input connection. A ±1 volt at 1 milliampere output is provided on the rear panel for convenient connection to recorders or other readout devices. Accuracy is ±2% of full scale at the meter and ±1% at the recorder output. A large 4-1/2 inch taut-band meter is provided for ease of readout.

j. The Model 155 is completely solid state, utilizing a MOS-FET chopper in its input circuit. The solid-state chopper requires little power to drive, which gives long battery life and permits the use of inexpensive batteries. It also has low noise and increased sensitivity.

k. Another significant design characteristic of the Model 155 is its electrical and mechanical ruggedness. All components except for the meter, battery, input and output connectors are mounted on a single printed circuit. For calibration or servicing the circuit board may be conveniently and quickly removed from the instrument.

l. Circuit isolation from chassis ground is greater than 10^{12} ohms shunted by 0.01 microfarad. This high isolation generally eliminates the need for guarding the Model 155.

1-3. APPLICATIONS.

a. As a null detector the Model 155 can be used with potentiometers, bridges, ratio devices and comparator circuits.

b. As a microvoltmeter it is ideal for measuring semiconductor resistivity, thermopile and thermocouple potentials, Hall-effect potentials, contact resistances, biologically generated emfs, electrochemical potentials, and strain guage outputs.

c. Other applications include monitoring power supply stability, DTA measurements, resistance thermometry and thermal conductivity measurements.

d. The Model 155 is useful as a general purpose instrument in the research laboratory as well as in electronic development work and process control applications.

e. Its excellent sensitivity limits the need for expensive potentiometer systems to measure microvolt level signals accurately. It can measure a signal of 30 microvolts or less as accurately as some complex potentiometer systems.

TABLE 2. Model 155 Front Panel Controls (Figure 1).
The Table briefly describes each control and indicates the paragraph which contains instructions on the use of the control.

Control	Functional Description	Paragraph
Power Switch	Turns instrument off, checks zero, sets instrument for normal operation, checks battery condition.	2-3, 2-4
ZERO Control	Allows input zeroing.	2-4, 2-9
+ Terminal (input hi)	Connects input to signal source.	2-1, 2-4
- Terminal (input lo)	Connects input to signal source.	2-1, 2-4
GUARD Terminal	Provides partial guarding for circuitry	2-1
CASE Terminal	Connects instrument case to ground.	2-1
RANGE Switch	Selects full scale voltage sensitivity.	2-4

TABLE 3. Model 155 Rear Panel Terminals (Figure 2).
The Table briefly describes each terminal and indicates the paragraph which contains instructions on the use of the terminal.

Control	Functional Description	Paragraph
GUARD	Provides alternate connection to ground.	2-2
OUTPUT HI	Provides output voltage proportional to input voltage between this terminal and OUTPUT LO. For recording.	2-2, 2-6
OUTPUT LO	Reference point for output voltage. Common to INPUT LO. Common tie point for use with external supplies.	2-2, 2-3, 2-6
+ POWER INPUT	Application of positive voltage to this terminal powers instrument circuits.	2-2, 2-3
+ BATTERY	Provides direct access to positive voltage from internal battery.	2-2, 2-3
- POWER INPUT	Application of negative voltage to this terminal powers instrument circuits.	2-2, 2-3
- BATTERY	Provides direct access to negative voltage from internal battery.	2-2, 2-3

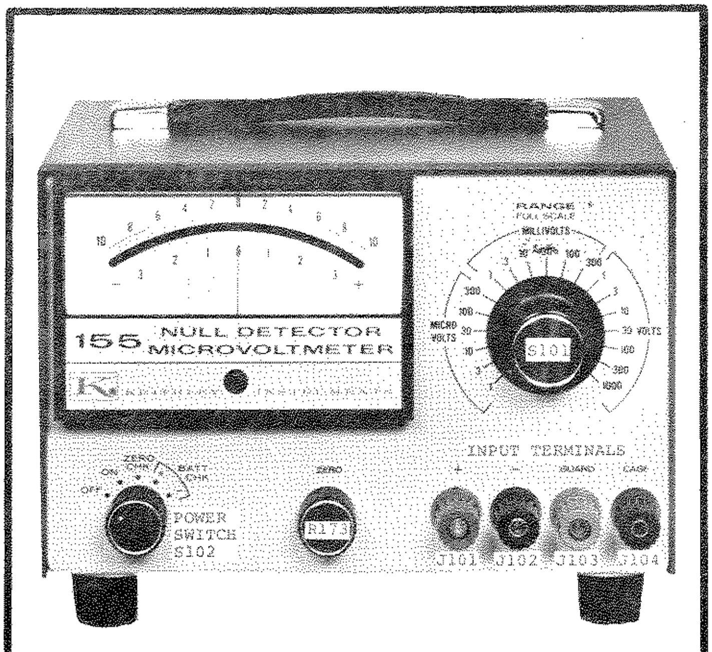


FIGURE 1. Model 155 Front Panel Controls.

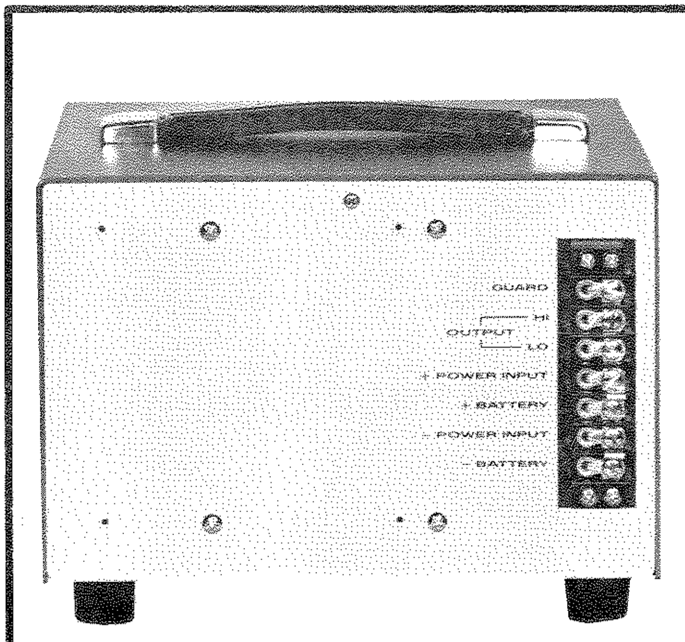


FIGURE 2. Model 155 Rear Panel Terminals.

SECTION 2. OPERATION

2-1. INPUT CONNECTIONS.

a. The Model 155 uses four binding posts on the front panel for all input signal connections: +, -, GUARD and CASE.

1. The + (red) and - (black) Terminals are the Model 155 input high and low respectively. The voltage to be measured is applied differentially between these two terminals.

2. The blue GUARD Terminal is provided for use with guarded potentiometers. When no circuit guard is available, short the GUARD Terminal to the - Terminal.

3. The green CASE Terminal provides easy connection to the instrument case. It should normally be tied to the building ground to provide electrostatic shielding for the instrument's circuits.

b. If the signal to be measured is less than 1 millivolt, use copper wires to connect the source to the Model 155 input. This minimizes the error due to thermoelectric voltages that may develop due to temperature differences in the measurement circuit.

c. Use shielded input leads when the source resistance is high, above 1 kilohm, or when long cables are necessary. Tie the shield to building ground. Also, shield the source being measured.

d. For low impedance measurements (under 100 ohms) shielded input cable is usually unnecessary due to the extremely high ac rejection of the Model 155.

2-2. BARRIER STRIP CONNECTIONS. A seven terminal Barrier Strip Connector is mounted on the rear panel. It provides 1) connection for the power supplies to drive the Model 155 circuits, 2) an output voltage related to the signal being measured, and 3) an alternate connection to the circuit guard.

a. The rear panel GUARD Terminal is electrically identical to the front panel GUARD Terminal (paragraph 2-1a).

b. The OUTPUT HI and OUTPUT LO Terminals provide an output voltage equal to the input voltage divided by the RANGE Switch setting. For example, a 15 microvolt signal being measured on the 30 microvolt range would produce an output signal of 15 μV/30 μV = 0.5 volt. These two terminals may be used for recording the output of the Model 155 (Refer to paragraph 2-6).

c. The OUTPUT LO Terminal is common to the front panel - Terminal (Input Low). However, the OUTPUT LO Terminal should not be used as an input connection because 1) the power supply current that flows in the output leads generates a voltage due to the wire resistance and 2) the output circuitry has not been designed for low thermally developed voltages in the leads.

d. The positive voltage from the internal batteries is connected directly to the + BATTERY Terminal. The negative voltage is connected directly to the - BATTERY Terminal. The common between the positive and negative internal supplies is connected directly to the OUTPUT LO Terminal. Power to operate the Model 155 must be applied to the OUTPUT LO, + POWER INPUT and - POWER INPUT Terminals. The Model 155 is supplied with barrier strip shorting links to accomplish this function. (Refer to paragraph 2-3 for operation from power supplies, internal or external).

2-3. POWER SUPPLIES OPERATION AND CONDITION CHECK. The Model 155 internal circuitry may be powered either by its internal battery supply or by an external supply.

NOTE

Refer to paragraph 2-2d for internal electrical connections of the terminals used for power supplies.

a. To power the Model 155 circuits with the internal supply, attach the +BATTERY Terminal to the +POWER INPUT Terminal and the -BATTERY Terminal to the -POWER INPUT Terminal on the rear panel Barrier Strip Connector with the provided shorting links.

b. To power the circuits with an external supply, attach the positive external supply to the +POWER INPUT Terminal, the negative external supply to the -POWER INPUT Terminal and the external supply common to the OUTPUT LO Terminal. Make sure that there are no shorting links connected between the + and - BATTERY Terminals and the + and - POWER INPUT Terminals.

c. In order for the Model 155 to function properly the supplies used to power the circuits must be of sufficient strength. To check the state of the supplies, internal or external, set the Power Switch to the BATT CHK position. Check the positive supply by setting the Switch to the + position, and the negative supply by setting it to the - position. In each case the meter needle should deflect to within the green strip on the meter face. If the meter needle does not deflect to within the strip for each supply, then that supply is not providing enough power for proper operation.

1. If an external supply is being used and the battery check shows a low reading, correct the indicated supply.

2. If the Model 155 internal battery supply is being used and the battery check shows a low reading, replace the indicated batteries immediately to prevent corrosion. Table 4 shows the internal batteries checked for the + and - position of the Power Switch. It is recommended, however, that if the reading in either + or - position is low, all of the internal batteries be replaced.

3. The battery supplies consist of 4 inexpensive disposable zinc-carbon batteries (2 for the positive supply and 2 for the negative). The batteries are 9 volt 2N6 Mallory (246 Eveready) or equivalent. Replacements may be obtained at most drug and variety stores. When used continuously, a new battery compliment should provide well over 2000 hours of operation if the recorder output is

TABLE 4.
Battery Checked for Power Switch Position.

Power Switch Position	Batteries Checked
BATT CHK +	BT101
BATT CHK -	BT102

not used. If the recorder output is used, the batteries will normally provide more than 1000 hours of operation. When the Model 155 is used intermittently the battery life is limited by the shelf life of the batteries.

2-4. OPERATING PROCEDURES.

a. With the Power Switch set to OFF, check the meter zero. If necessary, adjust with the meter mechanical zero.

b. Turn the Power Switch to the BATT CK positions and check the battery condition per paragraph 2-3c.

c. Set the front panel controls as follows:

Power Switch	ZERO CK
RANGE Switch	as necessary

d. Follow the input connection precautions outlined in paragraph 2-1. Connect the unknown voltage differentially between the + and - Terminals on the front panel. Set the Power Switch to ON and increase sensitivity with the RANGE Switch, rechecking zero on each range sensitivity increase. Continue to increase sensitivity until the greatest on scale deflection is obtained. Read the voltage as the percentage of full scale that the meter reads times the RANGE Switch setting, positive or negative scale.

e. For sensitive measurements, measurements below 10 millivolts, see paragraphs 2-7 through 2-10.

2-5. FLOATING OPERATION.

a. The Model 155 may be connected between two potentials, neither of which is at ground. It can be floated up to 1200 volts off ground.

b. In this mode, the Barrier Strip Connector is floating at the input potential. Therefore, be careful to keep the Connector from shorting to any low voltage point.

c. The Model 155 is excellent for measuring signals off ground because of the extremely high resistance between the input terminals and the case. However, the 10^{12} ohm isolation specification can be maintained only as long as the front panel binding posts and the area around the Barrier Strip Connector are kept clean.

d. Except for the above outlined precautions, operation for the Model 155 in floating configuration is the same as outlined in paragraph 2-4.

2-6. RECORDING.

a. The Model 155 has an output of ±1 volt at up to ±1 milliampere for recording. It can be used directly with 1 volt and 1 milliampere recorders. If the Model 155 is used for floating measurements, the recorder must also be floating.

b. To record the Model 155 output connect the OUTPUT HI and OUTPUT LO Terminals on the Barrier Strip Connector to the respective input high and low terminals on the recorder. Adjust the recorder sensitivity and zero as desired. The system is now ready to record.

c. The actual isolation of the recording system is the parallel combination of the isolation of the Model 155 and the recorder. Thus the 10^{12} ohm isolation of the Microvoltmeter may be compromised by the recorder low-to-ground isolation.

2-7. ACCURACY CONSIDERATIONS. For sensitive measurements, other external considerations besides the Model 155 will affect the accuracy. Effects not noticeable when working with higher voltages are very important with microvolt signals. The Model 155 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors which affect accuracy: noise and source resistance, thermal emfs and stray pickup.

2-8. NOISE AND SOURCE RESISTANCE.

a. The limit of resolution in measuring voltages with the Model 155 is determined by the noise present. The input noise of the Microvoltmeter is 150 nanovolts peak-to-peak. This noise is inherent in the Model 155 itself and will be the minimum amount present in all measurements. The 150 nanovolts of noise is due to the instruments voltage noise. The noise at the Model 155 input increases beyond this minimum when the noise current passes through a source resistor and thereby generates a voltage noise. Thus the total noise becomes a function of the source resistance and is given by the equation

$$n^2 = e_n^2 + \left(i_n R_S\right)^2 \qquad \text{equation 1.}$$

where n is the total input noise;

e_n is the input voltage noise of the Model 155;

i_n is the input current noise;

R_S is the parallel combination of source resistance and input impedance;

b. Even on the most sensitive range, the noise due to the current is not appreciable until R_s reaches approximately 10 kilohms. Thus, for an R_s of zero ohms to 10 kilohms the noise at the input is effectively the inherent 150 nanovolts peak-to-peak. Beyond 10 kilohms the noise due to R_s becomes evident and a limiting factor in the measurement. Therefore, it is recommended that for sensitive measurements R_s be kept relatively low and, if possible, below 10 kilohms.

c. The input impedance of the Model 155 is at least one megohm as long as the instrument amplifiers are not saturated, i.e., as long as the meter needle is on scale. On higher ranges it is even greater (see specifications). Therefore, the Model 155 can measure signals with a large amount of source resistance on the input without degrading performance. Note, however, that if the source resistance is high, the signal seen at the input of the Model 155 will be reduced by the voltage division between the source resistance and the Model 155 input resistance.

2-9. THERMAL EMFS.

a. Thermal emfs (thermo-electric potentials) are generated by thermal differences between two junctions of dissimilar metals. These can be large compared to the signal which the Model 155 can measure.

b. Thermal emfs can cause the following problems:

1. Instability or zero offset much higher than expected.

2. The instrument is sensitive to and responds to temperature changes. This is seen by touching the circuit, by putting a heat source near the circuit, or by a regular pattern of instability, corresponding to heating and airconditioning symtems or changes in sunlight.

c. To minimize the drift caused by thermal emfs use copper leads to connect the circuit to the Model 155. The input terminals of the Model 155 are of a copper alloy, and using the same metal or metals having the same thermo-electric power as the input will result in minimal generation of thermal emfs. The leads to the input may be shielded or unshielded, as necessary (See paragraph 2-10).

d. Widely varying temperatures within the circuit can also create thermal emfs. Therefore, maintain constant temperatures to minimize these thermal emfs.

e. The ZERO Control can be used to buck out constant offset voltages.

2-10. SHIELDING.

a. The Model 155 is quite insensitive to ac voltages superimposed upon a dc signal at the input terminals. However, ac voltages which are extremely large compared with the dc signal may erroneously produce a dc output. Therefore, if there is ac interference, the circuit should be shielded and the shield connected to the Microvoltmeter ground, particularly for low-level sources.

b. Improper shielding can cause the Model 155 to reach in one or more of the following ways:

1. Unexpected offset voltages.

2. Inconsistent readings between ranges.

c. To minimize pickup, keep the voltage source and the Microvoltmeter away from strong ac magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each shield at only one point.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL.

a. The Keithley Model 155 Microvoltmeter is basically composed of a variable gain chopper amplifier, an offset voltage suppression circuit, an ac attenuator filter, input attenuators, an output monitoring circuit and power supplies (See Figure 3).

b. The main signal flow path is as follows: An input signal is applied through the Power Switch to the Range Switch where it is divided to a determined ratio by the Range Switch Resistors. A MOS FET chopper converts this dc input signal to an ac signal. The ac signal is amplified, demodulated, dc amplified and applied to the meter and the output. A feedback network samples the signal at the output and compares it to the input. The dc input signal and the feedback signal are compared at the input of the chopper and the voltage-difference signal between the two is increased. The ac amplifier amplifies the difference signal. The ac signal is then demodulated and enters a dc amplifier. The dc amplifier output is connected to the meter, the output terminals and the feedback network. The feedback resistors determine full-scale range.

c. The power source for the Model 155 is derived from disposable batteries.

NOTE

The circuit designations referred to in this section are for Schematic Diagram 22354E found at the back of the manual.

3-2. CHOPPER AMPLIFIER. The basic chopper amplifier consists of a chopper (sometimes called a modulator) which switches the input dc signal on and off to produce an ac output. This ac is then amplified and demodulated to regain the dc signal. Further amplification is then achieved with a dc amplifier. The negative feedback is employed around the total amplifier to achieve gain accuracy and gain stability. Synchronous demodulation is obtained by synchronizing the demodulating switch with the chopper. The individual circuits in the chopper amplifier are described as follows.

a. MOS FET Chopper.

1. The field-effect transistor when used as a chopping device provides low offset currents, low offset voltages, low noise and low drive power. A series shunt chopping configuration provides low noise and high input impedance.

2. Transistors Q101 and Q102 are the chopper. Resistor R184 and Capacitor C104 are used to minimize the problem of the chopper drive feeding into the signal channel.

b. AC Amplifier. The ac amplifier is composed of a low noise amplifier and a variable gain amplifier.

1. A bi-polar transistor, Q103, biased for operation at low current levels is the input device. Transistors Q103 and Q104, and associated

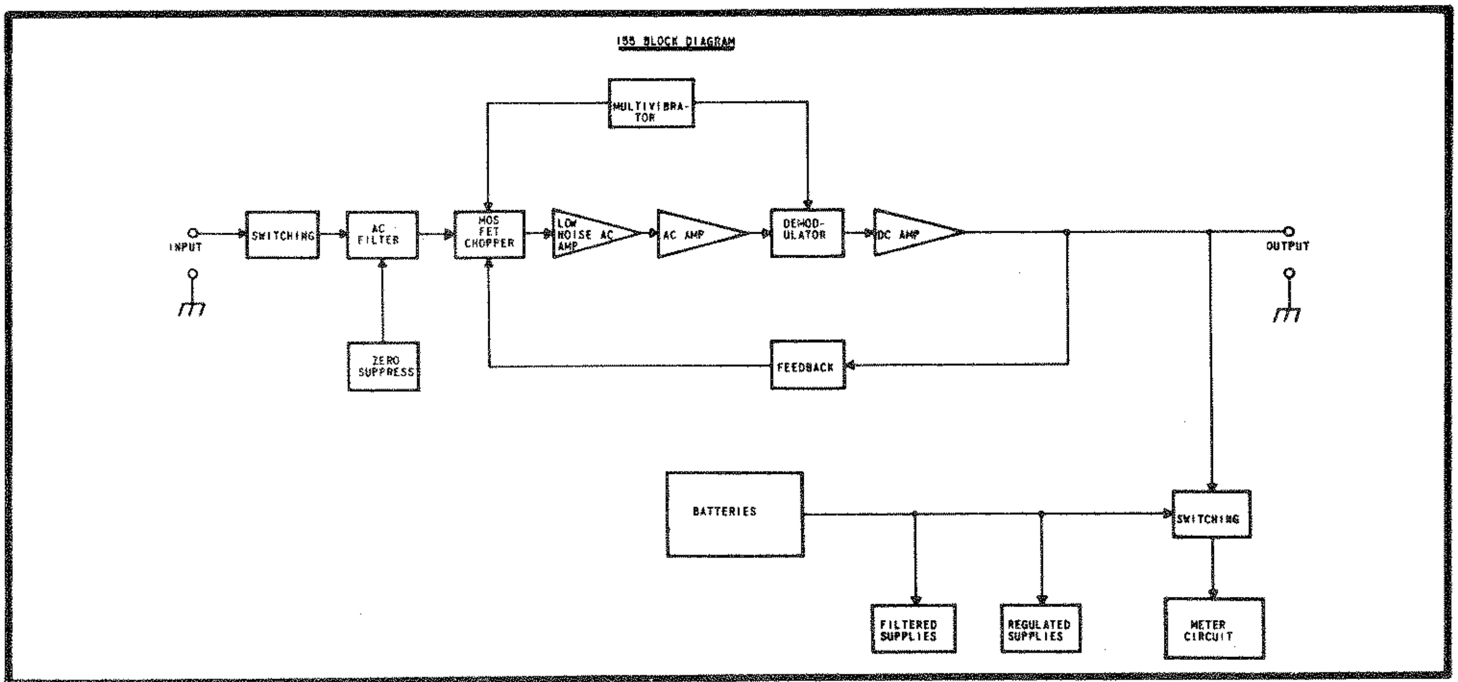


FIGURE 3. Block Diagram of Model 155 Circuits.

components, are a low noise amplifier with a gain of 34, as fixed by the feedback resistors R129 and R131.

2. The low noise amplifier is followed by a variable gain ac amplifier consisting of transistors Q105, Q106 and Q107 and associated components. It is necessary to have high gain when measuring very low voltages, and less gain when the total chopper amplifier is to be used at lower gain to prevent oscillations. For this reason, the gain of the second amplifier is varied by switching the feedback resistor. Resistor R147 and R148 along with capacitor C128 provide a high frequency cutoff for the attenuation of the spikes generated in the chopper by the chopper drive.

c. Demodulator. Field-effect transistor Q118 acts as a switch which is synchronized with the input chopper and thus provides synchronous demodulation. The average value of the signal obtained at the junction of capacitor C112, and resistor R149, is proportional to the dc input signal. Because of the switching action of Q118, the signal at this junction is shorted to ground for half of each chopping cycle. Consequently this dc signal has a large chopper frequency component.

d. DC Amplifier.

1. The function of this amplifier is twofold: It gives additional amplification to the relatively small signal seen at the output of the demodulator, and it integrates the output of the demodulator, thus removing most of the chopper frequency ripple which appears there. Complimentary symmetry output is used for the amplifier to meet the requirements of low idling power while still being capable of providing 1 milliampere of output current.

2. The dc amplifier is composed of three differential amplifiers and emitter follower. The signal from the output of the demodulator is applied to the first differential dc amplifier, composed of transistors Q116 and Q108, and amplified. The second amplifier, transistors Q109 and Q110, amplifies the output signal from the first amplifier and applies it to a third differential amplifier, Q111 and Q112, for further amplification. Emitter followers Q113, Q114 and Q115 are an impedance changing circuit to provide low output impedance.

e. Total Loop DC Feedback.

1. The Model 155 uses negative feedback to achieve gain accuracy and stability and assure high input impedance. The resistors are switched into the feedback current in such a way as to maintain low feedback current and avoid excessively high value resistors in the feedback loop.

2. The feedback network, composed of resistors R118 through R126 and R185, is formed from the output of the dc amplifier to the input of the chopper amplifier. The Range Switch, S101, selects the feedback ratio used for each range.

f. Multivibrator.

1. The multivibrator circuit generates the drive voltage for the chopper and demodulator.

2. Transistors Q120 through Q123 and their associated components are an astable multivibrator. Output voltages are taken at the emitters of Q120 and Q123. These output voltages are opposite phase square waves and are used directly as the chopper drive. The output at the emitter of Q120 is also used as the demodulator drive.

3-3. OFFSET SUPPRESSION CIRCUITS.

a. When measuring signals in the microvolt region it is often desirable to suppress the zero voltage level so that small changes may be readily observed. For this reason a front panel ZERO Control, R173, is provided. This control is non-linear so that for normal operation (suppression of less than $\pm 5\ \mu V$) accurate zeroing may be easily achieved, while still having available suppression of at least ±25 V.

b. Offset current is suppressed by the circuit consisting of potentiometer R104 and resistors R110 and R186.

3-4. HIGH FREQUENCY ATTENUATE INPUT FILTER. The frequency attenuating filter at the input of the Model 155 provides approximately 50 dB of ac rejection at 60 Hz. The filter is a 3-section RC ladder filter consisting of resistors, R107, R108, R111 and R112 and capacitors C101, C102 and C103.

3-5. INPUT ATTENUATION.

a. The chopper amplifier has a minimum gain of 100 and a maximum output voltage of ±1 volt. This means it is necessary to attenuate signals larger than 10 millivolts to prevent saturation of the chopper amplifier. The input attenuator resistors R102, through R106 and R113 through R117, are switched by the RANGE Switch, S101. One decade of attenation is necessary to handle signals as high as 100 millivolts. Two decades of attentuation are necessary to handle signals as large as 1 volt, and so on. Input attenuation is switched in a decade at a time, and the gain of the chopper amplifier is alternated between 333 and 100 for all ranges above 10 millivolts.

b. Because of potential instability in the resistance value of high value resistors, potentiometers have been placed in series with all high value resistors in the attenuator string. Thus, the instrument can be accurately calibrated even if the high value resistors drift.

3-6. POWER SUPPLIES.

a. Power for the Model 155 is provided by four 9 volt zinc-carbon batteries. The idling current of the Model 155 is approximately 500 microamperes. Thus the battery life for most applications will be the same as the battery shelf life. If the recorder output is used, a maximum of 1 mA may be drawn from it, so the battery life will still be normally in excess of 1000 hours.

b. Because the battery noise may increase and terminal voltage will decrease with battery age, and because it is necessary to have fixed voltage for the offset suppression circuits, zener supplies consisting of transistors D106, D107 and associated components provide a regulated ±6 V. The low noise amplifier supplies are isolated from the other supplies by filters consisting of resistor R167 and R168 and capacitors C116 and C117.

TABLE 5.
Equipment Recommended for Calibrating and Troubleshooting the Model 155. Use these instruments or their equivalent.

Instrument	Use
Fairchild Instruments 7050 DVM, 1.5 to 1000 volts full scale, 0.1% accuracy, 1.5 kΩ to 15 MΩ input resistance	General Calibration and Troubleshooting
Hewlett Packard 200CD Oscillator	Normal Mode and Common Mode Rejection Checks
Hewlett Packard 5210A Frequency Meter	Multivibrator Adjust
Keithley Instruments 241 High Voltage Supply	General Calibration
Keithley Instruments 260 Nanovolt Source	Rise Time Check and Range Accuracy Verification
Keithley Instruments 370 Recorder	Drift Check
Keithley Instruments 500 Megohmmeter	Initial Adjustment
Keithley Instruments 662 Differential Voltmeter	DC Amplifier Balance Adjust
Tektronix dc coupled Model 503 Oscilloscope	General Calibration and Troubleshooting
5 μF Polystyrene Capacitor	Normal Mode and Common Mode Rejection Checks
1000:1 Voltage Divider	Normal Mode and Common Mode Rejection Checks

SECTION 4. SERVICING

4-1. GENERAL. Section 4 contains the maintenance and troubleshooting procedures for the Model 155 Microvoltmeter. Follow these procedures as closely as possible to maintain the performance of the instrument.

4-2. SERVICING SCHEDULE. Periodically check the condition of the batteries, using the convenient battery check as described in paragraph 2-3. Except for battery replacement, the Model 155 requires no periodic maintenance beyond the normal care required of high quality electronic equipment.

4-3. PARTS REPLACEMENT. The Replaceable Parts List in Section 7 describes the electrical components of the Microvoltmeter. Replace components only as necessary. Use only reliable replacements which meet the specifications.

4-4. TROUBLESHOOTING.

a. The procedures which follow give instructions for repairing troubles which might occur in the Model 155. Use the procedures outlined and use only specified replacement parts. Table 5 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, contact Keithley Instruments, Inc., or its representative.

b. Table 6 contains the more common troubles which might occur. If the repairs indicated do not clear up the trouble, find the difficulty through a circuit-by-circuit check, such as given in paragraph 4-6.

c. Refer to the circuit description in Section 3 to find the more critical components and to determine their function in the circuit. The complete circuit schematic, 22345E, is given in Section 7 at the back of the manual.

4-5. PRELIMINARY PROCEDURES.

a. Before initiating any troubleshooting procedures, double-check the system to make sure that the Model 155 is indeed faulty. Once this is determined, turn the Microvoltmeter Power Switch to OFF and gather the tools and instruments that may be necessary to disassemble, troubleshoot, repair and reassemble the instrument. Table 5 lists equipment recommended for troubleshooting.

b. If the trouble is such that the Model 155 must be disassembled (i.e. other than battery check, etc.), then disassemble the instrument to the point where the circuits are accessable and the power may be safely turned on.

c. If the user is quite familiar with the instrument, he may be able to deduce what circuit is most likely to be faulty from the symptoms of the fault. In such a case, time may be saved by checking out

TABLE 6.
Model 155 Troubleshooting.

Trouble	Probable Cause	Solution
Excessive Zero Offset	Input transistors may be defective	Check Q101 and Q102 (paragraph 4-6e); replace if faulty.
	Batteries failing	Replace batteries.
	DC Amplifier Balance potentiometer, R151, out of adjustment	Adjust per paragraph 4-6h or 5-5.
	Mechanical meter zero out of adjustment	Adjust correctly.
Excessive Offset Current	Input transistors may be defective	Check Q101 and Q102 (paragraph 4-6e); replace if faulty.
	Offset Current Suppress potentiometer, R109, out of adjustment	Adjust per paragraph 5-8.
Instrument inaccurate on all ranges	Meter Calibrate potentiometer, R183, out of adjustment	Adjust per paragraph 5-6.
Instrument inaccurate on 300 mV and 1V ranges	Accuracy Set potentiometer, R104, out of adjustment	Adjust per paragraphs 5-7 and 5-13.
Instrument inaccurate on 3V and higher ranges	Accuracy Set potentiometer, R101, out of adjustment	Adjust per paragraphs 5-7 and 5-13.
Apparent Oscillation in Output	Chopper frequency beating with line frequency	Adjust Multivibrator Frequency Set potentiometer, R178. (Paragraphs 4-6e and 5-4).
	Multivibrator Frequency Set potentiometer, R178, out of adjustment	Check per paragraph 4-6e and adjust per paragraph 5-4.

hunches. Otherwise, it is best to proceed in the manner given in paragraph 4-6.

d. Before starting a step-by-step check, inspect the circuit visually. Solid-state circuitry usually has a very low failure rate. Consequently, a high percentage of the problems which arise will be due to such things as broken wires, dirt between switch contacts, loose battery clips, etc.

e. Turn the Model 155 Power Switch to ON and check out the circuit according to paragraph 4-6. When the trouble is located, turn the Power Switch to OFF, make the repair and reassemble the instrument. Also, after the repair has been made, a final check should always be made to make sure that the instrument is working properly.

4-6. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the condition of the batteries. If these are found to be defective, replace them.

b. If the batteries are satisfactory, set the Range Switch to 1000 VOLTS, Power Switch to ZERO CHK and check the voltage at the plus and minus battery check points (these are points 1 and 2 given in Figure 4). The voltage at each point should be approximately +16.2 and -16.2 volts respectively.

1. Check for battery current of less than 3 milliamperes if the plus and minus 16.2 volts cannot be obtained. If the 3 milliamperes is present, then there is a short circuit between the battery leads in the Power Switch.

2. If the 3 milliamperes cannot be obtained, then there is a shorted component loading the supplies. Replace the faulty component.

c. If the plus and minus battery supplies are found to be satisfactory, then check the filtered plus and minus battery supplies (these are points 3 and 4 given in Figure 4). Check these supplies for approximately plus and minus 14.9 volts respectively. If unobtainable, then the fault is in the associated circuitry components. Find the component and replace it.

d. If the filtered battery voltages are satisfactory, check the regulated plus and minus 6 volt supplies for +6 volts ±2V and -6 volts ±2V respectively. Check these voltages at points 5 and 6 shown in Figure 4. If these values are unobtainable, then the fault lies in the associated circuitry. Find the faulty component and replace it.

e. If the regulated voltage supplies are satisfactory, then the trouble may lie in the multivibrator circuit. Check the multivibrator waveform with a dc coupled Model 503 Oscilloscope at the gates of FET Q101 and Q102 (test points 7 and 8, Figure 4). Set the Oscilloscope to 2 volts per division vertical and 1 millisecond per division horizontal. The waveform should be near symmetrical 7 to 12 volts peak-to-peak (Figure 5). A little overshoot may be observed on some units.

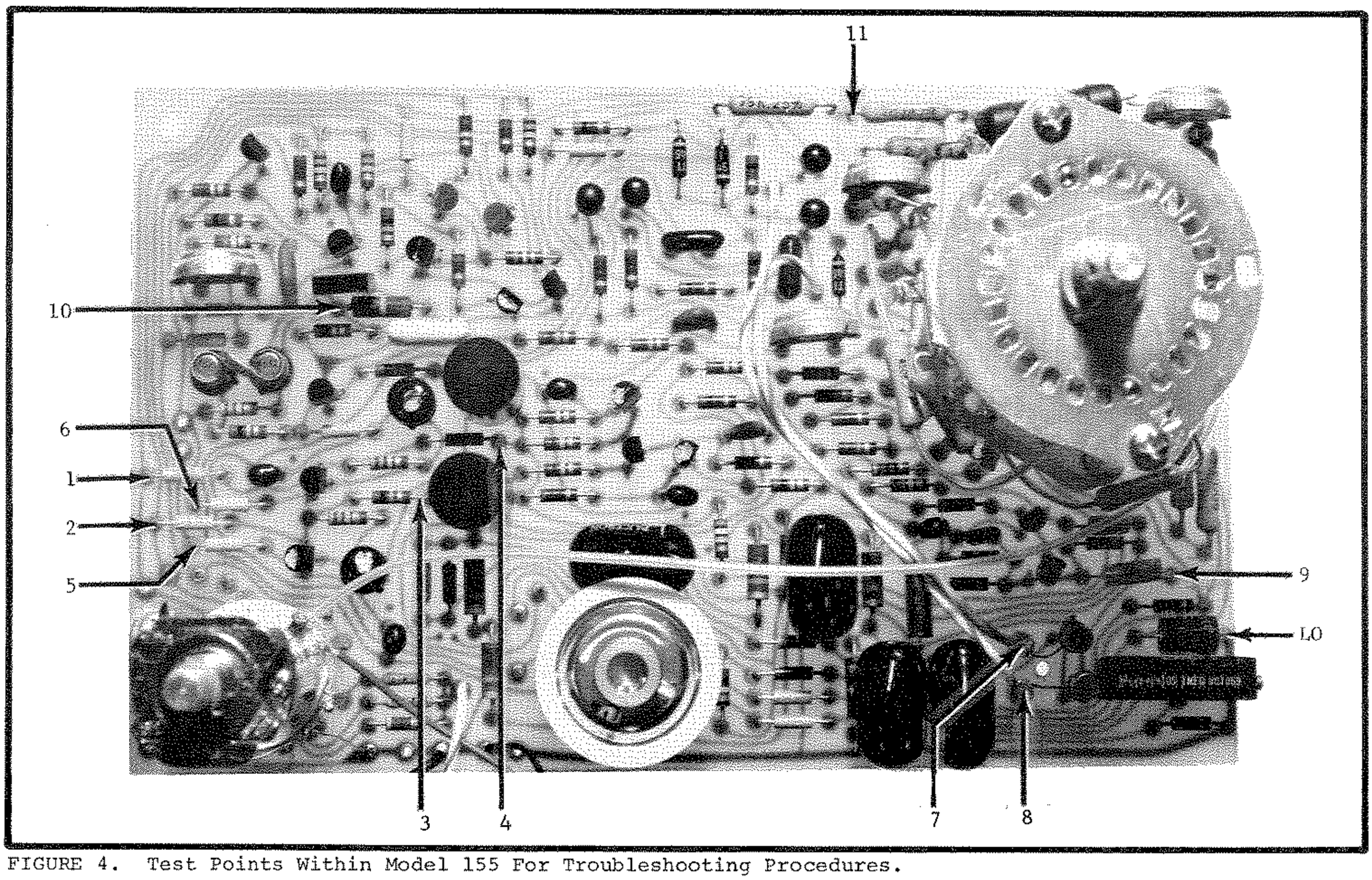


FIGURE 4. Test Points Within Model 155 For Troubleshooting Procedures.

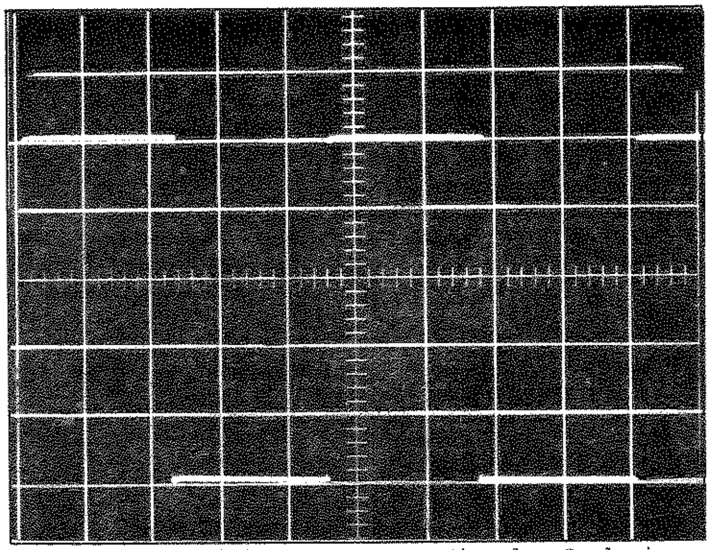


FIGURE 5. Multivibrator Output Signal. Scale is 2V/div. vertical and 1 msec/div. horizontal.

1. Are both chopper drives present? If not, taking care to prevent damage to Q101 and Q102, remove the gate lead from the standoff.

a) Are both chopper drives now present? If not, repair the multivibrator.

b) If the chopper drives are present, replace Q101 and Q102.

2. After either repairing the multivibrator or replacing the FETs, and if both chopper drivers are present, check for a signal at the output of the FETs (point 9, Figure 4).

a) If there is no signal, the fault lies in the input harnessing, switches or the input filter.

b) If there is a signal, replace Q101 and Q102.

c) After repairing the fault and/or replacing Q101 and Q102, replace the gate leads.

NOTE

Defective input FETs Q101 and Q102 may be the cause of ac amplifier unbalance or large current offset.

f. Check for a square wave at the demodulator test point, (point 10, Figure 4). If there is no square wave, then the fault lies in the ac amplifier consisting of transistors Q103 to Q107. Find and replace the defective transistor(s). To localize

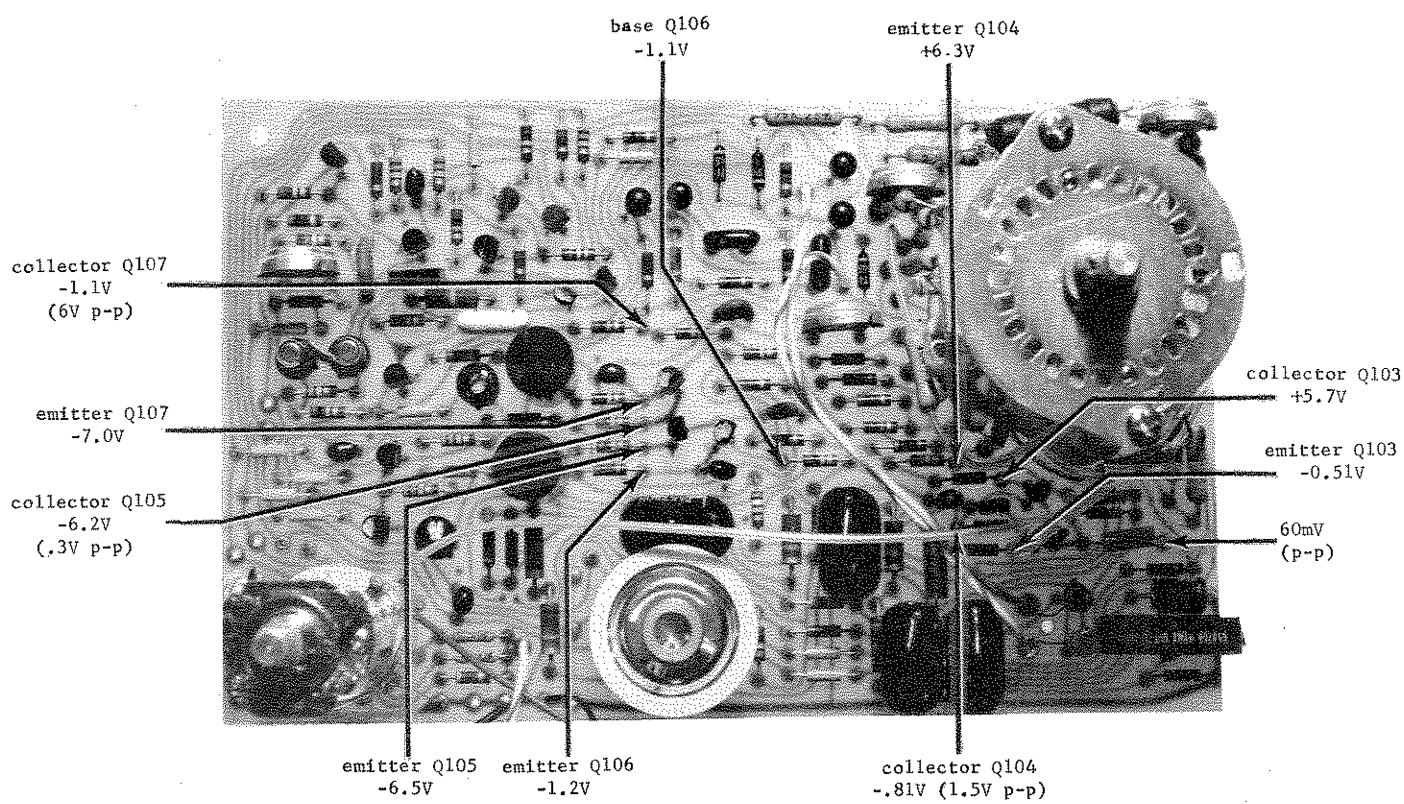


FIGURE 6. Test Points Within the AC Amplifier Circuit and Indicated Nominal Voltages to be Expected at the Test Points.

the trouble in the ac amplifier refer to Figure 6. It shows test points within the ac amplifier circuit and indicates nominal voltages to be expected at the test points. Nominal voltage measurements are made with the feedback test point (point 11 in Figure 4) jumpered to low, the Model 155 Range Switch set to 1000 VOLTS and the Power Switch at ZERO CHK. Voltages may be slightly higher or lower than the nominal voltage listed.

g. If there is a square wave at the demodulator test point, short the test point to low and check for a square wave again. If there is no square wave then the fault lies in the demodulator circuit. Find and repair the fault.

h. If the demodulator is found satisfactory, keep the demodulator test point shorted to low and check the dc amplifier operation.

1. Turn the DC Amplifier Balance potentiometer, R151, completely clockwise. The meter should peg in the minus direction. Then turn R151 completely counterclockwise. The meter should peg in the plus direction.

2. If the meter does not peg in both cases, then the fault lies in the dc amplifier circuit. Find the fault and repair it.

3. To localize the trouble in the dc amplifier, refer to Figure 7. It shows test points within the dc amplifier circuit and indicates nominal voltages to be expected at the test points.

a) Nominal voltage measurements are made with the Model 7050 Digital Voltmeter. The demodulator test point is jumpered to low, the Range Switch at 1000 VOLTS and Power Switch to ZERO CHK. The Model 7050 common must be above ground.

b) Connect the Model 7050 across the collection of transistors Q109 and Q110. Turn DC Balance potentiometer, R151, to achieve a reading near 0 (balance). When balanced, the voltage to low should be near nominal values listed.

i. If the dc amplifier circuit is found to operate satisfactorily, then the trouble is in the output switching or meter circuits. Locate and repair the trouble.

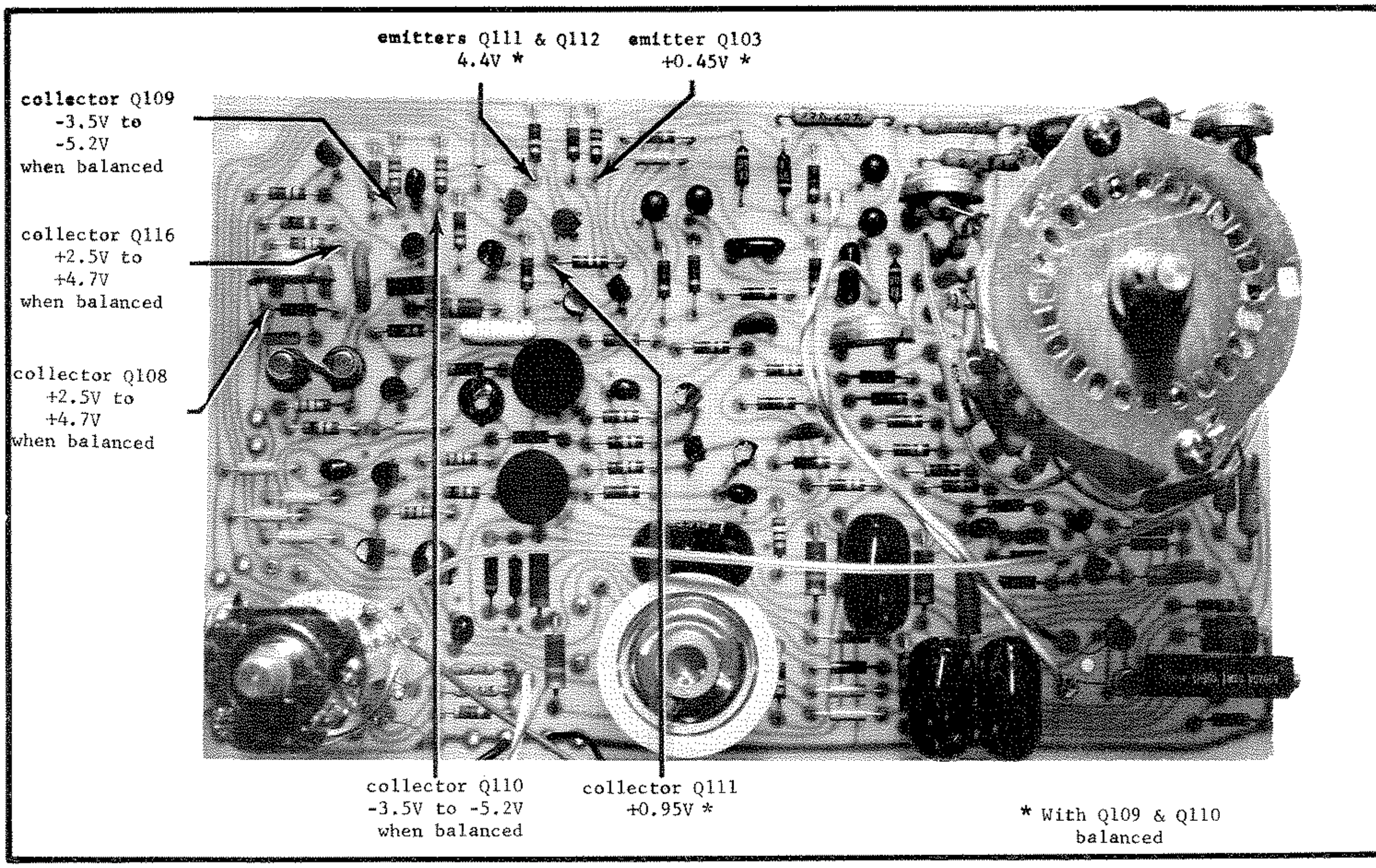


FIGURE 7. Test Points Within DC Amplifier Circuit and Indicated Nominal Voltages to be Expected at Test Points.

SECTION 5. CALIBRATION

5-1. GENERAL. The function of the calibration section is to provide a method of checking the Model 155 to make sure that it operates within the specifications given in Table 1, page ii.

a. The following procedures are recommended for calibrating and adjusting the Model 155. Use the equipment in Table 5. If proper facilities are not available or if difficulty is encountered, contact Keithley Instruments, Inc., or its representatives to arrange for factory calibration.

b. If the Model 155 is not within specifications after the calibrations and adjustments, refer to the troubleshooting procedures in Section 4 or contact Keithley Instruments, Inc., or its nearest representative.

NOTE

Figure 4 shows the location of internal test points used in calibrating the Model 155.

TABLE 7.
Model 155 Internal Controls.

Control	Circuit Desig.	Paragraph
Accuracy Set	R101	4-7, 4-13
Accuracy Set	R104	4-7, 4-13
Offset Current Suppress	R109	4-3, 4-8
DC Amplifier Balance	R151	4-3, 4-5
Multivibrator Frequency Set	R178	4-4
Meter Calibrate	R183	4-6

5-2. INITIAL ADJUSTMENTS.

a. Set the Model 155 Power Switch to OFF and RANGE Switch to 1000 VOLTS.

b. Check the Barrier Strip Connector on the rear panel of the Model 155. Make sure that shorting links are placed between the +POWER SUPPLY and +BATTERY Terminals and between the -POWER SUPPLY and -BATTERY Terminals.

c. Connect a Model 500 Megohmmeter between Model 155 front panel -(low) and CASE Binding Posts. Check to make sure the isolation between these two posts is greater than 10^{12} ohms. Connect the ground lead of the Model 500 to the Model 155 CASE Binding Post to minimize pickup.

d. Adjust the Model 155 meter for zero with the Mechanical Zero.

e. Check the battery condition by setting the Power Switch to BATT CHK + and - positions. For each polarity the meter needle should indicate 70% to 100% of full scale (green area). New batteries typically indicate greater than 86% of full scale (18.5 volts or more). After checking batter condition, set the Power Switch to OFF.

NOTE

See paragraph 2-3 also for checking the condition of the batteries.

5-3. PRELIMINARY CALIBRATION PROCEDURES.

a. Make sure that Offset Current Suppress Potentiometer, R109, is at least one turn from either end. Jumper the center tap of potentiometer R109 to the low end of resistor R186. Do not remove this jumper until specifically stated in paragraph 5-6.

b. Turn the Power Switch to ZERO CHK. Within a few moments the meter needle should come to zero indication. If necessary, zero the meter with the ZERO Control. Increase the Model 155 sensitivity to 100 microvolts and zero the meter.

c. If the Model 155 is inoperative, that is if the meter pins, etc., then check the voltage at the test points given in Table 8 to the values indicated in Table 8. If these voltages are found satisfactory, check the multivibrator per paragraph 5-4. If all the above checks are satisfactory, localize the trouble to the ac or dc section of the amplifier by shorting the demodulator test point (point 10, Figure 4) to low and adjusting DC Amplifier Balance Potentiometer, R151, from one end to the other. If potentiometer R151 can swing the meter full scale from + to - and vice versa, the problem is in the ac section of the amplifier. If it cannot, the problem is in the dc section. (Refer to the troubleshooting procedures 4-6).

TABLE 8.
Test Points within the Model 155. Table refers to the test points called out in Figure 4, paragraph 4-6, and gives the voltage expected at each point.

Test Point	Voltage
1	approximately +16.2 volts
2	" -16.2 volts
3	" +14.9 volts
4	" -14.9 volts
5	+6V ±2V
6	-6V ±2V

5-4. MULTIVIBRATOR ADJUST.

a. Connect the Model 5210A Frequency Meter between the multivibrator test point (point 11, Figure 4) and low. Adjust the Multivibrator Frequency Set Potentiometer, R178, for a reading of 220 Hz ±3 Hz.

b. Then connect a dc coupled Model 503 Oscilloscope between the multivibrator test point and low, and observe the waveform. The Oscilloscope should be set at 2 volts per division vertical and at a 1 millisecond sweep. The wave form should be near symmetrical 7 to 12 volts peak-to-peak square wave (refer to Figure 5 in paragraph 4-6e).

5-5. DC AMPLIFIER BALANCE ADJUST.

a. Connect the Model 155 output to the Model 662

Differential Voltmeter. Set the Model 155 Power Switch to ZERO CHK and read zero from the Model 662.

1. Set the Model 155 RANGE Switch to 100 MICROVOLTS and adjust the ZERO Control for 0±2 mV at the output exclusive of noise (typical noise is from 2 to 5 mV peak-to-peak).

2. Set the RANGE Switch to 1000 VOLTS and adjust the DC Amplifier Balance Potentiometer, R151, for 0±0.5 mV at the output.

3. If necessary, repeat steps 1 and 2.

b. Once adjusted, step the RANGE Switch from 100 MICROVOLTS through 1000 VOLTS. Large zero shifts (8 mV or more) between ranges generally indicates that input FETs Q101 and Q102 may be defective.

5-6. OFFSET CURRENT SUPPRESS CALIBRATION.

NOTE

Make sure the Model 155 cover is on during this test procedure. Diodes D101 through D105 may be sensitive to light and the adjustment is void without the cover on.

a. Remove the jumper from between the center tap of potentiometer R109 and the low end of resistor R186.

b. Shield the Model 155 input. (The input may be shielded by affixing banana plugs inside a metal case and covering the four front panel binding posts with the case, being careful to insert the banana plugs into the GUARD and CASE Terminals). Shielding is necessary to reduce pickup.

c. Set the Model 155 Power Switch to ZERO CHK and the RANGE Switch to 100 MICROVOLTS.

1. Adjust the ZERO Control for zero meter indication.

2. Open the input by setting the Power Switch to ON and adjust the Offset Current Suppress Potentiometer, R109, for near zero meter indication.

d. Set the Power Switch to ZERO CHK and the RANGE Switch to 30 MICROVOLTS.

1. Adjust the ZERO Control for zero meter indication.

2. Set the Power Switch to ON and adjust potentiometer R109 for less than a ±5 μV shift (0±5 minor divisions on the lower meter scale).

3. If necessary, repeat steps 1 and 2 to obtain less than 5 μV shift on the meter when Switching the Power Switch between ZERO CHK and ON Positions. (The Model 155 can be readily adjusted for less than 2 μV shifts).

e. With the Power Switch set to ON step the RANGE Switch from 30 MICROVOLTS to 1 VOLT. Offset on the 100 and 300 microvolt ranges should be less than 5 microvolts decreasing to a negligible offset on the 1 millivolt through 1 volt ranges.

5-7. METER CALIBRATION.

a. Connect the Model 241 Voltage Supply to the Model 155 input and connect the output to the Model 7050 DVM.

b. Set the Model 155 RANGE Switch to 1 VOLT and apply ±1 volt to the input with the Model 241.

1. Adjust the ZERO Control and/or the input voltage to obtain a +1.000 volt at the output.

2. Adjust the Meter Calibrate Potentiometer, R183, for a full scale positive deflection on the Model 155 meter scale.

c. Apply -1 volt to the Model 155 input and adjust the ZERO Control and/or the input voltage to obtain -1.000 volt at the output.

1. Note the negative full scale meter deflection.

2. If necessary, adjust potentiometer R183 to split the difference between the positive and negative full scale deflections.

d. Typical positive and negative full scale error is less than 1% (1/2 minor division).

5-8. ACCURACY SET CALIBRATION.

a. Keep the Model 155 connected as in above paragraph 5-7.

b. Set the RANGE Switch to 1 VOLT and the Power Switch to ZERO CHK.

1. Adjust the ZERO Control for 0.000 volts at the output.

2. Apply 1.000 volt to the input and adjust Accuracy Set Potentiometer R101 for 1.000 volt at the output.

c. Set the RANGE Switch to 10 VOLTS and the Power Switch to ZERO CHK.

1. Adjust the ZERO Control for 0.000 volts at the output.

2. Apply 10.000 volts to the input and adjust Accuracy Set Potentiometer R104 for 10.00 volts at the output.

NOTE

Always adjust potentiometer R101 before potentiometer R104 because R101 affects R104.

5-9. NOISE CHECK (Keep Model 155 cover on to minimize noise pickup).

a. Set the Model 155 Power Switch to ZERO CHK and the RANGE Switch to 1 MICROVOLT. Zero the instrument with the Zero Control. After zeroing, observe the meter noise for less than 150 nanovolts peak-to-peak (7 minor divisions on the upper meter scale). Observe the meter for a period of 15 seconds.

b. Next, observe the meter noise in the same manner on the 3 microvolt and 100 microvolt ranges. The noise on the 3 microvolt range should be approximately the same as that on the 1 microvolt range decreasing to less than 1% (1/2 division on the upper meter scale) on the 100 microvolt range.

5-10. RISE TIME CHECK (Keep Model 155 cover on to minimize noise pickup).

a. Connect the Model 260 Nanovolt Source to the Model 155 input and a dc coupled Model 503 Oscilloscope to the output. The vertical scale of the Oscilloscope should be set at 0.2 volt per division.

b. Set the Model 155 RANGE Switch to 1 MICROVOLT and the Power Switch to ON.

1. Zero the Model 155 Microvoltmeter with ZERO Control then apply +1 microvolt with the Model 260 to the input and observe the Model 155 10% to 90% rise time on the meter. This rise time must be less than 5 seconds and typically it is less than 3 seconds.

2. Repeat this test with a -1 microvolt signal.

c. Set the Model 155 RANGE Switch to 100 MICROVOLTS and the Power Switch to ON.

1. Zero the Microvoltmeter with ZERO Control.

2. Apply +100 microvolts with the Model 260 to the input and observe the 10-90% rise time on the Model 503 Oscilloscope. This rise time must be less than 1 second and typically is less than 1/2 second. (Figure 8 shows a typical rise time of the Model 155 on the 100 microvolt range).

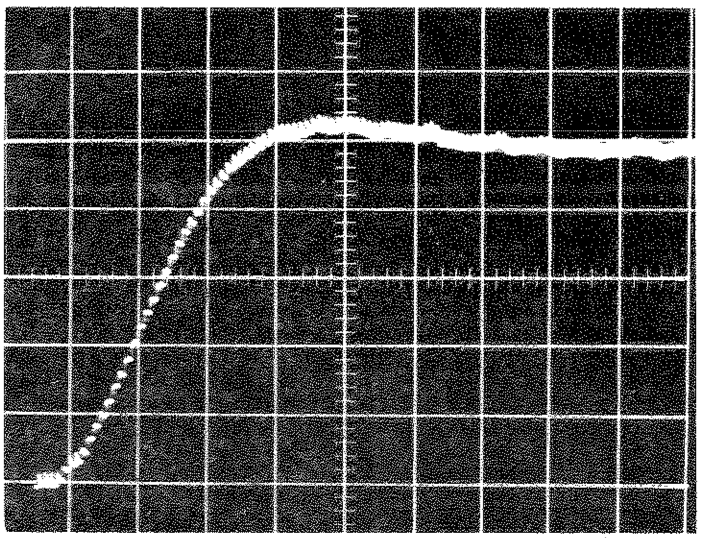


FIGURE 8. Typical 10-90% Rise Time on 100 Microvolt Range. Scale is 20 mV/cm vertical and 0.1 sec/cm horizontal.

5-11. OVERLOAD RECOVERY CHECK.

a. Place a 10 kilohm resistor across the Model 155 input and then connect the Model 241 to the input.

b. Set the Model 155 RANGE Switch to 30 MICROVOLTS and the Power Switch to ON. Zero the meter with the ZERO Control.

c. Apply 30 volts to the input for approximately one second. The Microvoltmeter should recover from this overload within five seconds.

d. Set the RANGE Switch to 1 MICROVOLT and apply 1 volt to the input for approximately one second. The instrument should recover within 20 seconds.

e. Remove the 10 kilohm resistor from across the input.

5-12. DRIFT CHECK.

a. Connect the Model 370 Recorder to the Model 155. Set the Microvoltmeter RANGE Switch to 1 MICROVOLT and the Recorder attenuator to 1 volt. Recorder calibration is now 1 microvolt full scale.

b. After a half-hour warm-up, re-zero the instrument. Using zero as a reference, the Model 155 must not drift more than 0.5 microvolt either side of zero in 24 hours. (In that 24 hour span the instrument will wander about the zero reference but should never deviate more than 0.5 microvolt from reference). Figure 9 shows a typical Model 155 drift.

5-13. RANGE ACCURACY VERIFICATION.

a. Check the 1000 volt through 100 microvolt ranges for 1 volt ±1% at the Model 155 output and ±2% of full scale (1 minor upper scale division) on the meter. Check the 30 microvolt through 1 microvolt ranges for ±2% of full scale exclusive of noise and drift.

1. To check the 1000 volt through 3 volt ranges use the Model 241 to apply the voltages to the Model 155 input. Monitor the output with the Model 7050 DVM.

2. To check the 1 volt through 1 microvolt ranges, use the Model 260 to apply the voltage to

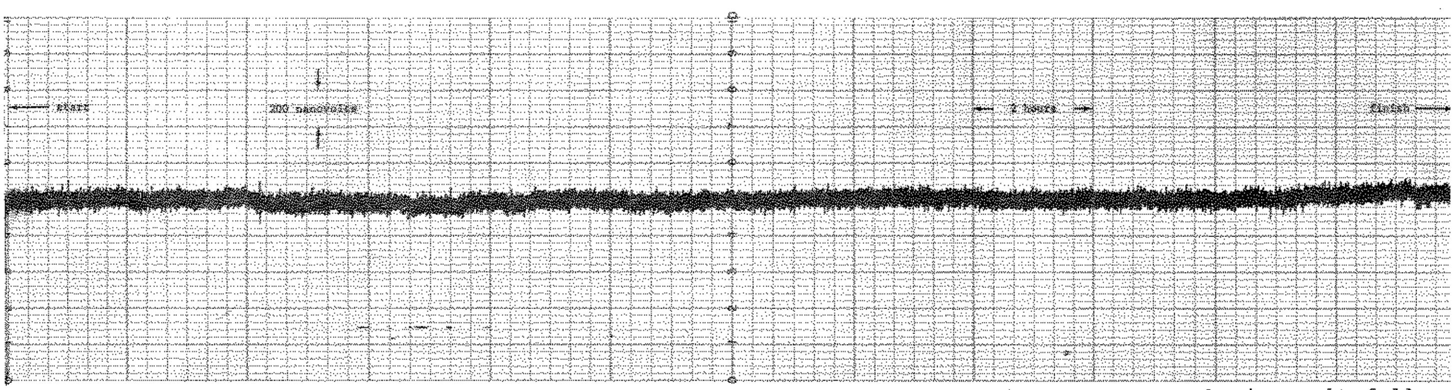
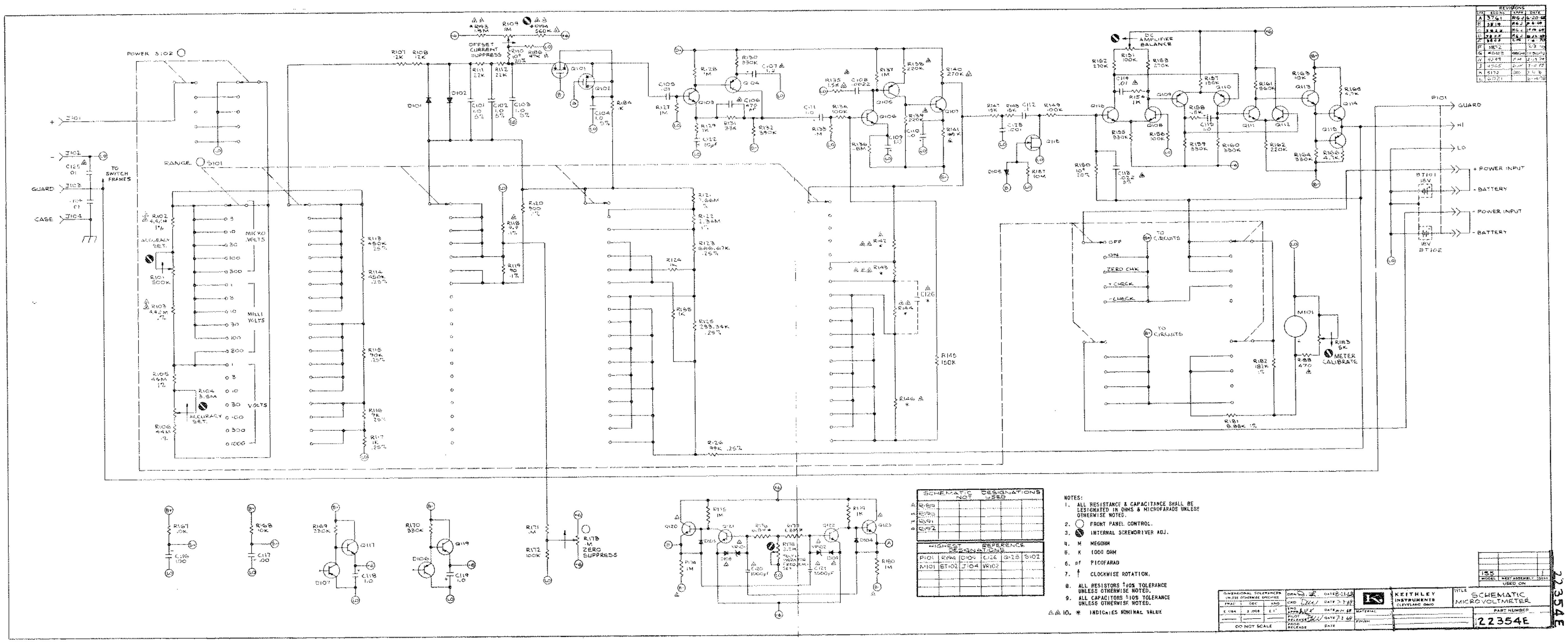


FIGURE 9. Typical 24-Hour Drift Chart for Model 155. This particular drift was run at 1 microvolt full scale and 0.75 inch per hour. Notice that it is well below the specified Model 155 drift. The user may, if desired, perform the drift check at a faster rate and on a less sensitive scale as long as the specified drift can be resolved.


POWER S102
RANGE S101
MICRO VOLTS
MILLI VOLTS
VOLTS
ACCURACY SET
OFFSET CURRENT SUPPRESS
ZERO SUPPRESS
AMPLIFIER BALANCE
METER CALIBRATE
TO SWITCH FRAMES
GUARD
CASE
HI
LO
+ POWER INPUT
+ BATTERY
- POWER INPUT
- BATTERY
OFF
ON
ZERO CHK
TO CIRCUITS
SCHEMATIC DESIGNATIONS NOT USED
HIGHEST REFERENCE DESIGNATIONS
NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. FRONT PANEL CONTROL.
3. INTERNAL SCREWDRIVER ADJ.
4. M MEGOHM
5. K 1000 OHM
6. pf PICOFARAD
7. CLOCKWISE ROTATION.
8. ALL RESISTORS ±10% TOLERANCE UNLESS OTHERWISE NOTED.
9. ALL CAPACITORS ±10% TOLERANCE UNLESS OTHERWISE NOTED.
10. * INDICATES NOMINAL VALUE
DO NOT SCALE
KEITHLEY INSTRUMENTS CLEVELAND OHIO
TITLE SCHEMATIC MICROVOLTMETER
PART NUMBER 22354E
155
USED ON
22354E

ZONE	LTR	ECO NO	REVISION	DATE
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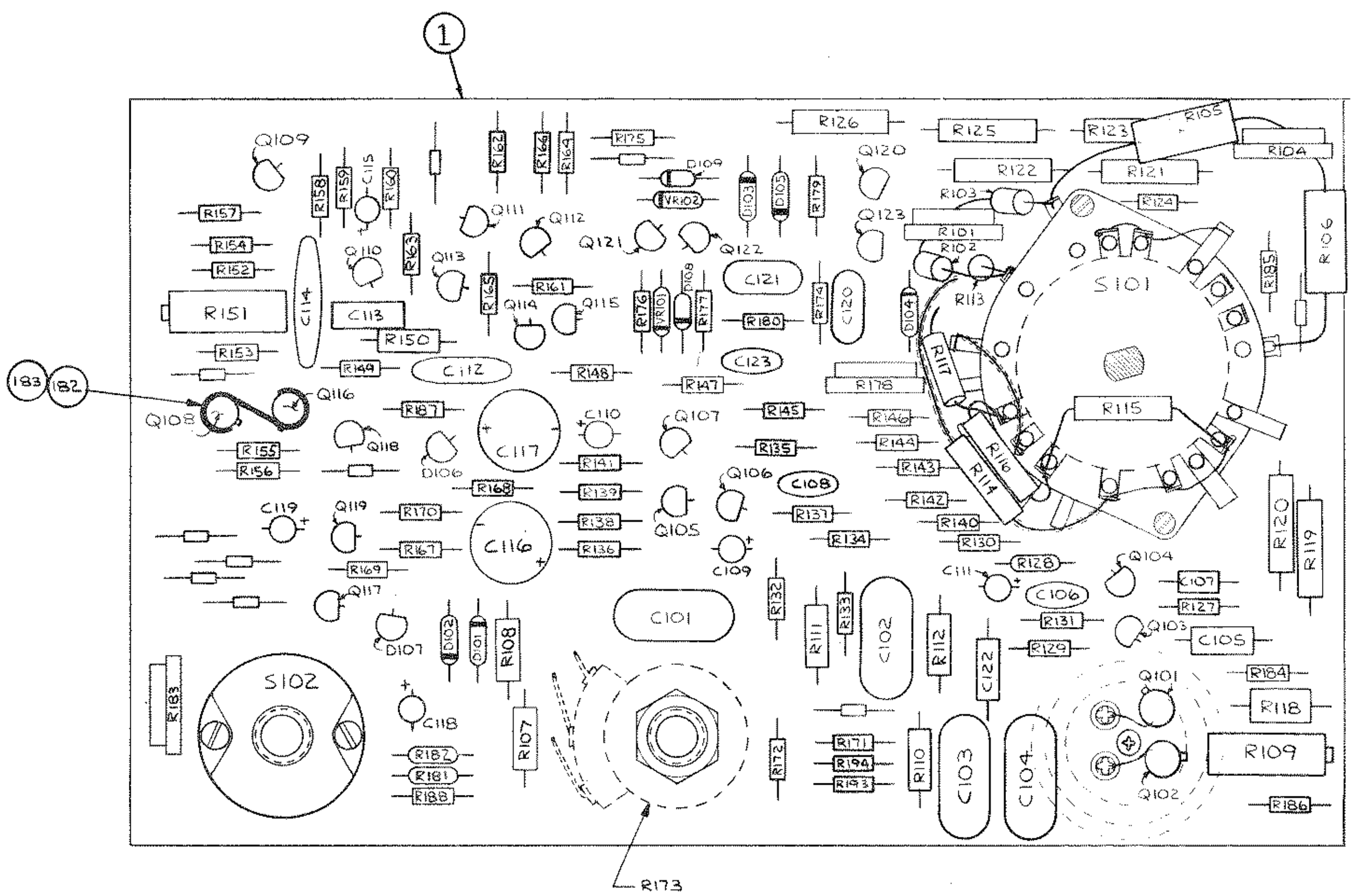
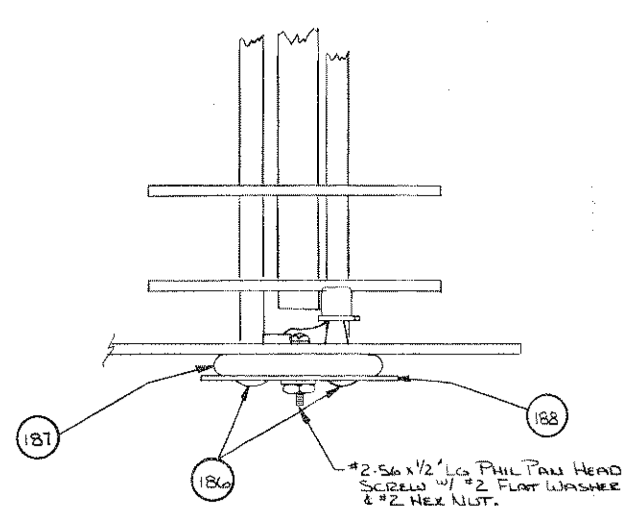




ITEM	PART NO	SCHEM DESIG	ZONE
1	23740C	PC-242	B1
2			
3	C-185-1.0	C101	C3
4	"	C102	C3
5	"	C103	D3
6	"	C104	D3
7	C-47-.01	C105	D3
8	C-22-470pF	C106	D3
9	C-80-1.2	C107	D3
10	C-152-.0022	C108	C3
11	C-170-1.0	C109	C3
12	"	C110	B2
13	"	C111	D3
14	C-41-.1	C112	B2
15	C-152-.022	C113	B2
16	C-22-.01	C114	B2
17	C-170-1.0	C115	B2
18	C-211-100	C116	B3
19	"	C117	B2
20	C-170-1.0	C118	B3
21	"	C119	A3
22	C-21-1000pF	C120	C2
23	"	C121	C2
24	C-80-10	C122	D3
25	C-64-1000pF	C123	C2
26			
27			
28			
29			
30			
31			
32	RF-14	D101	B3
33	"	D102	B3
34	"	D103	C1
35	"	D104	C2
36	"	D105	C1
37	24218A	D106	B2
38	"	D107	B3
39	RF-28	D108	C2
40	"	D109	C2
41			
42			
43			
44			
45			
46			
47	24598A	Q101	D3
48	"	Q102	D3
49	24217A	Q103	D3
50	TG-61	Q104	D3
51	"	Q105	C3
52	24217A	Q106	C3
53	"	Q107	C2
54	TG-64	Q108	A2
55	TG-61	Q109	B1
56	"	Q110	B2
57	24219A	Q111	B2
58	"	Q112	B2
59	24217A	Q113	B2
60	"	Q114	B2
61	TG-61	Q115	B2
62	TG-64	Q116	B2
63	24217A	Q117	B3
64	TG-41	Q118	B2
65	TG-61	Q119	B3
66	24220A	Q120	C1
67	"	Q121	C2
68	"	Q122	C2
69	"	Q123	C2
70			

ITEM	PART NO	SCHEM DESIG	ZONE
71			
72	DZ-40	VR101	C2
73	"	VR102	C2
74			
75			
76			
77			
78			
79			
80			
81	RP-59-500K	R101	C2
82	R-12-4.42M	R102	C2
83	R-12-4.42M	R103	D2
84	RP-59-3.5M	R104	E1
85	R-13-44M	R105	D1
86	"	R106	E2
87	R-1-12K	R107	B3
88	"	R108	B3
89	RP-64-1M	R109	D3
90	R-37-109	R110	C3
91	R-1-22K	R111	C3
92	"	R112	C3
93	R-127-450K	R113	D2
94	"	R114	D3
95	R-127-90K	R115	D2
96	R-127-9K	R116	D2
97	R-127-1K	R117	D2
98	R-95-9.9	R118	E3
99	R-135-90	R119	E3
100	R-135-900	R120	E3
101	R-12-7.66M	R121	D1
102	R-12-2.34M	R122	D1
103	R-127-666.67K	R123	D1
104	R-76-1K	R124	D2
105	R-127-233.33K	R125	D1
106	R-127-99K	R126	C1
107	R-76-1M	R127	D3
108	R-88-1M	R128	D3
109	R-76-1K	R129	D3
110	R-76-330K	R130	D3
111	R-76-33K	R131	D3
112	R-76-330	R132	C3
113	R-76-1M	R133	C3
114	R-76-100K	R134	C3
115	R-76-1.5K	R135	C2
116	R-76-1.5M	R136	B3
117	R-76-1M	R137	C2
118	R-76-220K	R138	B3
119	"	R139	B3
120	R-76-270K	R140	C3
121	R-88-165K	R141	B2
122	R-76-12M *	R142	C3
123	R-76-8.2M *	R143	C2
124	R-76-1M *	R144	C2
125	R-76-150K	R145	C2
126	R-76-220K *	R146	C2
127	R-76-15K	R147	C2
128	"	R148	B2
129	R-76-100K	R149	B2
130	R-37-10³	R150	B2
131	RP-64-100K	R151	A2
132	R-76-270K	R152	A2
133	"	R153	A2
134	R-76-1K	R154	A2
135	R-76-330K	R155	A2
136	R-76-100K	R156	A2
137	R-76-150K	R157	A1
138	R-76-1.5K	R158	B1
139	R-76-330K	R159	B1
140	"	R160	B1

ITEM	PART NO	SCHEM DESIG	ZONE
141	R-76-560K	R161	B2
142	R-76-220K	R162	B1
143	R-76-10K	R163	B2
144	R-76-330K	R164	B1
145	R-76-4.7K	R165	B2
146	"	R166	B1
147	R-76-10K	R167	B3
148	"	R168	B3
149	R-76-330K	R169	B3
150	"	R170	B3
151	R-76-1M	R171	C3
152	R-76-100K	R172	C3
153	RP-69-1M	R173	C3
154	R-76-1M	R174	C2
155	"	R175	C1
156	R-76-6.8M	R176	C2
157	"	R177	C2
158	RP-59-3.5M	R178	C2
159	R-76-1M	R179	C2
160	R-76-1M	R180	C2
161	R-88-8.65K	R181	B3
162	R-88-182K	R182	B4
163	RP-59-5K	R183	A3
164	R-76-1K	R184	D3
165	"	R185	D2
166	R-76-47K	R186	E3
167	R-76-10M	R187	B2
168	R-76-470	R188	B4
169			
170			
171			
172			
173	R-76-1.5M	R193	C3
174	R-76-560K	R194	C3
175			
176			
177			
178	SW-310A	S101	D2
179	SW-312A	S102	A3
180			
181			
182	HS-8	—	A2
183	MK-6	—	A2
184			
185			
186	HP-14		D6
187	GA-14		C6
188	23617A		E6
189			
190			
191			
192			
193			
194			
195			
196			
197			
198			
199			
200			

MODEL	NEXT ASSEMBLY	QTY.
155		

USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 6-23-78	SCALE 2:1	TITLE COMPONENT LAYOUT PC-242
XX = ±.015 ANG ±1°	DRN. M.S.	ENG. APPR.	
XXX = ±.005 FRAC ±1/64	MATERIAL		NO. 23741D
SURFACE MAX	FINISH		

the Microvoltmeter input. Monitor the output on the 1 volt through 100 microvolt ranges with the Model 7050.

3. Check the 1000 volt and 10 microvolt ranges for both positive and negative polarity. All other ranges may be checked using only one polarity.

b. If necessary, adjust the Accuracy Set Potentiometer, R104, to bring in all ranges from 3 volts to 1000 volts within tolerance. Also, the Accuracy Set Potentiometer, R101, may be adjusted to bring the 300 millivolt and 1 volt ranges within tolerance. Note, however, that re-adjusting potentiometer R101 will require rechecking the 3 volt through 1000 volt ranges (refer to note of paragraph 5-8).

5-14. NORMAL MODE REJECTION CHECK.

a. Set the Model 155 Power Switch to ZERO CHK.

b. Set up the rejection check equipment as follows: apply a signal from the Model 200CD Oscillator through a 5 μF capacitor to a 1000:1 divider and connect the divider output to the Model 155 input. Connect the Model 155 -(low), GUARD and CASE Terminals together. Monitor the Signal Generator with the Model 503 Oscilloscope.

c. Set the Oscillator frequency to 50 Hz and the output to minimum.

1. Set the Model 155 Power Switch to ON, RANGE Switch to 1 MICROVOLT and zero the Microvoltmeter with the ZERO Control. Due to thermals on the input, it should require approximately one minute for the instrument to stabilize.

2. Increase the Oscillator output to 10 volts peak-to-peak. There should be no shift in the meter reading. (Do not confuse noise and drift for a shift in meter reading).

5-15. COMMON MODE REJECTION CHECK.

a. Use the same setup as in paragraph 5-14 except apply the signal between the +(high) and CASE Terminals and connect the +(high) and -(low) Terminals together.

b. Check Model 155 zero.

c. Set the Oscillator frequency to 50 Hz and output to minimum.

1. Set the Model 155 Power Switch to ON, RANGE Switch to 1 MICROVOLT and zero the instrument with the ZERO Control. Allow time for the unit to stabilize (approximately one minute).

2. Increase the Oscillator output to 1 volt peak-to-peak. There should be no shift in the meter reading. (Do not confuse noise and drift for a shift in meter reading).

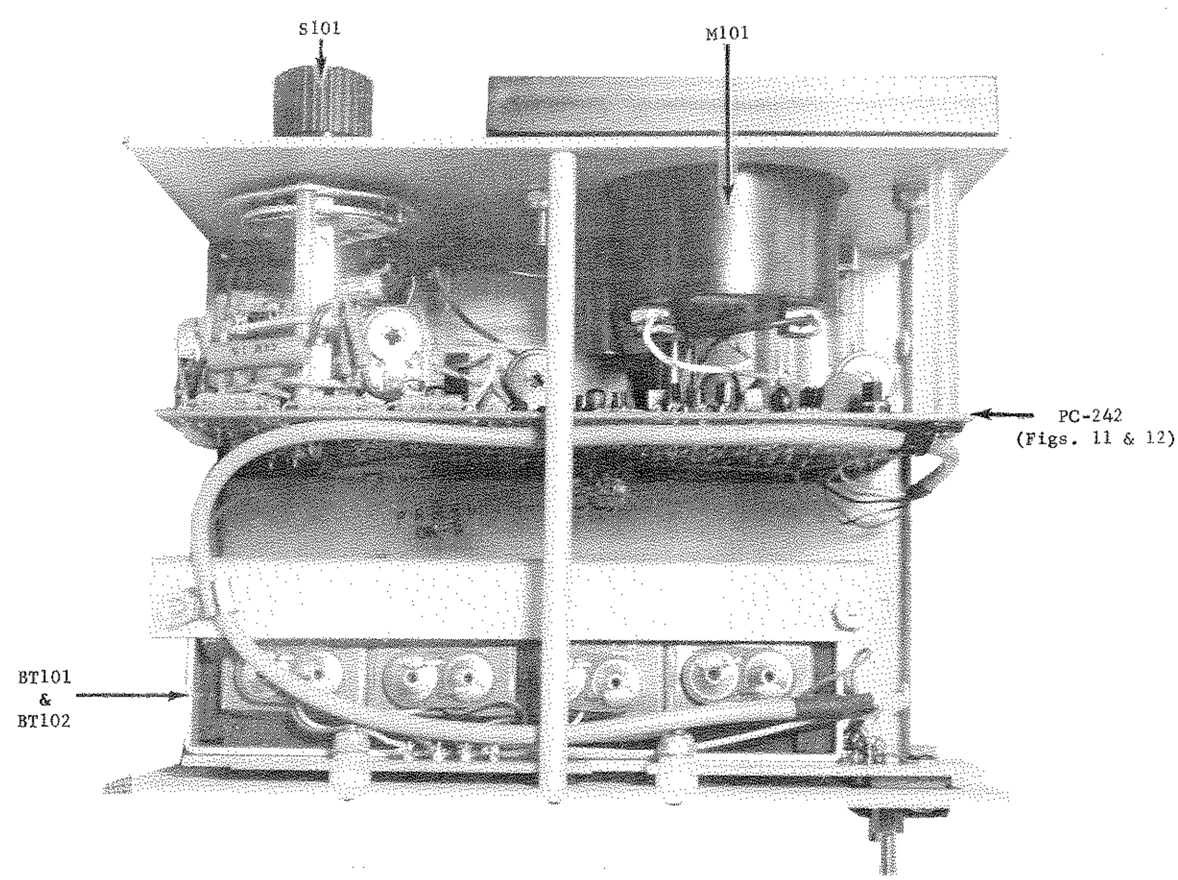


FIGURE 10. Top View Model 155 Chassis. Front panel faces up. View shows location of batteries and PC-242. See Figures 11 and 12 for Model 155 component locations.

SEE

COMPONENT LAYOUT

23741D

FIGURE 11. Component Layout for PC-242 (capacitors, diodes, and transistors). See Figure 12 for resistor locations.

SEE

COMPONENT LAYOUT

23741D

FIGURE 12. Resistor Layout for PC-242. For other component locations see Figure 11.

SECTION 6. ACCESSORIES

6-1. GENERAL. The following accessories can be used with the Model 155 to provide additional convenience and versatility.

6-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 1001 Rack Mounting Kit

Description:

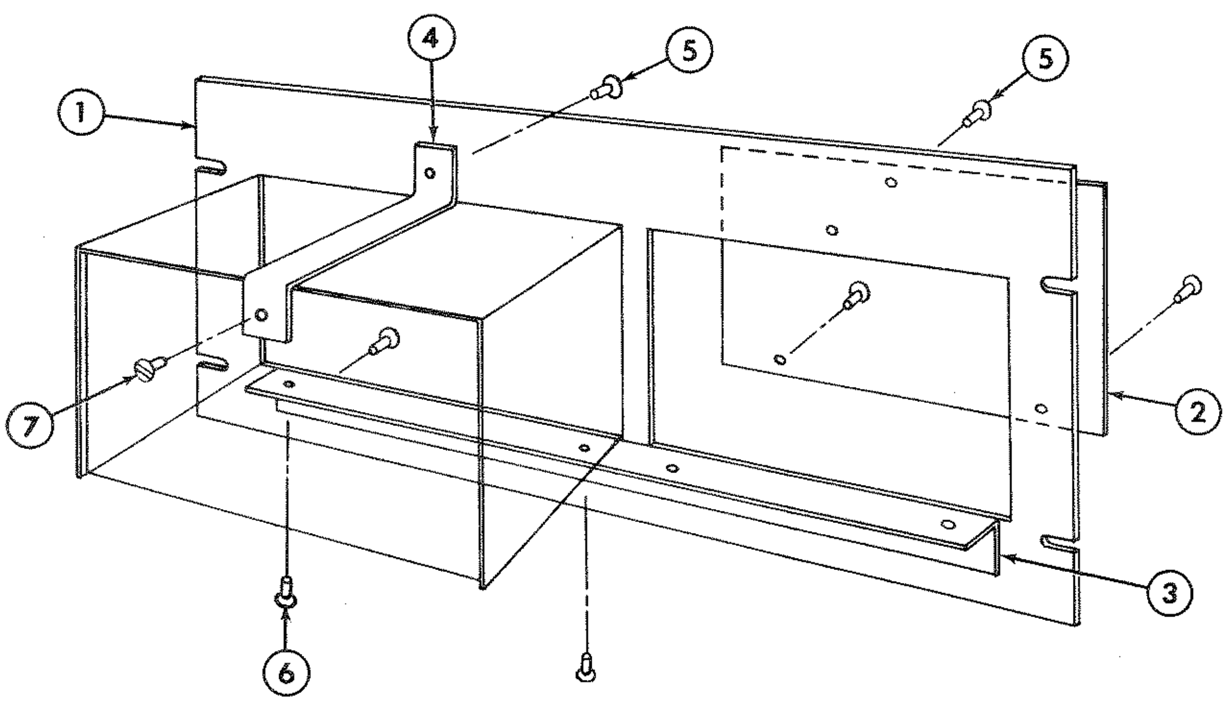
The Model 1001 is a rack mounting kit with overall dimensions, 7 inches high x 19 inches wide x 6-3/4 inches deep.

Application:

The Model 1001 converts the instrument from bench mounting to rack mounting. It is suitable for mounting one instrument in one-half of a standard 19 inch rack or two instruments side-by-side. Cover plate, Item 2 is furnished for use when only one instrument is mounted.

Parts List:

Item No.	Description	Qty. Per Assembly	Keithley Part No.
1	Panel	1	23901D
2	Cover Plate	1	23909A
3	Lower Brace	1	23906B
4	Upper Brace	2	23752A
5	Screw #10-32 x 3/8"	6	---
6	Screw #6-32 x 3/8"	4	---
7	Screw #6-32 x 1/2"	2	---



Model 1554 Power Supply

Description:

The Model 1554 is a self-contained regulated power supply for operation from 117 or 234V a-c, 50-60 Hz.

Application:

The Model 1554 is designed for use with this instrument permitting line or battery operation (without degrading isolation). The supply mounts on the rear panel of the instrument chassis.

Specifications:

OUTPUT: ±18 Volts Nominal.

ISOLATION: Greater than 10^{12} ohms to ground or line at up to 50% relative humidity and 25°C, less than 0.2 picofarad coupling to line.

CONTROLS: Switch, three position, LINE/OFF/BATT.

CONNECTOR: Wiring harness.

POWER REQUIRED: 105-125V or 210-250V a-c, 50-60 Hz.

DIMENSIONS: Added 2-1/4" depth to rear of instrument.

Connections:

NOTE: A color-coded wire harness is used for connections to the rear panel barrier strip. Remove shorting links between + INPUT and + BATTERY and - INPUT and - BATTERY.

Wire Harness Lead Color	Barrier Strip Connection
Orange	+ INPUT
Red	+ BATTERY
Gray	- INPUT
Brown	- BATTERY
Black	LO
Blue	GUARD

SECTION 5 REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Models 155 and 1554. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column indicates the figure picturing the parts. The name and address of the manufacturers listed in the "Mfg. Code" column are in Table 12.

7-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered through Keithley Instruments, Inc., or its representatives. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley representative or the Sales Service Department, Keithley Instruments, Inc.

TABLE 11. Abbreviations and Symbols.

A	ampere	Fig.	Figure	Ω	ohm
Cb	Carbon	k	kilo (10^3)	p	pico (10^{-12})
CerD	Ceramic, Disc			Poly	Polystyrene
Comp	Composition	μ	micro (10^{-6})		
				req'd	required
DCb	Deposited Carbon	M	mega (10^6) or megohm	Ref.	Reference
		Mfg.	Manufacturer		
EAL	Electrolytic, Aluminum	MtF.	Metal Film	V	volt
ETT	Electrolytic, tantulum	My	Mylar		
				W	watt
F	farad	No.	Number	WW	Wirewound

MODEL 155 REPLACEABLE PARTS LIST
(Refer to Schematic Diagram 22354E for circuit designations)
BATTERIES

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
BT101	9V Zinc Carbon (2 cells required)	09823	2N6	BA-17*	10
BT102	9V Zinc Carbon (2 cells required)	09823	2N6	BA-17*	10

*When ordering replacement batteries, specify two each of BA-17.

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	1 μF	100 V	My	Paktron	MF825	C185	11
C102	1 μF	100 V	My	Paktron	MF825	C185	11
C103	1 μF	100 V	My	Paktron	MF825	C185	11
C104	1 μF	100 V	My	Paktron	MF825	C185	11
C105	.01 μF	200 V	My	13050	SM1A	C47-.01M	11
C106	470 pF	600 V	CerD	72982	ED-470	C22-470P	11
C107	1.2 μF	20 V	ETT	05397	K1R2J20	C80-1.2M	11
C108	.0022 μF	600 V	CerD	72982	ED-.0022	C22-.0022M	11
C109	1 μF	35 V	ETT	05397	KIE 35	C170-1M	11
C110	1 μF	35 V	ETT	05397	KIE 35	C170-1M	11
C111	1 μF	35 V	ETT	05397	KIE 35	C170-1M	11
C112	0.1 μF	50 V	My	84411	601 PE	C41-.1M	11
C113	.022 μF	100 V	Poly	13934	E3FR-222-1-C	C152-.022M	11
C114	.01 μF	600 V	CerD	72982	ED-.01	C22-.01M	11
C115	1 μF	35 V	ETT	05397	KIE 35	C170-1M	11
C116	100 μF	25 V	EAL	29309	JC8100258P	C211-100M	11
C117	100 μF	25 V	EAL	29309	JC8100258P	C211-100M	11
C118	1 μF	35 V	ETT	05397	KIE 35	C170-1M	11
C119	1 μF	35 V	ETT	05397	KIE 35	C170-1M	11
C120	1000 pF	100 V	Mica	84171	DM15-102-J	C21-1000 pF	11
C121	1000 pF	100 V	Mica	84171	DM15-102-J	C21-1000 pF	11
C122	10 μF	20 V	ETT	05397	K10RJ20K	C80-10M	11
C123	.001 μF	600 V	CerD	72982	ED-.001	C22-.001M	11
C124	.01 μF	1200 V	MPCb	STL	PC2WR	C262-0.01M	
C125	.01 μF	1200 V	MPCb	STD	PC2WR	C262-0.01M	
C126	.01 μF (Nominal)*	500 V	Poly	CLB	CPR-*	C138-.01M*	

CONNECTORS AND TERMINALS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
J101	+ Input Terminal	58474	DF31RC	BP-8R	1
J102	- Input Terminal	58474	DF31BC	BP-8B	1
J103	GUARD Terminal	58474	DF31BLUC	BP-8BLU	1
J104	CASE Terminal	58474	DF31GC	BP-8G	1
P101	Barrier Strip Connector	71785	140Y	TE-68	2
---	Shorting links, 2 req'd	71785	140J-1	BP-17	2

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	11
D102	Silicon	1N645	01295	RF-14	11
D103	Silicon	1N645	01295	RF-14	11
D104	Silicon	1N645	01295	RF-14	11
D105	Silicon	1N645	01295	RF-14	11
D106	Silicon	2N3638	07263	TG-33	11
D107	Silicon	2N3638	07263	TG-33	11
D108	Rectifier	1N4148	01295	RF-28	
D109	Rectifier	1N4148	01295	RF-28	

METER

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
M101	Meter	80164	---	ME-82	10

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	500 kΩ	1/4 W	Cb	76055	MTC55L1	RP59-500K	12
R102	4.42 MΩ	10% 1/4 W	DCb	07716	DCC	R12-4.42M	12
R103	4.42 MΩ	10% 1/4 W	DCb	07716	DCC	R12-4.42M	12
R104	3.5 MΩ	1/4W	Cb	76055	MTC355L1	RP59-3.5M	12
R105	44 MΩ	1%, 1 W	DCb	91637	DC-1	R13-44M	12
R106	44 MΩ	1%, 1 W	DCb	91637	DC-1	R13-44M	12
R107	12 kΩ	10%, 1/2 W	Comp	01121	EB	R1-12K	12
R108	12 kΩ	10%, 1/2 W	Comp	01121	EB	R1-12K	12
R109	1 MΩ	20%, 0.75W	Cermet	73138	77PR1M	RP64-1M	12
R110	10^9 Ω	20%, 1/2 W	Comp	75042	GBT	R37-10^9	12
R111	22 kΩ	10%, 1/2 W	Comp	01121	EB	R1-22K	12
R112	22 kΩ	10%, 1/2 W	Comp	01121	EB	R1-22K	12
R113	450 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-450K	12
R114	450 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-450K	12
R115	90 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-90K	12
R116	9 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-9K	12
R117	1 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-1K	12
R118	9.9Ω	0.1%, 1/4 W	WW	01686	7009	R95-9.9	12
R119	90 Ω	0.1%, 1/2 W	MtF	07716	CEC T-1	R135-90	12
R120	900 Ω	0.1%, 1/2 W	MtF	07716	CEC T-1	R135-900	12
R121	7.66 MΩ	1%, 1/2 W	DCb	07716	DCC	R12-7.66M	12
R122	2.34 MΩ	1%, 1/2 W	DCb	07716	DCC	R12-2.34M	12
R123	666.67 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-666.67K	12
R124	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	12
R125	233.33 kΩ	1/4%, 1/2 W	MtF	07716	CEC-TO	R127-233.33K	12
R126	99 kΩ	10%, 1/4 W	Comp	01121	CB	R76-99K	12
R127	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R128	1 MΩ	1%, 1/8 W	MtF	07716	CEA-1MΩ	R88-1M	12
R129	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	12
R130	3330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-3330K	12

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R131	33 kΩ	10%, 1/4 W	Comp	01121	CB	R76-33K	12
R132	390 kΩ	10%, 1/4 W	Comp	01121	CB	R76-390K	12
R133	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R134	100 kΩ	10%, 1/4 W	Comp	01121	CB	R76-100K	12
R135	1.5 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1.5K	12
R136	1.5 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1.5M	12
R137	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R138	470 kΩ	10%, 1/4 W	Comp	01121	CB	R76-470K	12
R139	470 kΩ	10%, 1/4 W	Comp	01121	CB	R76-470K	12
R140	270 kΩ	10%, 1/4 W	Comp	01121	CB	R76-270K	12
R141	165 kΩ*	1%, 1/8 W	MtF	07716	CEA-165KΩ-1%	R88-165K*	12
R142	22 MΩ*	10%, 1/4 W	Comp	01121	CB	R76-22M*	12
R143	8.2 MΩ*	10%, 1/4 W	Comp	01121	CB	R76-8.2M*	12
R144	1.2 MΩ*	10%, 1/4 W	Comp	01121	CB	R76-1.2M*	12
R145	150 kΩ	10%, 1/4 W	Comp	01121	CB	R76-150K	12
R146	220 kΩ*	10%, 1/4 W	Comp	01121	CB	R76-220K*	12
R147	15 kΩ	10%, 1/4 W	Comp	01121	CB	R76-15K	12
R148	15 kΩ	10%, 1/4 W	Comp	01121	CB	R76-15K	12
R149	100 kΩ	10%, 1/4 W	Comp	01121	CB	R76-100K	12
R150	10^9 Ω	20%, 1/2 W	Comp	75042	GBT	R137-10^9	12
R151	100 kΩ	1/4 W	Cb	76055	MTC15L1	RP59-100K	12
R152	270 kΩ	10%, 1/4 W	Comp	01121	CB	R76-270K	12
R153	270 kΩ	10%, 1/4 W	Comp	01121	CB	R76-270K	12
R154	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	12
R155	330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-330K	12
R156	100 kΩ	10%, 1/4 W	Comp	01121	CB	R76-100K	12
R157	150 kΩ	10%, 1/4 W	Comp	01121	CB	R76-150K	12
R158	1.5 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1.5K	12
R159	330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-330K	12
R160	330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-330K	12
R161	560 kΩ	10%, 1/4 W	Comp	01121	CB	R76-560K	12
R162	220 kΩ	10%, 1/4 W	Comp	01121	CB	R76-220K	12
R163	10 kΩ	10%, 1/4 W	Comp	01121	CB	R76-10K	12
R164	330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-330K	12
R165	4.7 kΩ	10%, 1/4 W	Comp	01121	CB	R76-4.7K	12
R166	4.7 kΩ	10%, 1/4 W	Comp	01121	CB	R76-4.7K	12
R167	10 kΩ	10%, 1/4 W	Comp	01121	CB	R76-10K	12
R168	10 kΩ	10%, 1/4 W	Comp	01121	CB	R76-10K	12
R169	330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-330K	12
R170	330 kΩ	10%, 1/4 W	Comp	01121	CB	R76-330K	12
R171	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R172	100 kΩ	10%, 1/4 W	Comp	01121	CB	R76-100K	12
R173	1 MΩ	±20%, 1/3 W	Cb	71450	VA-45-1M	RP69-1M	1
R174	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R175	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R176	*6.8 MΩ	10%, 1/4 W	Comp	01121	CB	R76-6.8M	12
R177	*6.8 MΩ	10%, 1/4 W	Comp	01121	CB	R76-6.8M	12
R178	3.5 MΩ	1/4 W	Cb	76055	MTC355L1	RP59-3.5M	12
R179	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R180	1 MΩ	10%, 1/4 W	Comp	01121	CB	R76-1M	12
R181	8.85 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-8.85K	12
R182	182 kΩ	1%, 1/8 W	MtF	07716	CEA	R88-182K	12
R183	5 kΩ	1/4 W	CB	76055	MTC53L1	RP59-5K	12
R184	470 Ω	10%, 1/4 W	Comp	01121	CB	R76-470	12
R185	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	12
R186	47 kΩ	10%, 1/4 W	Comp	01121	CB	R76-47k	12
R187	10 MΩ	10%, 1/4 W	Comp	01121	CB	R76-10M	12
R188	1 kΩ	10%, 1/4 W	Comp	01121	CB	R76-1K	12
R193	1.5 MΩ*	10%, 1/4 W	Comp	01121	CB	R76-1.5M*	--
R194	560 kΩ*	10%, 1/4 W	Comp	01121	CB	R76-560K*	--

*Nominal value, factory selected.

SWITCHES AND CONTROLS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
S101	Rotary Switch less components, RANGE	80164	SW-310	1, 10
---	Rotary Switch with components, RANGE	80164		
---	Knob Assembly, Range Switch	80164		
S102	Rotary Switch Assembly (POWER) (Order parts for above assembly as follows:) (1) SW-312A, (1) SW-312, (2) 23631A, (2) #2-56 x 3/8 slotted screws, (2) #2-56 nuts Assembly is soldered to pc board.	80164	23961B	
---	Knob Assembly, Power Switch	80164		
---	Zero Control (R173)	71450	RP69-1M	1
---	Knob Assembly, Zero Control	80164		1

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101*	HN1030	80164	24598A	11
Q102*	HN1030	80164	24598A	11
Q103	2N5089	04713	24217A	11
Q104	2N5087	04713	TG-61	11
Q105	2N5087	04713	TG-61	11
Q106*	2N5089	04713	24217A	11
Q107*	2N5089	04713	24217A	11
Q108	A642L	73445	TG-64	11
Q109	2N5087	04713	TG-61	11
Q110	2N5087	04713	TG-61	11
Q111*	2N5089	04713	24217A	11
Q112*	2N5089	04713	24217A	11
Q113*	2N5089	04713	24217A	11
Q114*	2N5089	04713	24217A	11
Q115	2N5087	04713	TG-61	11
Q116	A642L	73445	TG-64	11
Q117*	2N5089	04713	24217A	11
Q118	MPF103	04713	TG-41	11
Q119	2N5087	04713	TG-61	11
Q120*	2N3565	07263	24220A	11
Q121*	2N3565	07263	24220A	11
Q122*	2N3565	07263	24220A	11
Q123*	2N3565	07263	24220A	11

VOLTAGE RECTIFIERS (VR)

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
VR101	1N746A	12954	DZ-40	
VR102	1N746A	12954	DZ-40	

MODEL 1554 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 23985D for circuit designations).

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	400 µF	40V	EAL	73445	C437AR/G400	C150-400M	15
C102	400 µF	40V	EAL	73445	C437AR/G400	C150-400M	15
C103	400 µF	40V	EAL	73445	C437AR/G400	C150-400M	15
C104	400 µF	40V	EAL	73445	C437AR/G400	C150-400M	15
C105	1.0 µF	35V	ETT	05397	KEI 35	C170-1M	15
C106	1.0 µF	35V	ETT	05397	KEI 35	C170-1M	15

*Specially selected transistors.

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Zener	1N720	01295	DZ-35	15
D102	Zener	1N720	01295	DZ-35	15
D103	Silicon	1N645	01295	RF-14	15
D104	Silicon	1N645	01295	RF-14	15
D105	Silicon	1N645	01295	RF-14	15
D106	Silicon	1N645	01295	RF-14	15

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
F101(117 or 234V)	Fuse, slow blow, 1/100 A	75915	3AG	FU-30	-
P101	Line Cord, 6 feet	93656	4638-13	CO-5	-
---	Cable Clamp	28520	SR-5P-1	CC-4	-
T101	Transformer	80164	---	TR-122	-

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	1 kΩ	10%, 1/2 W	Comp	01121	EB	R1-1K	15
R102	4.7 kΩ	10%, 1/2 W	Comp	01121	EB	R1-4.7K	15
R103	1 kΩ	10%, 1/2 W	Comp	01121	EB	R1-1K	15
R104	4.7 kΩ	10%, 1/2 W	Comp	01121	EB	R1-4.7K	15
R105	10 kΩ	10%, 1/2 W	Comp	01121	EB	R1-10K	15
R106	10 kΩ	10%, 1/2 W	Comp	01121	EB	R1-10K	15
R107	2.2 kΩ	10%, 1/2 W	Comp	01121	EB	R1-2.2K	15
R108	2.2 kΩ	10%, 1/2 W	Comp	01121	EB	R1-2.2K	15

SWITCHES

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
S101	Slide Switch, 117-234V	80164	---	SW-151	14
S102	Slide Switch, Battery	80164	---	SW-306	14

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101	2N5089	04713	TG-62	15
Q102	2N5087	04713	TG-61	15

TABLE 12.
Mechanical Parts List.

Description	Quantity Per Assembly	Keithley Part No.	Fig. No.
1) Chassis	1	22584D	13, 14
Top Cover Assembly	---	22673B	13
2) Cover, Sheet Metal	1	22585C	
3) Screws	4	---	
Handle Assembly	---	---	13
11) Handle	1	HH-18	
12) Screws #6-32 x 3/8" R.H. Slotted	2	---	
Feet Assembly	---	---	14
4) Feet	4	FE-5	
5) Ball	4	FE-6	
6) Screws #8-32 x 3/8" Phillips, Pan Head	4	---	
Tilt Bail Assembly	---	---	14
7) Bail	1	17147B	
8) Right Assembly	1	19206B	
9) Left Assembly	1	19205B	
10) Screws #6-32 x 1/4" Phillips, Pan Head	2	---	

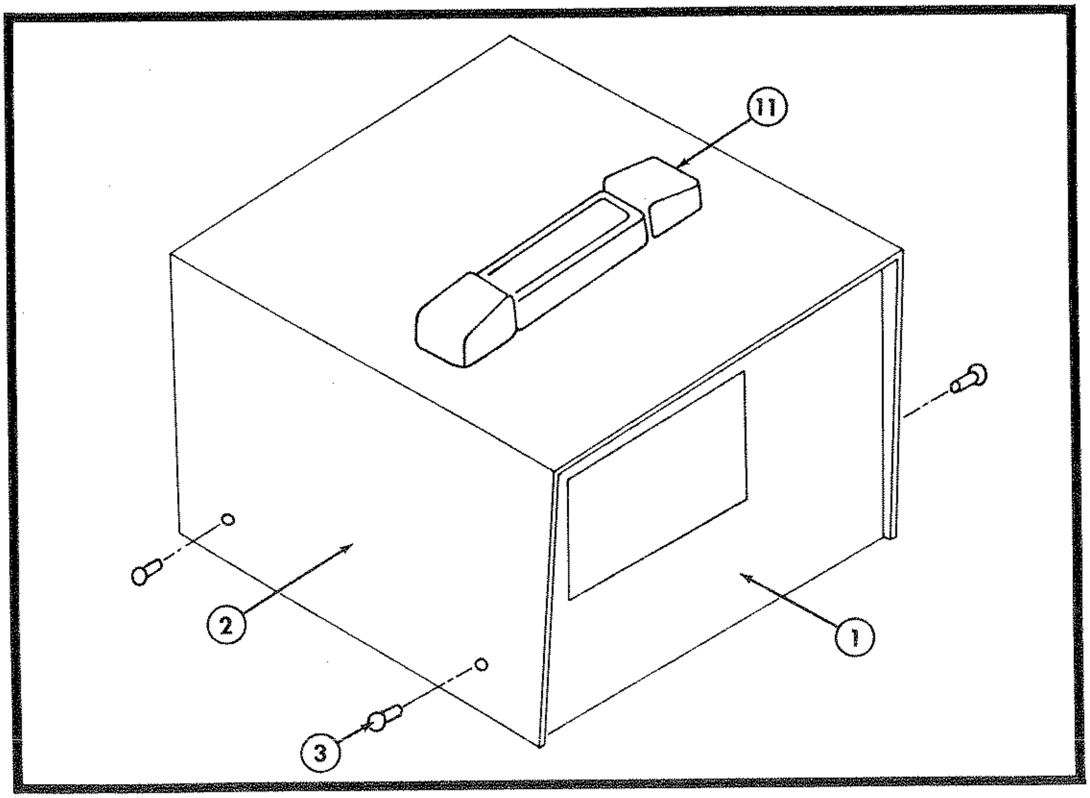


FIGURE 13. Cover Assembly

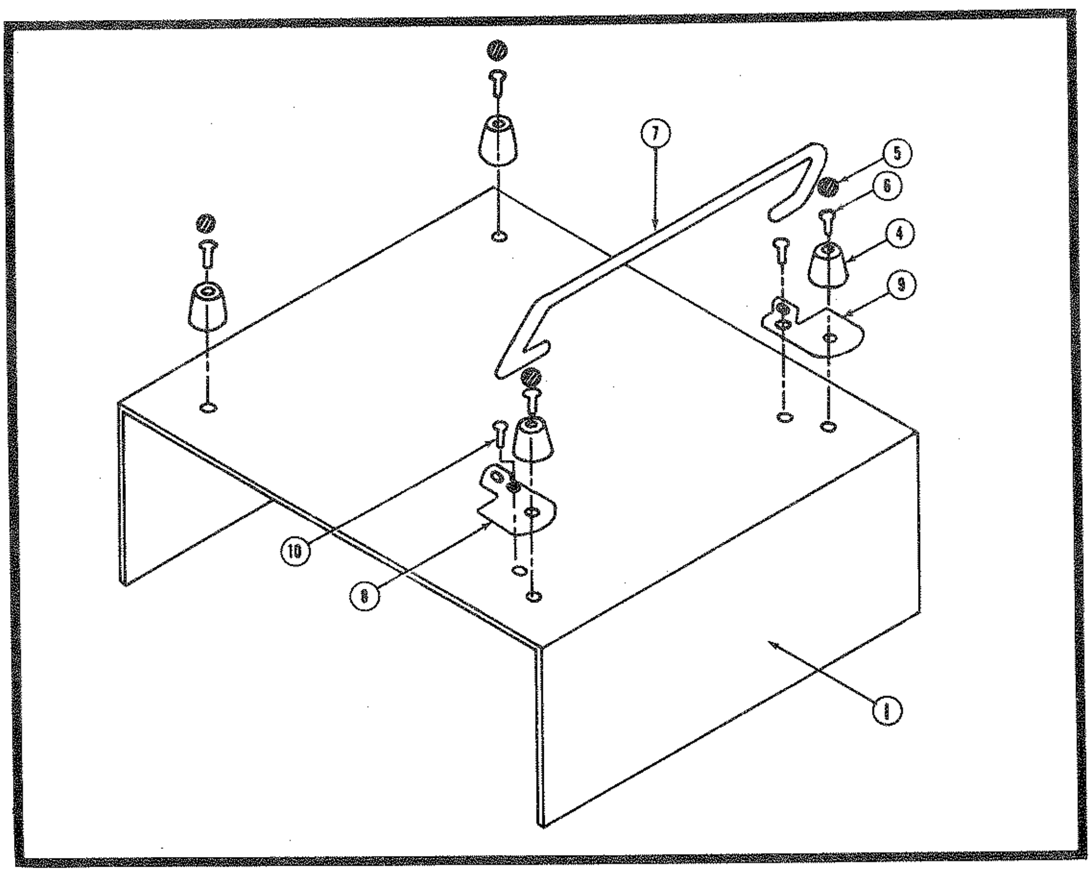
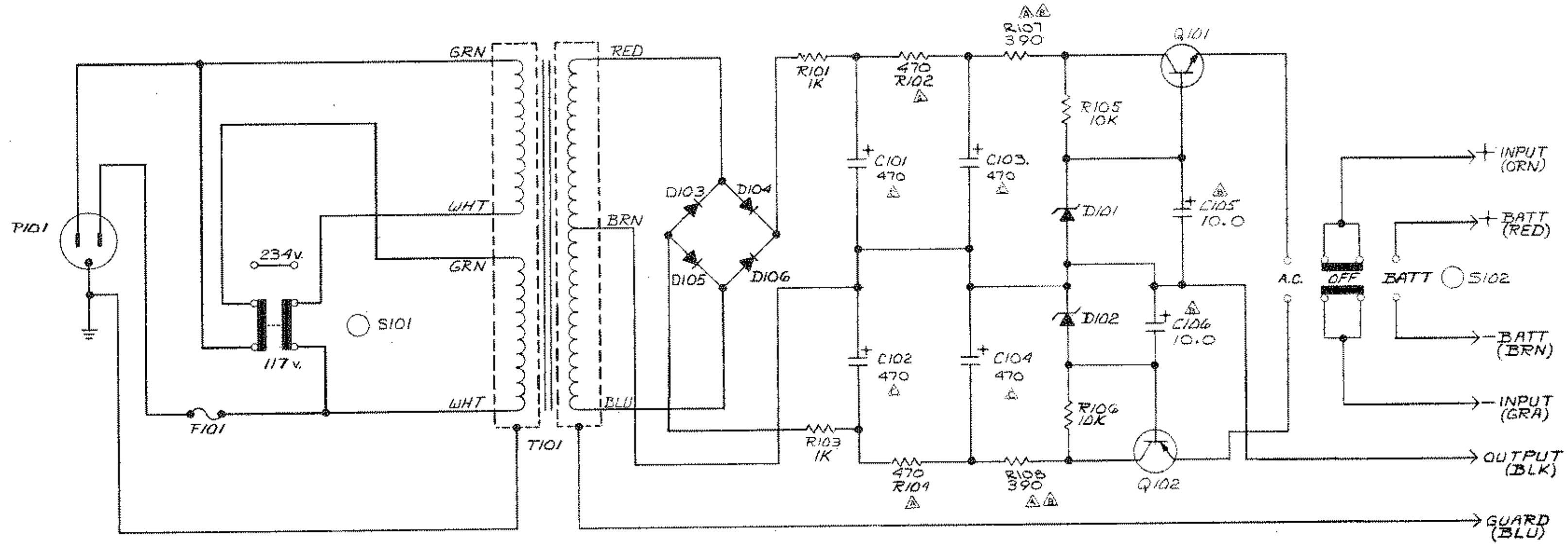


FIGURE 14. Chassis Bottom View

TABLE 13.
Code-to-Name List.

01121	Allen-Bradley Corp. 1201 South 2nd Street Milwaukee, Wis. 53204
01295	Texas Instruments, Inc. Semiconductor-Components Division 13500 North Central Expressway Dallas, Texas 75231
01686	RCL Electronics, Inc. 195 McGregor Street Manchester, N.H. 03102
04713	Motorola Semiconductor Products Inc. 5005 East McDowell Road Phoenix, Ariz. 85008
05397	Union Carbide Corp. Linde Div. Kemet Dept. 11901 Madison Cleveland, Ohio 44107
07263	Fairchild Camera & Instrument Corp. Semiconductor Division 313 Frontage Road Mountain View, California
07716	IRC, Inc. 2850 Mt. Pleasant Burlington, Iowa 52601
09823	Burgess Battery Co. Division of Servel Inc. Foot of Exchange Street Freeport, Illinois
13050	Potter Co. Highway 51 North Wesson, Miss. 39191
13934	Midwec Corp. 602 Main Oshkosh, Nebraska 69154
28520	Heyman Mfg. Co. 147 N. Michigan Ave. Kenilworth, N.J.
56289	Sprague Electric Co. North Adams, Mass.
58474	Superior Electric Co., The 383 Middle Street Bristol, Conn. 06012
71400	Bussmann Mfg. Div. of McGraw-Edison Co. 2538 W. University St. St. Louis, Mo.
71450	CTS Corp. 1142 W. Beardsley Avenue Elkhart, Indiana
71785	Cinch Mfg. Co. and Howard B. Jones Div. 1026 S. Homan Avenue Chicago, Illinois 60624
72982	Erie Technological Products, Inc. 644 W. 12th Street Erie, Pennsylvania 16512
73445	Amperex Electronic Co., Div. of North American Philips Co., Inc. Hicksville, N.Y.
75042	IRC Inc. 401 North Broad Street Philadelphia, Pennsylvania 19108
75915	Littlefuse, Inc. 800 E. Northwest Hwy. Des Plaines, Ill. 60016
76005	Mallory Controls Division of Mallory P. R. and Co., Inc. State Road 28 W Frankfort, Indiana
80164	Keithley Instruments, Inc. 28775 Aurora Road Cleveland, Ohio 44139
84171	Arco Electronics, Inc. Community Drive Great Neck, N.Y. 11022
84411	TRW Capacitor Division 112 W. First Street Ogallala, Nebraska
91637	Dale Electronics, Inc. Post Office Box 609 Columbus, Nebraska 68601
93656	Electric Cord Co. 1275 Bloomfield Ave. Caldwell, N.J.
97933	Raytheon Co. Components Division Semiconductor Operation Mountain View, California

REVISIONS			
LTR	ECO NO.	APPR.	DATE
A	PCM-1058		
B	3837		
C	4094	TG	



NOTES. 1. ALL RESISTORS AND CAPACITORS ARE DESIGNATED IN OHMS AND MICROFARDS UNLESS OTHERWISE NOTED.

◯ FRONT PANEL CONTROL.

K 1000 OHMS

SCHEMATIC DESIGNATIONS NOT USED				HIGHEST SCHEMATIC DESIGNATIONS			
				Q102	S102	C106	R108
				D106	T101	F101	P101

1554	23917B	1
MODEL	NEXT ASSEMBLY	QUAN
USED ON		

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

DO NOT SCALE

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

TITLE SCHEMATIC

PART NUMBER 23985D