

INSTRUCTION MANUAL

**MODEL 621**

ELECTROMETER

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To exercise this warranty, call your local field representative or the Cleveland factory, DDD 216-248-0400. You will be given assistance and shipping instructions.

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Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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SECTION I - INTRODUCTION

The Keithley Model 621 Electrometer is an ultra-high impedance voltmeter with full-scale ranges of 0.10, 0.30, 1.0, 3.0, 10, 30, and 100 volts. Accuracy is within 2% of full scale on all ranges.

The maximum input resistance is greater than  $10^{14}$  ohms; in addition, the input resistance may be varied in decade steps from  $10^6$  ohm to  $10^{10}$  ohms by means of the shunt resistors built into the instrument. Thus, the 621 is not only appropriate for measurement in high-impedance circuits, but also can be used where a high input impedance would merely introduce unwanted pickup.

The 621 may be used as a direct-reading ammeter from  $10^{-4}$  to  $10^{-11}$  ampere full scale. This seven decade range is covered in overlapping 3 x and 10 x scales. Accuracy is within 3% of full scale from  $10^{-4}$  to  $10^{-9}$  ampere, and 4% of full scale from  $3 \times 10^{-9}$  to  $10^{-11}$  ampere.

Two current measuring methods are available to the user of the 621. They are selected by a slide switch at the back of the instrument. Normally, current is determined by measuring the voltage drop across a resistor shunted from input to ground. Alternately, negative feedback can be applied to the input of the voltmeter through the current measuring resistor. This largely eliminates the input drop and increases measuring speed, particularly on the more sensitive ranges.

The 621 measures  $10^5$  to  $10^{12}$  ohms with a two-terminal input. A 1000-volt external supply would further extend the range to  $10^{14}$  ohms. Unlike conventional ohmmeters, information is presented on the same linear scales used for current and voltage readings. Accuracy is within 3% of full scale up to  $3 \times 10^{10}$  ohms, within 5% beyond.

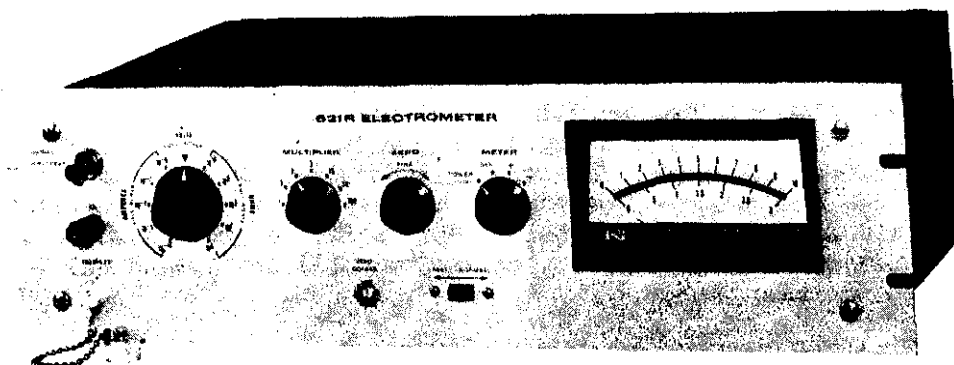
As a dc preamplifier, the 621 has gains of 0.1, 0.3, 1, 3, 10, 30, and 100. Gain accuracy is within 1% on all gain steps. The continuing stability of the gain is assured by a large feedback factor on all ranges.

The output is either 10 volts for driving high impedance devices such as oscilloscopes or pen recorder amplifiers, or 1 ma for driving low impedance recorders or similar devices. A calibration potentiometer is provided with the 1 ma position for calibrating recorders. A slide switch next to the output connector permits selecting the desired output.

MODEL 621R: Although this manual specifically describes the 621, the instructions also apply to the Model 621R Electrometer. The principal difference between the two models is the 621R is designed for rack mounting. (See Figure 1) Both models have the same performance specifications, operating and maintenance procedures, circuit and components. Besides the cabinet dimensions, the models differ in the placement of two switches (see section II) and the layout of components within the chassis.



FIGURE 1. The Model 621 Electrometer is shown at left. The Model 621R pictured below has the same specifications as the Model 621, but it is designed for rack mounting.



## SECTION II - SPECIFICATIONS AND DESCRIPTION

SPECIFICATIONS:AS A VOLTMETER:

RANGE: 0.1 volt full scale to 100 volts in seven 1x and 3x ranges.  
ACCURACY:  $\pm 2\%$  of full scale on all ranges exclusive of drift.  
ZERO DRIFT: Less than 3 millivolts per hour after 2-hour warm-up.  
INPUT IMPEDANCE: Greater than  $10^{14}$  ohms shunted by 30 picofarads. Input resistance may be selected in decade steps from  $10^6$  to  $10^{10}$  ohms.

AS AN AMMETER:

RANGE:  $10^{-11}$  ampere full scale to  $10^{-4}$  ampere in fifteen 1x and 3x ranges.  
ACCURACY:  $\pm 3\%$  of full scale on  $10^{-4}$  to  $10^{-9}$  ampere ranges using smallest available multiplier setting;  $\pm 5\%$  of full scale on  $3 \times 10^{-10}$  to  $10^{-11}$  ampere ranges.  
GRID CURRENT: Less than  $5 \times 10^{-14}$  ampere.

AS AN OHMMETER:

RANGE:  $10^5$  ohms full scale to  $10^{12}$  ohms in fifteen linear 1x and 3x ranges.  
ACCURACY:  $\pm 4\%$  of full scale on  $10^5$  to  $10^{10}$  ohm ranges using largest available multiplier setting;  $\pm 6\%$  of full scale on  $3 \times 10^{10}$  to  $10^{12}$  ohm ranges.

AS AN AMPLIFIER:

INPUT IMPEDANCE: Greater than  $10^{14}$  ohms shunted by 30 picofarads. Input resistance may be selected in decade steps from  $10^6$  to  $10^{10}$  ohms.  
OUTPUT: Either voltage or current recorder output.  
VOLTAGE RECORDER OUTPUT:  $\pm 10$  volts for full-scale input. Internal resistance is 9.1 kilohms. Output polarity is opposite input polarity.  
Gain: 0.1, 0.3, etc., to 100.  
Frequency Response (Within 3 db): dc to 200 cps.  
Noise: Less than 3% peak-to-peak of full scale.  
CURRENT RECORDER OUTPUT:  $\pm 1$  milliampere for full-scale input (variable).

GENERAL:

POLARITY: Meter switch selects left-zero (positive or negative) scales. Meter switch does not reverse polarity of outputs.  
CONNECTORS: Input: Teflon-insulated UHF type; ground binding post. Output: Amphenol 80-PC2F.  
POWER: 105-125 or 210-250 volts, 50-60 cps, 35 watts.  
DIMENSIONS, WEIGHT: 9-1/2 inches high x 6-1/2 inches wide x 9-1/2 inches deep; net weight, 12 pounds.  
ACCESSORIES SUPPLIED: Mating input and output connectors.

DESCRIPTION:

The Keithley Model 621 is a line operated multipurpose DC measuring instrument of extremely wide range. The measuring ranges are summarized below:

**VOLTAGE:** 100 millivolts to 100 volts full scale. The input impedance is greater than  $10^{14}$  ohms shunted by approximately 30 micro-microfarads on the VOLTS position of the RANGE switch. The input resistance may be varied from  $10^{10}$  ohms to  $10^6$  ohms in decade steps by rotating the RANGE switch in the AMPERES range marking.

**HIGH VOLTAGE WITH ACCESSORIES:** The Model 6102A, 10:1 divider probe extends the measuring range to 1000 volts. The divider resistance is  $10^{10}$  ohms and its division accuracy is 1%.

The Model 6103A, 1000:1 divider probe extends the measuring range to 30 KV. Its input resistance is  $10^{12}$  ohms and its division accuracy is 3%.

**CURRENT:**  $10^{-4}$  amperes to  $10^{-11}$  amperes full scale. The current is measured either by measuring the drop across a resistor shunted across the input, or by placing the NORMAL-FAST switch on the back panel in the FAST position, and applying negative feedback around the shunt resistor. This makes the input drop negligible and improves speed of response considerably on the low current ranges.

**OHMS:**  $10^5$  ohms to  $10^{12}$  ohms full scale. The linear ohms scale is achieved by measuring the unknown resistor with a known, constant current flowing through it. The voltage drop across the sample is then proportional to the resistance. Resistance from  $10^5$  ohms to  $10^{12}$  ohms full scale is measured by a two terminal method.

**DC AMPLIFIER:** The frequency response of the Model 621 as an amplifier is from DC to 200 cycles on all ranges. The output is either 10 volts or 1 milli-ampere for full scale meter deflection. In the NORMAL micro-microammeter position the output is not grounded. The output polarity is opposite the input signal polarity.

For directions pertaining to the use of recorders see section IV-E.

Front panel controls and terminals are:

RANGE switch, located in the center of the front panel under the meter. This control selects VOLTS, OHMS, or AMPERES. On the AMPERES position, a shunt resistor whose value is the reciprocal of the designated range may be used to decrease the input resistance as well as to measure current.

MULTIPLIER switch, located in the center directly under the meter, determines the voltage sensitivity of the dc amplifier, and sets the voltage range when the RANGE is set on VOLTS. On OHMS or AMPERES, the setting of this knob multiplied by the OHMS or AMPERES setting gives the full scale meter range.

ZERO control, located to the left of the MULTIPLIER switch under the meter, is used to set the meter to zero.

METER switch, at the right under the meter, turns the instrument on and determines meter polarity.

OPERATE - ZERO CHECK switch, located at the bottom right, selects normal operation or zero check position. In the ZERO CHECK position, the input terminals are shorted through 4.7 megohms, while the amplifier input is shorted.

INPUT terminal is a teflon-insulated UHF type receptacle located in the lower left corner of the front panel. The mating connector and an accessory binding post which plugs into the center of the connector are supplied with the 621. A ground binding post labeled G is mounted on the front panel above the input terminal.

Rear panel controls and terminals are:

FUSE at the upper left. With 110 volts AC power, use 1.0 ampere SLO-BLO fuse; with 220 volts power, use 0.5 amperes fuse.

POWER INPUT. Unless indicated, instrument is wired for 117 volts 50-60 cps. For 230 volt operation, consult the circuit schematic diagram.

RECORDER CALIBRATION. Used to calibrate 1 ma. recorders, so their scale corresponds with the panel meter.

1 MA - 10V. In the 1 MA position, OUTPUT will drive 1 milliamperere recorders. In the 10V position, the output is 10 volts for full scale panel meter deflection.

OUTPUT connector for external recorders is an Amphenol type 80-PC2F receptacle. The mating connector is an Amphenol type 80 MC2M.

NORMAL-FAST. This control is locked in NORMAL position. In FAST position, current measurements are made with feed-back around the shunt resistor.

COARSE ZERO. If the amplifier is quite badly unbalanced, the COARSE ZERO switch is used to bring the front panel ZERO control in range.

MODEL 621R: The specifications and controls described for the 621 in this section are the same for the 621R except for the location of two switches. On the 621R, the ZERO COARSE and FAST-NORMAL switches are located on the front panel. The function and operation of the switches are the same as for the 621.



### SECTION III - CIRCUIT DISCUSSION

The basic element of the Model 621, is a highly accurate, stable dc voltmeter with a full scale sensitivity of 100 millivolts and an input impedance greater than  $10^{11}$  ohms shunted by 30 micro-microfarads. Amperes and ohms are measured by the use of resistance standards. The various connections necessary for amperes and ohms measurements will be discussed following the detailed description of the amplifier.

#### A. VOLTMETER

Refer to DR 13515-D at the rear of the manual. The amplifier proper consists

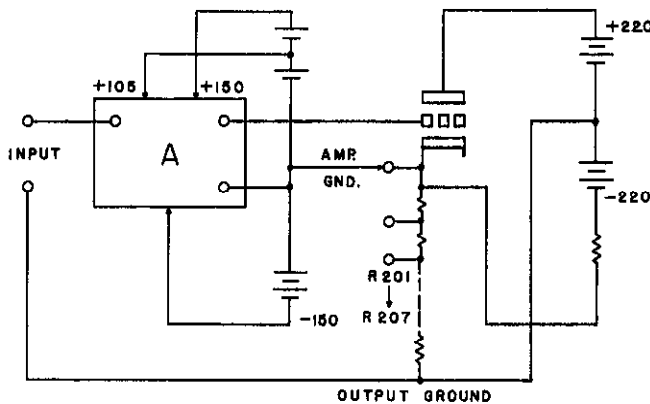


FIGURE 621-1

of V-1 and V-2. V-3 is a cathode follower which drives the amplifier at the same instantaneous potential as the input signal. In other words the neutral or ground terminal of the amplifier is not grounded to the chassis but is attached either directly or through divider R-201 through R-207 to the output cathode follower. Figure 621-1 shows this diagrammatically. The amplifier A is driven by the cathode follower. If it is desired to have unity gain, the amplifier is connected directly to the cathode. To increase the voltage gain, a fraction of the output voltage rather than all of it is fed back.

The purpose of this arrangement is to allow the input to accept relatively large input voltages without use of input dividers, which are neither stable nor accurate at high impedance. Consequently, the Model 621 will accept 100 volts without the use of input dividers, preserving the high input impedance and accuracy of the amplifier. Accessory probes are available for extending the voltage range at reduced input resistance and accuracy.

Since the amplifier proper is driven by the cathode follower, the plus and minus 220 volt supplies for the cathode follower are referred to input ground while the +150 and +105 volt, and -150 volt supplies for the amplifier are referred to amplifier ground which is "floating". In subsequent discussion, reference will be made to the amplifier ground as "floating ground" and to cathode follower ground as "output ground".

The amplifier input consists of a 5886 electrometer tube. The filament is operated through a dropping resistor network from the regulated B plus supply. The control grid of V-1, the electrometer tube, is protected by R-102, a 4.7 megohm resistor, by-passed for high frequencies by C-102. The input switch, S-2 connects the grid of V-1 to the input terminal on the OPERATE position and connects it to ground, through the 4.7 megohm protective resistor, on ZERO CHECK.

The balance controls function by adjusting the dc voltages of the electrometer tube screen and the grid of V-2.

V-2 forms an ordinary differential amplifier and the output is taken into V-3 the output cathode follower.

The voltmeter sensitivity is determined by the fraction of the cathode follower voltage fed back via the divider, R-201 through R-207.

The OUTPUT is derived directly from the 6CM6 cathode. If the output switch (S-6) is set at 10 V, R-127 is set across the output terminals. If the output switch is set at 1 ma, R-127 in combination with R-128 are used to provide enough series resistance so that 1 milliampere flows into the recorder terminals. R-128 calibrates the recorder on all ranges.

The feedback loop is stabilized against oscillation by C-116 together with R-112. The gain is kept high enough so that there is a large feedback factor on all ranges, but the gain is not allowed to become high enough to cause oscillation.

#### B. AMMETER

Grid current of the input electrometer tube fixes the minimum current that may be measured. The Model 621 grid current will usually be less than  $2 \times 10^{-14}$  amperes.

- (1) Shunt Resistor Method (NORMAL) In the normal operating connection as shown in Figure 3 current is measured by placing a resistor across the input terminals and measuring the voltage drop. The voltage drop is selected by the MULTIPLIER switch; the setting is the input voltage drop for full-scale meter deflection.

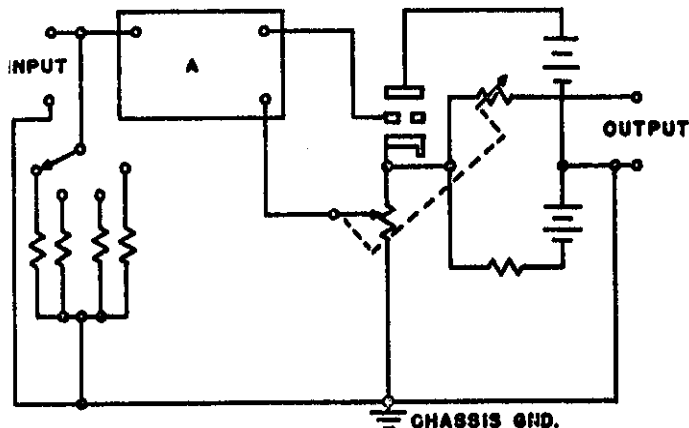


FIGURE 3. Normal Ammeter Operation Schematic

- (2) Feedback Method (FAST) In the voltmeter discussion above, floating ground has been driven by the cathode follower and output ground has been connected to the low impedance side of the input connector. In the FAST connection, shown in Figure 4, the amplifier ground is connected to the low impedance side of the input; the cathode follower ground floats, and negative feedback is applied through the shunt resistor.

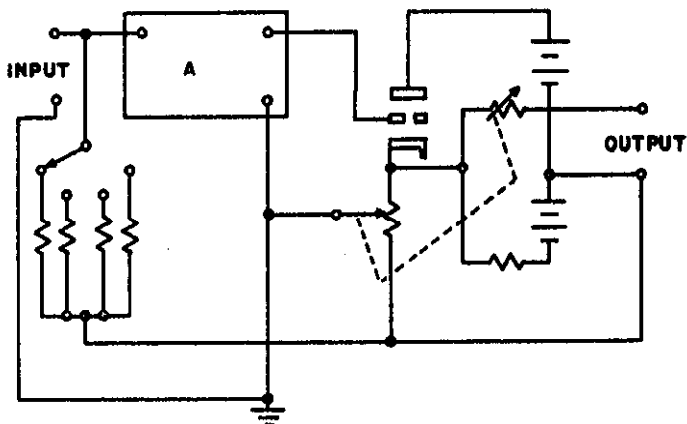


FIGURE 4. Fast Ammeter Operation Schematic

In the Model 621, it is possible to use this connection with currents of 100 microamperes or less. To change the connection, remove the lock from the NORMAL-FAST switch at the bottom of the rear panel and change it to the FAST position. The advantages of this connection are:

- (a) The effect of input capacity is largely neutralized, that is, the time constant of the input and cable capacity and the shunt resistor used will be decreased at least 100 times as compared to the NORMAL connection, corresponding to a 100-fold increase in response speed.
- (b) The input drop will be reduced at least 100 times.

If Figure 4 is again consulted it will be seen that this connection converts the 621 into an operational amplifier with a resistor from the output to the input. Therefore, the following cautions apply:

- (a) The input cannot be shorted since this will remove the feedback.
- (b) The internal impedance of the current source being measured should not be less than about one-tenth of the value of the feedback resistor used for measurement.
- (c) This connection should not be used for measuring the leakage current of capacitors since the connection of a capacitor to the input causes the circuit to be transformed into a differentiator with the resultant extreme sensitivity to very small voltage transients. For this measurement the NORMAL should be used.

### C. OHMMETER

- (1) Normal Method. The Model 621 employs a linear scale to provide a megohmmeter of high accuracy.

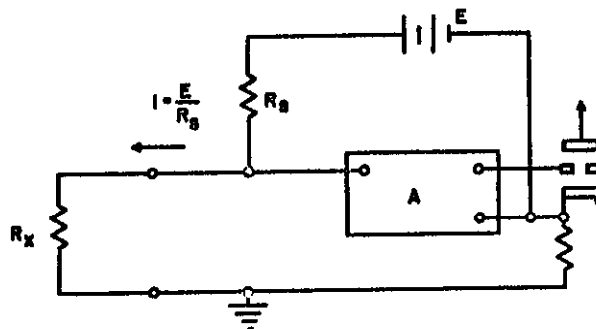


FIGURE 5. Normal Ohmmeter Operation Schematic.

The linear ohms scale is achieved by supplying a constant current to the sample and measuring the voltage drop across it. The method used to obtain a constant current, is illustrated in Figure 5. The ground connections are in the NORMAL position, that is, the amplifier ground is driven and the cathode-follower ground is attached to the input ground. The voltage source is only one volt. However, it is attached between floating ground and the grid of the voltmeter while, as before, the test sample is attached between input ground and the voltmeter grid. Since feedback to

the amplifier ground keeps it at virtually the same potential as the input grid regardless of the input voltage, the voltage across the current source resistor cannot change. Therefore, this arrangement provides a true current source regardless of the input voltage.

- (2) Use of External Voltage Supply. With the constant current method of measuring resistance, the voltage across the unknown may not be arbitrarily selected, and the time of measuring capacitor leakage tends to be log, since constant-current charging is slower than the exponential charge available with an RC circuit.

Due to these facts, it may be desirable to use an external voltage supply and measure the leakage current on the AMPERES scale (NORMAL operation). The unknown is connected between the input terminal of the electrometer and

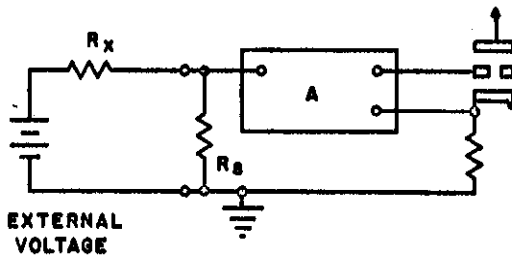


FIGURE 6. Ohmmeter with External Voltage Supply Schematic

the source of voltage. This is shown in Figure 6. If the applied voltage is large compared to the voltage drop across the electrometer (so that the voltage across the sample is substantially the applied voltage) the resistance is simply equal to the voltage applied divided by the current measured. If the voltage drop is an appreciable fraction of the applied voltage, the resistance equals the voltage applied minus the input drop divided by the current measured. It will

be rarely necessary to correct for the input drop of the electrometer due to the excellent voltage sensitivity of the Model 621.

It is advisable to use the NORMAL micro-microammeter connection for the measurement of leakage resistance of capacitors in this manner, since instability is likely to occur using the FAST connection. However, in cases where the capacity shunted across the sample is small, it will be possible to realize a considerable increase in speed of response by utilizing the FAST connection.

Some precautions are recommended when testing capacitors. Be sure that capacitors have discharged before removing from test circuit. With the 621 input switch on ZERO CHECK, the input is shorted to ground through 4.7 megohms, providing a discharge path for the capacitor.

It should be further noted that capacitor measurement is likely to be a slow process in any case due to the fact that it may take considerable time for the molecular orientation of the dielectric to take place at the testing potential. It may take minutes or even hours in some cases to achieve a stable reading.

SECTION IV - OPERATIONA. PREPARING THE INSTRUMENT FOR OPERATION

(1) Connect to power line of proper voltage and frequency. Unless otherwise indicated at rear of instrument, the Model 621 is wired for 100 to 130 volts 50 to 60 cps. If it is desired to operate on 200 to 260 volts 50 to 60 cps, consult DR 13515-D at rear of the manual for instructions.

(2) Set controls as follows:

MULTIPLIER:	100
RANGE SWITCH:	VOLTS
OPERATE SWITCH:	ZERO CHECK
INPUT TERMINAL:	Shield with Cap.

(3) Turn the METER switch to meter +. The instrument should come to zero in approximately 30 seconds. Final stability within drift specifications will not be achieved for 2 hours.

(4) Rotate the MULTIPLIER switch toward the high sensitivity end, adjusting ZERO as required. If it is impossible to zero the meter with the front panel ZERO control, use COARSE BAL control on rear panel to bring the instrument within range of the ZERO control.

(5) Connect leads as required for measurement. If high impedance is involved, the input should be shielded using a coaxial connection or shielded enclosure. The various accessories for the Model 621 may be used.

If the impedance is low and leads can be kept short, the binding post adapter furnished with the instrument may be used.

The Keithley Model 6101A, Shielded Test Probe, will suffice for most measurements.

B. MEASURING VOLTAGE

Place RANGE switch at VOLTS. Turn MULTIPLIER switch to expected sensitivity and check meter zero. Move OPERATE switch up to OPERATE and read. If the sensitivity of the instrument is increased, recheck the zero setting.

For voltages greater than 100 volts, use the Model 6102A, 10:1 Divider Probe or the Model 6103A, 1000:1 Divider Probe, and measure as above.

C. MEASURING CURRENT

(1) NORMAL method

Turn RANGE switch to desired AMPERES range. Make sure the switch at the rear of the instrument is on the NORMAL position. Connect current source to input. The product of the reading on the RANGE switch and the MULTIPLIER gives the full scale range. Check zero first with OPERATE switch and then read unknown current. The full scale voltage drop across the instrument is the setting of the MULTIPLIER.

(2) FAST method

Proceed as above, except move the FAST-NORMAL switch at the rear of the instrument to the FAST position. The input drop is now negligible and the speed of response is increased approximately 100 times. However, observe the following cautions:

- (a) Use only the input switch to check zero; DO NOT SHORT INPUT.
- (b) The low side of the output is no longer grounded. Therefore, if the instrument is being used with an output recorder, the recorder must not be grounded to the case of the 621.
- (c) Do not use this position for the measurement of capacitor leakages.

#### D. MEASURING RESISTANCE.

- (1) NORMAL method ( $10^5$  ohms to  $10^{12}$  ohms full scale).

Turn RANGE switch to desired OHMS range. Make sure that NORMAL-FAST switch is in the NORMAL position. Connect resistance sample to be measured only after OPERATE switch has been moved to ZERO CHECK. Do not open-circuit instrument when on OHMS, since the input will develop a large voltage due to its constant current characteristic. However, if the sample is first connected and then the OPERATE switch is moved to OPERATE, the full scale input voltage will be the setting of the MULTIPLIER.

Before reading OHMS, turn RANGE switch to the approximate range of the unknown resistance. By manipulating the MULTIPLIER and the RANGE switch, the sample can be tested at a number of test potentials, if desired.

The full-scale ohms range is the RANGE switch setting times the MULTIPLIER.

- (2) EXTERNAL VOLTAGE method.

Any external voltage may be used. The unknown is connected between the test potential and the INPUT terminal of the electrometer. The current is then measured, using the NORMAL or FAST method, and the resistance calculated.

Proceed as follows:

- (a) Turn input switch to ZERO CHECK.
- (b) Connect unknown between INPUT terminal and source of potential. A switch should be connected in the high voltage line so that when the sample is disconnected from the potential, the low impedance end of the sample is grounded.
- (c) FAST-NORMAL switch should be at NORMAL
- (d) Apply potential to sample before switching to OPERATE. Start the RANGE switch at low current sensitivities and advance the sensitivity until a reading is obtained.

If the potential applied is at least 100 times the full scale ammeter drop (MULTIPLIER setting), the resistance is equal to:

$$\frac{\text{POTENTIAL APPLIED}}{\text{CURRENT READING}}$$

If the potential applied is not large compared to the ammeter drop, the resistance is equal to:

$$\frac{\text{POTENTIAL APPLIED} - \text{INPUT DROP (VOLTS)}}{\text{CURRENT READING}}$$

- (e) If it is possible to operate on FAST micro-microammeter, the input drop need not be considered in the calculation.

### E. USING EXTERNAL INDICATORS

The Model 621 output will drive 1-milliampere recorders and servo rebalance recorders, as well as higher impedance instruments such as pen recorder amplifiers and oscilloscopes.

(1) 10-Volt Output. Connect oscilloscopes and pen recorder amplifiers to the OUTPUT Receptacle. Pin no. 1 is the positive terminal. Set the Output Switch to 10 V. The Model 621 output is now 10 volts dc for full-scale meter deflection on any range. The frequency response ( $\pm 3$  db) is dc to 200 cps on any range. Maximum output amplitude is approximately 10 volts peak-to-peak. Maximum permissible load across the output terminals in this mode is one megohm. The METER Switch does not reverse the output polarity.

#### NOTE

The Model 621 may be used with the FEEDBACK Switch in FAST position with other instruments. However, make sure there is no common ground between the Electrometer case and the other instrument.

(2) 1-Milliampere Output. Connect 1-milliampere instruments, such as Esterline Angus, General Electric or Texas Instrument Rectiriter, to the OUTPUT Receptacle. Pin no. 1 is the positive terminal. Set the Output Switch to 1 MA. The output is approximately 1 milliampere for full-scale meter deflection on any range. For exact output, adjust the meter on the 0.1-volt range with the ZERO Control for full-scale deflection. Then adjust the 1 MA CAL Control until the recorder reads full scale. Check the recorder and meter zero and repeat adjustment if necessary. The METER Switch does not reverse the output polarity.

(3) For servo rebalance recorders, use a divider across the Model 621 OUTPUT Receptacle. See Figure 1A. Set the Output Switch to 1 MA. Use the 1 MA CAL Control to trim the output for full-scale recorder deflection. Operation is the same as for current outputs.

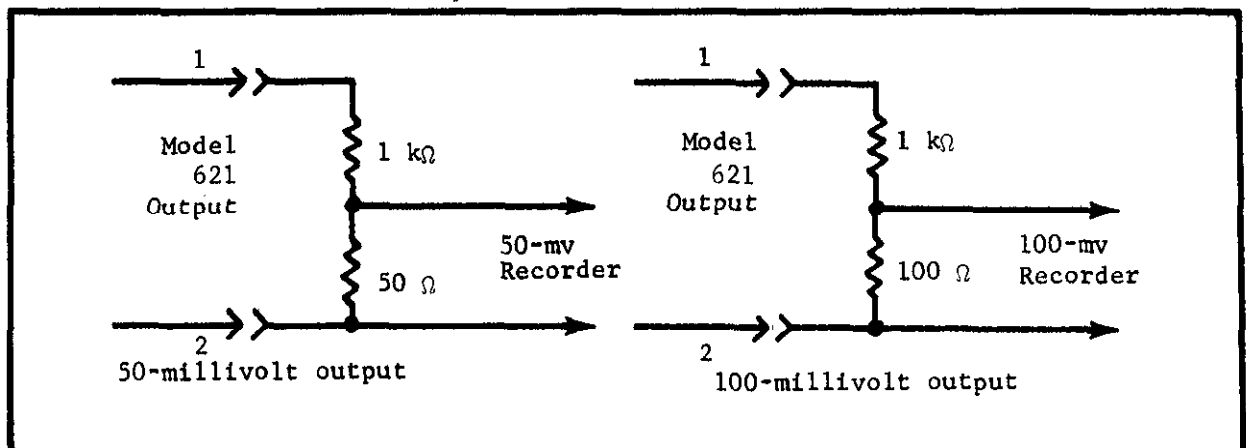


FIGURE 1A. Divider Circuits Across Model 621 Output. The dividers are for driving 50 and 100-millivolt recorders. Use 1% resistors in the dividers.

(4) When the FEEDBACK Switch is in the NORMAL position, the negative side of the output terminal is grounded to the instrument case. Therefore, no difficulty will be experienced using oscilloscopes and recorders with the Model 621 set for normal operation. In FAST position, however, neither side is grounded. If this is used, make sure there is no common ground between the recorder or oscilloscope and the Model 621 case.

F. CURRENT SOURCE. The Model 621 can be used as a current source from  $10^{-6}$  to  $10^{-10}$  ampere. Follow these procedures:

- (1) Set the FEEDBACK Switch to NORMAL, the Range Switch to OHMS and the METER Switch to + or -.
- (2) The current supplied at the INPUT Receptacle is the reciprocal of the OHMS Setting on the Range Switch. (For example,  $10^9$  OHMS indicates  $10^{-9}$  ampere current at the INPUT Receptacle.)
- (3) The Multiplier Switch does not affect the current at the INPUT Receptacle. It does affect the maximum input voltage drop, which is equal to the Multiplier Switch setting. For accurate output current, check the meter zero on the 1-volt position of the Multiplier Switch.

G. STATIC CHARGE MEASUREMENTS: The instrument is zeroed and the RANGE Switch placed on VOLTS. The voltage sensitivity is perhaps placed at 10 or 30 volts full scale. The charged object is then brought near the uncovered, unshielded input connector of the 621. Depending on the distance between the charge and the instrument, a voltage will be induced on the input terminal and can be read on the panel meter. The instrument zero should be checked frequently since accumulation of charge due to the electrometer tube grid current will cause a slow drift of input voltage.

Connecting a capacitor across the input reduces the drift due to grid current and also the sensitivity to charge. An electrode connected to the INPUT terminal which increases the capacitance between the INPUT terminal and the charged object will increase the sensitivity to charges.



SECTION V - ACCESSORIESA. MODEL 6101A, ACCESSORY PROBE:

The Model 6101A probe consists of an input connector, 3 feet of low noise cable and a shielded probe head. Its purpose is to allow convenient connection to the electrometer input.

B. MODEL 6102A, 10:1 DIVIDER PROBE:

The Model 6102A divider probe is intended for general purpose measurements where an extension of the upper voltage range of the 621 is desired. The division ratio is 10:1 correct to 1% and the probe input resistance is  $10^{10}$  ohms. The probe is supplied with a mating connector and 3 feet of cable.

C. MODEL 6103A, 1000:1 DIVIDER PROBE:

The Model 6103A probe is intended for very high voltage measurements at high impedance. The division ratio is 1000:1 correct to 3% and the probe input resistance is  $10^{12}$  ohms. The probe is supplied with a mating connector and 3 feet of cable.

D. MODEL 6104, TEST SHIELD:

The Model 6104 Test Shield is intended for use in making measurements where complete shielding of the component under test is required. External terminals are provided for either grounded tests, or a test requiring an external voltage source.

E. ORDERING ACCESSORIES:

The accessories listed above facilitate measurements and extend the range of the 621 Electrometer. To order the accessories, contact the nearest Keithley Instruments field representative or

Order Service Department  
Keithley Instruments, Inc.  
28775 Aurora Road  
Cleveland, Ohio 44139

SECTION VI - MAINTENANCE

No periodic maintenance is required. There are no internal batteries.

The calibration of the voltmeter is set by R-130 located on the P.C. Board. This is set at the factory and should not require adjustment. If recalibration is performed, an accurate voltage source should be used.

A. TROUBLE SHOOTING

The circuit is completely described in Section III. Study of that section will facilitate any trouble shooting.

The most usual trouble encountered is that on the most sensitive voltage range, with in input shorted, it is not possible to bring the meter pointer to zero. However, before assuming that the instrument is at fault make sure that resetting the COARSE BAL control at the rear of the instrument will not bring the instrument back into balance. If this does not work remove the instrument case, by removing the 3 screws on each side of the cover to gain access to all circuitry, 621; remove 2 screws and lift off cover, 621R. Follow this procedure:

- (1) Check for presence of regulated B-plus voltage by switching to meter + and checking at pin 1 of V-3 for +150 volts  $\pm 10\%$ ; pin 3 of V-2 for +108 volts  $\pm 10\%$ ; and pin 2 of V-4 for -150 volts  $\pm 10\%$ .
- (2) If correct voltage is present, check the plus and minus 220 volt supplies which supply the output cathode follower. The plus voltage is present on pin 9 of V-3. The minus voltage may be obtained from the bottom of the 100K cathode resistor of V-3. It is a 2 watt power resistor located on the printed circuit board. If this voltage is not correct consult the schematic and trouble shoot the supply in the usual manner.
- (3) If no defects are found so far, proceed by shorting floating ground to output ground to remove the negative feedback. This is most conveniently accomplished by shorting the two ends of the FAST-NORMAL switch on the rear panel. In this condition the instrument will become very sensitive and in operating the ZERO control, the meter will be very difficult to hold on scale. However, the indication that the circuit is operating satisfactorily is that it is possible to swing the voltage through the correct operating point as indicated on the voltage-resistance diagram.

Now with the MULTIPLIER at 0.1 volts, proceed to check the operating points of the tube electrodes.

Regardless of the condition of the amplifier balance, the filament, cathode and screen potentials, except for the screen of V-1, should be reasonably close to the values on the circuit diagram. The plate and grid potentials will, however, depend on the setting of the ZERO control. However, if it is possible to swing the voltage through the correct value it may be assumed that the stage is working. Proceed in this manner until the point is found where the voltage cannot be swung through the value marked on the diagram. At this point it will be relatively easy to find the fault. First check the tube involved and then check the components.

## Miscellaneous Troubles:

TROUBLE	CAUSE	REMEDY
Excessive grid current	Defective electrometer tube	Replace V-1
Excessive drift	Power supply not regulated	Check OB2 stability
Excessive microphonics	Defective electrometer tube	Replace V-1
Instrument does not zero	See section above	See section above

The Voltage-Resistance Diagram shows the proper positioning for inserting the electrometer tubes. Make certain fingers do not touch the glass base where the leads emerge when inserting the tubes.

## HOW TO ORDER PARTS

Order component parts directly from the manufacturer or from Keithley Instruments Inc. Order all structural parts from Keithley.

The Replaceable parts list gives the code number of the component's manufacturer in the MFG. CODE column. The name and address of the manufacturer having the code number is listed in the Manufacturers' Code Definitions Table immediately following the Replaceable Parts List. When ordering from the manufacturer, purchase only quality components meeting the listed specifications.

When ordering from Keithley Instruments, give a description of the part being ordered, the circuit designation, the Keithley part number, the instrument model number, and the instrument serial number. Send to:

Order Service Department  
Keithley Instruments, Inc.  
28775 Aurora Road  
Cleveland, Ohio 44139

## LIST OF SYMBOLS AND ABBREVIATIONS

a	Amperes	$\Omega$	Ohm
Cer	Ceramic Disc	p	Pica ( $10^{-12}$ )
CerV	Ceramic Variable	PST	Polystyrene Tubular
Comp	Composition	R	Resistor
CompV	Composition Variable		
DCb	Deposited Carbon	Sw	Switch
EC	Electrolytic Can	$\mu$	Micro ( $10^{-6}$ )
ETB	Electrolytic Tubular	V	Volts
f	Farad	Var	Variable
K	Kilo ( $10^3$ )	w	Watt
m	Milli ( $10^{-3}$ )	WW	Wire Wound
M	Mega ( $10^6$ )	WWVar	Wire Wound Variable
My	Mylar		

REPLACEABLE PARTS LIST - MODEL 621

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
C101	.001 $\mu$ f	600 V	Cer	72982	C22-.001
C102	.001 $\mu$ f	600 V	Cer	72982	C22-.001
C103	47 pf	500 V	Poly	71590	C138-47P
C104	.0022 $\mu$ f	600 V	Cer	72982	C22-.0022
C105	.01 $\mu$ f	600 V	Cer	14655	C22-.01
C106	470 pf	1000 V	Cer	71590	C64-470
C107	470 pf	1000 V	Cer	71590	C64-470
C108	20 $\mu$ f/20 $\mu$ f	500 V	ETB (Dual Section)	56289	C68-20/20
C109	20 $\mu$ f/20 $\mu$ f	500 V	ETB (Dual Section)	56289	C68-20/20
C110	20 $\mu$ f/20 $\mu$ f	500 V	ETB (Dual Section)	56289	C68-20/20
C111	20 $\mu$ f/20 $\mu$ f	500V	ETB (Dual Section)	56289	C68-20/20
C112	470 pf	1000 V	Cer	14655	C64-470
C113	470 pf	1000 V	Cer	14655	C64-470
C114	40 $\mu$ f	350 V	ETB	56289	C32-40
C115	40 $\mu$ f	350 V	ETB	56289	C32-40
C116	.0047 $\mu$ f	600 V	Cer	72982	C22-.0047
C117	.001 $\mu$ f	600 V	Cer	72982	C22-.001
C118	.01 $\mu$ f	600 V	Cer	14655	C22-.01

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
D-1	Rectifier LN3255	02735	RF-17
D-2	Rectifier LN3255	02735	RF-17
D-3	Rectifier LN3255	02735	RF-17
D-4	Rectifier LN3255	02735	RF-17
D-5	Rectifier LN3255	02735	RF-17
D-6	Rectifier LN3255	02735	RF-17
D-7	Rectifier LN3253	02735	RF-20
F-1 (220v)	Fuse, 0.5 A/3 AG	75915	FU-4
F-1 (110v)	Fuse, 1.0 A/3 AG	75915	FU-10
I-1	Meter lamp (Vendor No. 47)	72765	PL-4
I-2	Meter lamp (Vendor No. 323)	08806	PL-1
M-1	Meter, 1 ma	80164	ME-35

REPLACEABLE PARTS LIST - MODEL 621

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
R101	4.7 MΩ	10%, $\frac{1}{2}$ w	Comp	01121	R1-4.7M
R102	4.7 MΩ	10%, $\frac{1}{2}$ w	Comp	01121	R1-4.7M
R103	96 KΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-96K
R104	10 MΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-10M
R105	20 KΩ	30%	CompV	80164	RP12-20K
R106	9 KΩ	1%, 5 w	WW	91637	R41-9K
R107	1 KΩ	1%, $\frac{1}{2}$ w	DCb	01661	R12-1K
R108	500 Ω	1%, $\frac{1}{2}$ w	DCb	00327	R12-500
R109	15 KΩ	2 w	WWVar	80164	RP3-15K
R110	250 Ω	1%, $\frac{1}{2}$ w	DCb	01661	R12-250
R111	200 Ω	1%, $\frac{1}{2}$ w	DCb	01661	R12-200
R112	10 KΩ	10%, $\frac{1}{2}$ w	Comp	01121	R1-10K
R113	3.3 KΩ	10%, 2 w	Comp	01121	R3-3.3K
R114	100 KΩ	10%, 2 w	Comp	44655	R3-100K
R115	100 Ω	10%, 1 w	Comp	01121	R2-100
R116	270 Ω	10%, $\frac{1}{2}$ w	Comp	44655	R1-270
R117	150 KΩ	10%, $\frac{1}{2}$ w	Comp	01121	R1-150K
R118	3.3 KΩ	10%, 2 w	Comp	01121	R3-3.3K
R119	5 KΩ	5%, 10 w	WW	63743	R5-5K
R120	12.5 KΩ	5%, 10 w	WW	44655	R5-12.5K
R121	2 KΩ	5%, 5 w	WW	63743	R4-2K
R122	2.2 KΩ	5%, 10 w	WW	44655	R5-2.2K
R123	5 KΩ	10%, 2 w	WWVar	37942	RP3-5K
R124	220 KΩ	10%, $\frac{1}{2}$ w	Comp	44655	R1-220K
R125	1 MΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-1M
R126	1.5 MΩ	1%, $\frac{1}{2}$ w	DCb	01661	R12-1.5M
R127	9.1 KΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-9.1K
R128	15 KΩ	2 w	WWVar	80164	RP3-15K
R129	500 Ω	1%, $\frac{1}{2}$ w	DCb	00327	R12-500
R130	2 KΩ	20%, $\frac{1}{2}$ w	CbV	71450	RP12-2K
R131	47 KΩ	1%, $\frac{1}{2}$ w	DCb	01661	R12-47K
R132	23.3 KΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-23.3K
R133	100 KΩ	1%, $\frac{1}{2}$ w	Comp	01121	R1-100K
R134	1 KΩ	1%, $\frac{1}{2}$ w	DCb	01661	R12-1K
R201	91 Ω	1%, $\frac{1}{2}$ w	DCb	01661	R12-91
R202	273 Ω	1%, $\frac{1}{2}$ w	DCb	00327	R12-273
R203	910 Ω	1%, $\frac{1}{2}$ w	DCb	01661	R12-910
R204	2730 Ω	1%, $\frac{1}{2}$ w	DCb	00327	R12-2730
R205	9.1 KΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-9.1K
R206	27.3 KΩ	1%, $\frac{1}{2}$ w	DCb	01661	R12-27.3K
R207	91 KΩ	1%, $\frac{1}{2}$ w	DCb	00327	R12-91K
R208	6 KΩ	1%, $\frac{1}{2}$ w	DCb	01661	R12-6K

REPLACEABLE PARTS LIST - MODEL 621

Resistors (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Keithley Part No.
R301	10 <sup>10</sup> Ω	2%	Glass DCb	63060	R20-10 <sup>10</sup>
R302	10 <sup>9</sup> Ω	2%	Glass DCb	63060	R20-10 <sup>9</sup>
R303	100 MΩ	1%, 2 w	DCb	01661	R14-100M
R304	10 MΩ	1%, 1/2 w	DCb	00327	R12-10M
R305	1 MΩ	1%, 1/2 w	DCb	00327	R12-1M

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
S-1	Switch, Range	80164	SW-103
S-2	Switch, Operate	80164	SW-110
S-3	Switch, Meter	80164	SW-113
S-4	Switch, Multiplier	80164	SW-108
S-5	Switch, Slide, DPDT	79727	SW-45
S-6	Switch, Slide, DPDT	79727	SW-45
T-1 (Model 621)	Transformer, Power	80164	TR-23
T-1 (Model 621R)	Transformer, Power	80164	TR-57

VACUUM TUBES

Circuit Desig.	Tube Number	Mfg. Code	Keithley Part No.
V-1	5886-5	80164	EV-5886-5X
V-2	6BH8	85599	EV-6BH8
V-3	6CM6	80368	EV-6CM6
V-4	0A2	86684	EV-0A2
V-5	6627	86684	EV-6627
V-6	6626	86684	EV-6626

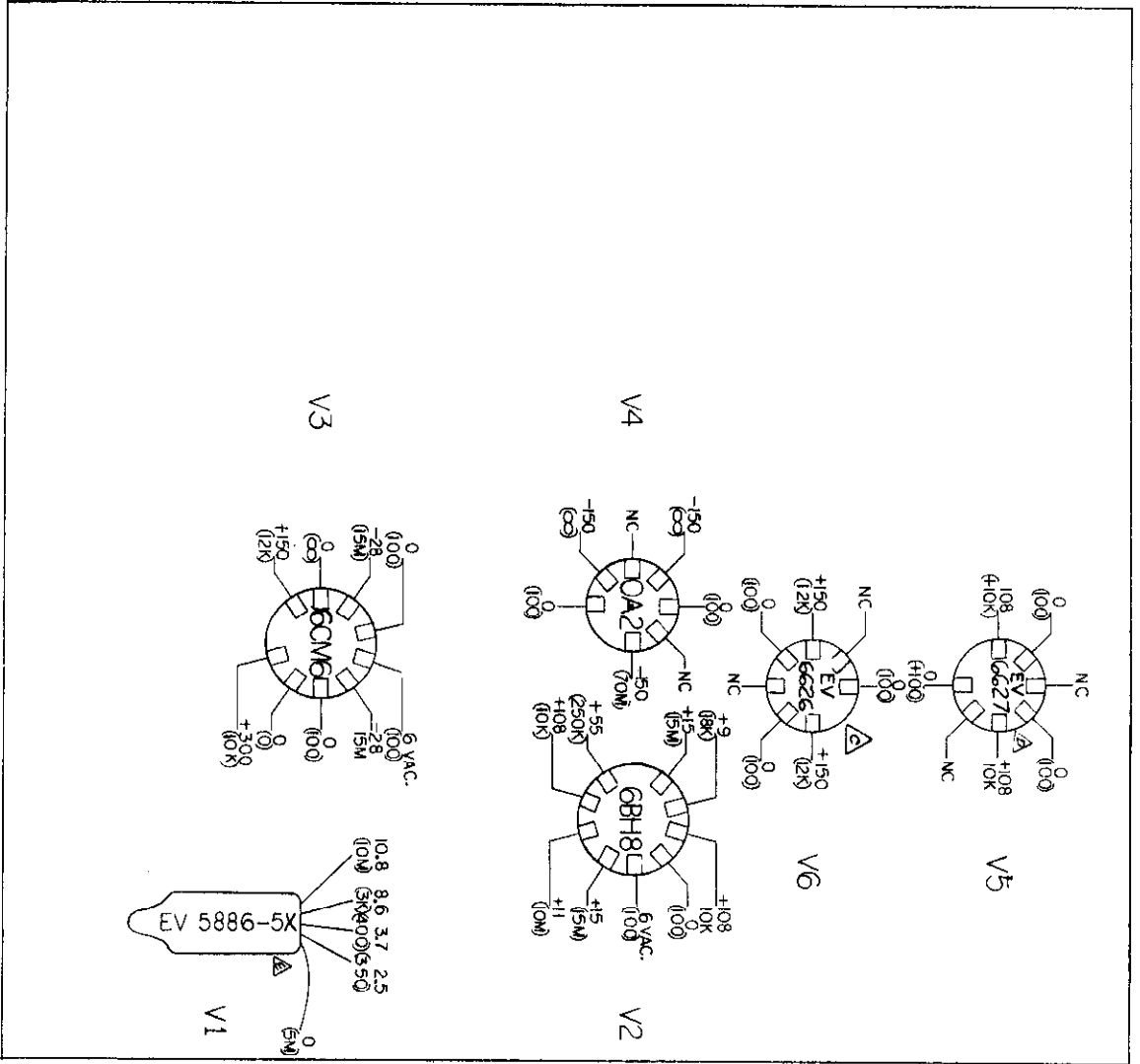
## MODEL 621 ELECTROMETER

## MANUFACTURERS' CODE DEFINITIONS

00327	Welwyn International, Inc. Cleveland, Ohio	71590	Centralab Division of Globe-Union, Inc. Milwaukee, Wis.
00686	Film Capacitors, Inc. New York, N. Y.	72765	Drake Mfg. Co. Chicago, Ill.
01121	Allen-Bradley Corp. Milwaukee, Wis.	72982	Gudeman Co. Chicago, Ill.
01661	Wilrite Products, Inc. Cleveland, Ohio	73445	Amperex Electronic Co. Division of North American Philips Co., Inc. Hicksville, N. Y.
02735	Radio Corp. of America Commercial Receiving Tube and Semiconductor Division Somerville, N. J.	75915	Littelfuse, Inc. Des Plaines, Ill.
08806	Miniature Lamp Dept. G. E. Co. Cleveland, Ohio	79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
14655	Cornell-Dubilier Electric Corp. Newark, N. J.	80164	Keithley Instruments, Inc. Cleveland, Ohio
37942	Mallory, P. R., and Co., Inc. Indianapolis, Ind.	80368	Sylvania Electric Products, Inc. New York, N. Y.
44655	Ohmite Mfg. Co. Skokie, Ill.	85599	Tube Department G. E. Co. Schenectady, N. Y.
56289	Sprague Electric Co. North Adams, Mass.	86684	Radio Corp. of America Electronic Components and Devices Harrison, N. J.
63060	Victoreen Instrument Co. Cleveland, Ohio	91637	Dale Electronics, Inc. Columbus, Nebr.
63743	Ward Leonard Electric Co. Mount Vernon, N. Y.	95333	Central Transformer Co., Inc. Chicago, Ill.
71450	CTS Corp. Elkhart, Ind.		



REV.	REVISIONS	DATE
A	ELECT RUN	
B	PRODUCTION	
C	ECO 2103	
D	ECO 2427	
E	ECO 3001	



ALL VOLTAGES MEASURED AT THE FOLLOWING CONDITIONS:

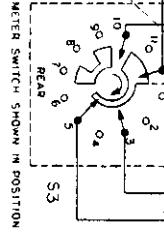
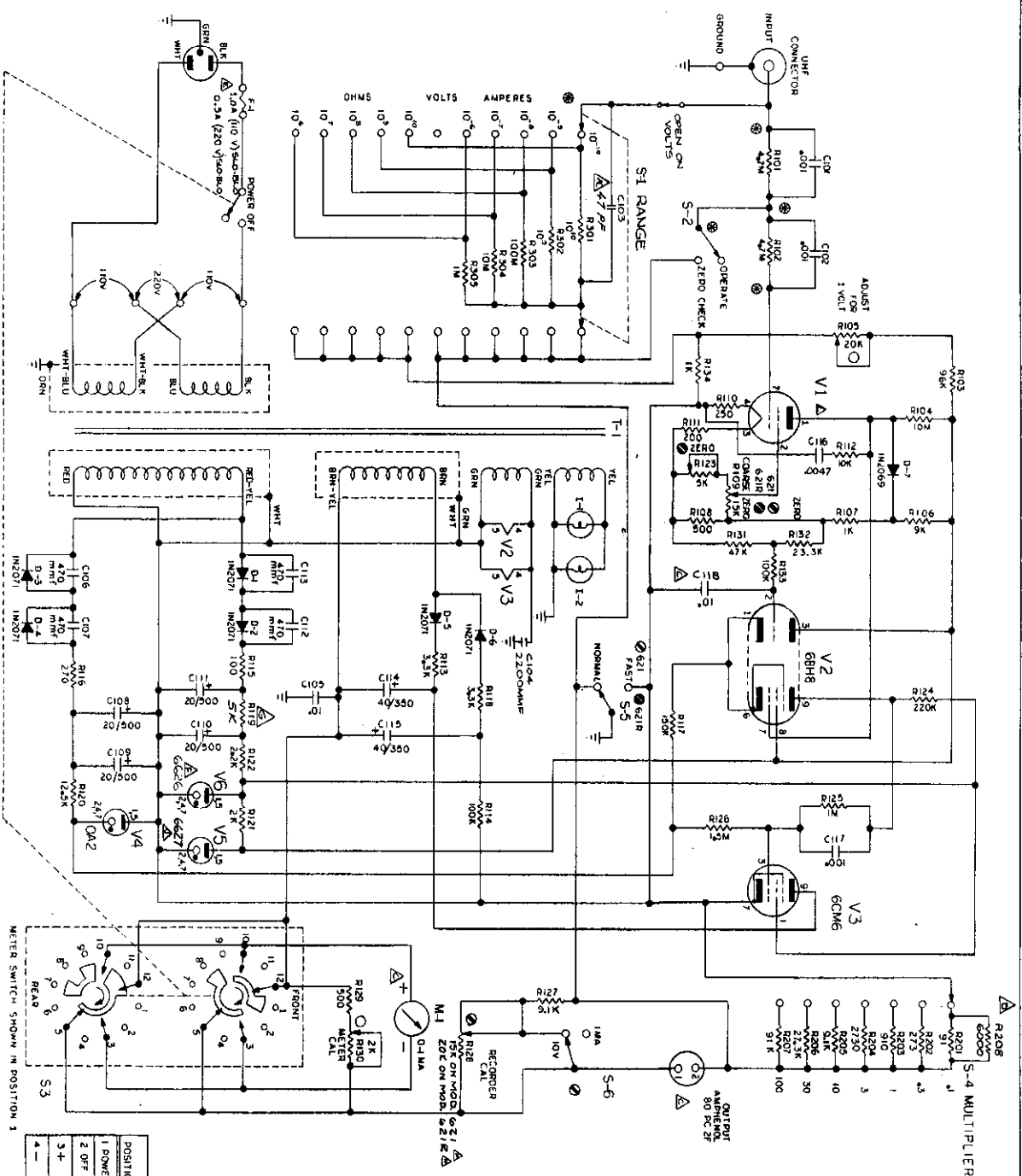
RANGE SWITCH IN VOLTS POSITION, ZERO CHECK SWITCH IN ZERO CHECK POSITION, MULTIPLIER SWITCH IN 0.1 POSITION, METER SWITCH IN + POSITION, FAST-NORMAL SWITCH IN NORMAL POSITION, INSTRUMENT ZEROED BEFORE MEASUREMENTS ARE TAKEN, ALL VOLTAGES TAKEN WITH 11 MEGOHM VTVM. VTVM GND AT FRONT PANEL GND TERMINAL. RESISTANCE MEASUREMENTS TAKEN WITH METER SWITCH IN OFF POSITION, ALL OTHER SWITCHES SAME AS ABOVE.

PROPERTY OF KEITHLEY INSTRUMENTS, INC.  
 KEITHLEY INSTRUMENTS, INC.  
 2215 K ST. N.E.  
 CLEVELAND, OHIO 44115  
 MADE IN U.S.A.

621 R	14035	MANUAL
621	14016	MANUAL
MODEL	B7M	NEXT ASSEM
USED ON		

DIMENSIONS			
MIN.	MAX.	TOLERANCE	UNIT
1.000	1.000	±0.005	INCH
2.540	2.540	±0.127	MILLIMETER
TITLE: VOLTAGE-RESISTANCE DIAGRAM			
DESIGNER: BARBA	CHECKER: BARBA	DATE: 11-7-60	QUANTITY: 14024-C
APPROVED: [Signature]			ENGINEER: [Signature]

14024-C



POSITION	TERMINALS CONNECTED
1 POWER OFF	1-5-8-12
2 OFF	5-9-12
3-4	3-12 5-10
4	3-5 10-12

REVISIONS		DATE
1	ECO 1521	NR
2	ECO 1521	NR
3	ECO 1521	NR
4	ECO 1521	NR
5	ECO 1521	NR
6	ECO 1521	NR
7	ECO 1521	NR
8	ECO 1521	NR
9	ECO 1521	NR
10	ECO 1521	NR
11	ECO 1521	NR
12	ECO 1521	NR

TITLE: SCHEMATIC  
 DRAWING NUMBER: 185159  
 KEITHLEY INSTRUMENTS, INC.  
 CLEVELAND, OHIO

**REPAIR AND CALIBRATION FORM**

For repair or calibration, please fill out this form and return it with your instrument to:  
 Sales Service Department  
 Keithley Instruments, Inc.  
 28775 Aurora Road  
 Cleveland, Ohio 44139

R- Do not write in this space.
-----------------------------------

User's Name \_\_\_\_\_ Telephone \_\_\_\_\_ Ext. \_\_\_\_\_  
 Company \_\_\_\_\_ Address \_\_\_\_\_  
 Division \_\_\_\_\_ City \_\_\_\_\_ State \_\_\_\_\_ Zip \_\_\_\_\_  
 Date \_\_\_\_\_ Model No. \_\_\_\_\_ Serial No. \_\_\_\_\_

- |  |  |
|--|--|
| 1. <u>Reason for Return</u><br><input type="checkbox"/> Repair and Recalibration<br><input type="checkbox"/> Recalibration only (No report, except as specified in item 4 on reverse)*<br>*If repairs are necessary to meet specifications, they will be in addition to the calibration. | 2. <u>Calibration Report Desired</u><br><input type="checkbox"/> Report of Calibration Certified Traceable to N.B.S.<br><input type="checkbox"/> Calibration Report<br><input type="checkbox"/> Certificate of Compliance<br><input type="checkbox"/> None<br>(for details, see reverse side of this form) |
|--|--|

3. To help repair the instrument, briefly describe the problem: \_\_\_\_\_  
 \_\_\_\_\_

4. Is the problem  Constant  Intermittant  
 Under what conditions does the problem occur:
- |  |   |
|--|---|
| a) Control setting _____<br>_____<br>b) Approx. Temperature _____ °F<br>c) Approx. Temperature variation ± _____ °F<br>d) Approx. Humidity (high, medium, low) _____ | e) Line voltage _____<br>f) Other (such as line transients, line variations, etc.) _____<br>_____ |
|--|---|

5. Please draw a block diagram of the system using the Keithley. List any other pertinent data which can help in the repair. Include charts or other data if available.
- Signal Source \_\_\_\_\_  
 Source Impedance \_\_\_\_\_  
 Readout Device:  
 Recorder  
 Oscilloscope  
 Other  
 None  
 Lengths & Types of Connecting Cables \_\_\_\_\_

6. What repairs or modifications have been made on this instrument which are not on file with the Keithley Repair Department? \_\_\_\_\_  
 \_\_\_\_\_

7. Please enclose any other pertinent data and charts which you feel might help the Repair and Calibration Department

\_\_\_\_\_  
 Signature \_\_\_\_\_  
 Title

## CALIBRATIONS AVAILABLE AT KEITHLEY INSTRUMENTS.

Listed and defined below are the four types of calibrations and their associated report formats which are presently available at Keithley Instruments. They fall into the following categories:

1. Report of Calibration Certified Traceable to the National Bureau of Standards
2. Calibration Report
3. Certificate of Compliance
4. Recalibration

All calibration and certification performed by Keithley Instruments is in accord with MIL-C-45662A.

Prices shown below are in addition to repair charges for any work necessary to place a customer's unit into first class condition prior to the calibration.

### 1. Report of Calibration Certified Traceable to the National Bureau of Standards.

This is a completely documented report, including all basic errors or deviations from nominal settings on appropriate ranges, terminals, dials, etc. Work is performed using the primary standards of the company with secondary transfers kept to a minimum. The NBS test numbers for the latest recalibration of the primary standards are furnished.

By definition, the above is performed in our Standards Laboratory so that random operator induced error is minimized and maximum protection to the equipment used is maintained.

This type of calibration is not recommended for instruments with a basic inaccuracy of 1% or greater. The precision involved in this report makes it uneconomical for such instruments. The Calibration Report listed below (No. 2) would be better suited in this case.

As of 12/1/67 the Report of Calibration Certified Traceable to the National Bureau of Standards is available on the following instruments at the prices listed:

Model 140 . . . . .	\$.325	Model 5155 (Complete Set) . .	\$265
Model 260 . . . . .	\$.220	Model 5155-10 <sup>8</sup> . . . . .	\$ 45
Model 261 . . . . .	\$.280	Model 5155-10 <sup>9</sup> . . . . .	\$ 45
Model 515 . . . . .	\$.520	Model 5155-10 <sup>10</sup> . . . . .	\$ 45
Model 630 . . . . .	\$.250	Model 5155-10 <sup>11</sup> . . . . .	\$ 55
Model 660A . . . . .	\$.200	Model 5155-10 <sup>12</sup> . . . . .	\$ 55
Model 662 . . . . .	\$.250	Model 5155-10 <sup>13</sup> . . . . .	\$ 75

### 2. Calibration Report.

This report shows only the cardinal range, terminal, dial, etc. errors as determined by production calibration equipment and personnel. The production equipment is maintained traceable by transfer techniques against the primary standards maintained by the company. We attest to this fact and list basic deviations from nominal but the conditions of calibration are not as precisely controlled as the previous report nor are NBS test numbers supplied.

This report is available for any instrument in our line. As of December 1, 1967, only the following price has been established for this report:

Model 261 . . . . . \$50

Prices for other units can be estimated upon request.

### 3. Certificate of Compliance.

This is merely a restatement of the basic guarantee that the instrument was calibrated on equipment that is maintained by our standards personnel against primary standards. No report is issued.

This Certificate of Compliance is available at no charge for any instrument with the exception of the Model 261.

A newly purchased Model 261 or one returned for repair or recalibration is automatically supplied with a Calibration Report (as described in (2) above). The nature of this instrument makes it necessary to complete this report to ascertain specified accuracy. This Calibration Report is forwarded to the customer with the instrument. The \$50 charge is incorporated as part of the normal calibration charge of the Model 261.

### 4. Recalibration.

This is a recalibration of the instrument according to our factory calibration procedures. The prices for this as of December 1, 1967 are as follows:

Model 260 . . . . .	\$75	(No report supplied. A Certificate of Compliance can be had at no charge if requested).
Model 261 . . . . .	\$50	(Calibration Report as described in (2) above is supplied. See (3) for explanation).

All other instruments are on a time and material basis for the particular unit involved.