OPERATING INSTRUCTIONS
FOR
TYPE 715-A
DIRECT-CURRENT
AMPLIFIER

Form 517-B

GENERAL RADIO COMPANY
CAMBRIDGE A, MASSACHUSETTS

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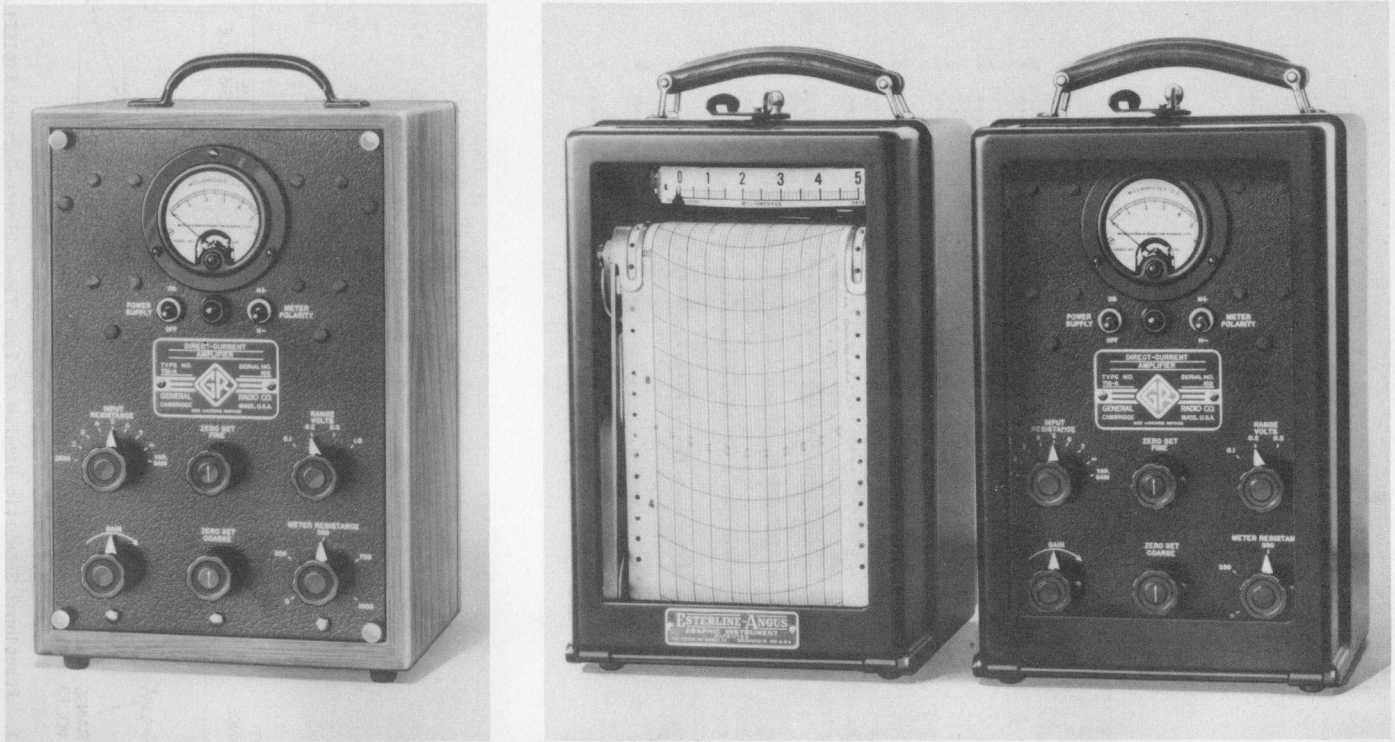

FRONTISPIECE. Type 715-AM Direct-Current Amplifier, shown at the left, is mounted in a walnut cabinet. Type 715-AE is mounted in a case to match the Esterline-Angus 5-milliampere recorder, shown at the right.

OPERATING INSTRUCTIONS
FOR
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PART 1
PURPOSE

The Type 715-A Direct-Current Amplifier is designed to be used as a calibrated d-c millivolt meter or microammeter in the measurement of small d-c voltages and currents. It is also designed for use with a 5-milliampere d-c recorder for the recording of variations of any electrical quantity which may be translated into variations in small d-c currents. The amplifier is completely a-c operated from 115/230-volt, 60-cycle supply. No batteries of any kind are used.

PART 2
ADVANTAGES

1. High sensitivity - 100 millivolts input gives full scale output current of 5 milliamperes on the most sensitive adjustment. (Transconductance equal to 50,000 micromhos.)

2. Stable operation - Freedom from drift caused by supply line voltages.

3. Adjustable input resistance - Input resistances in powers of 10 between 10^2 and 10^7 ohms may be selected by a panel control. Short-circuit, open-circuit and variable gain positions are also provided.

4. Small size and light weight - Make the instrument a convenient adjunct to the graphic recorder in portable applications.

5. Linear response over a range substantially greater than the range of the meter or recorder, for either polarity of input voltage.

PART 3
PRINCIPLES OF OPERATION

The instrument consists, essentially, of a three-stage direct-coupled amplifier. (See functional schematic diagram, Figure 1, and complete circuit diagram, Figure 3.) Degeneration is employed to adjust the gain to the desired values and to stabilize the amplifier against changes in tube characteristics. A bridge-type balancing circuit, employing a voltage regulator tube is used to remove the steady plate current of the output tube from the meter, or recorder, circuit. The meter consequently indicates only the change in output current.

In direct-coupled amplifiers of this type, any change in heater voltage of the first tube acts exactly as a small change in grid bias of this tube. Consequently, in order to stabilize the zero adjustment of the whole amplifier, it is necessary to

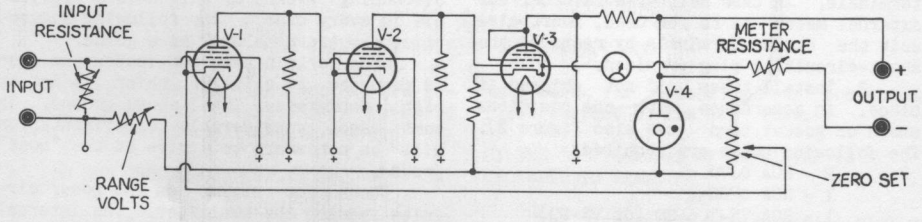

FIGURE 1. Functional Schematic Diagram of Type 715-A Direct-Current Amplifier.

stabilize carefully the heater voltage of the first tube. In the Type 715-A Direct-Current Amplifier this is done through the use of a regulating transformer and a filament ballast lamp.

The instrument is actually calibrated as a voltmeter, having four ranges of 0.1, 0.2, 0.5 and 1.0 volt. On each range, maximum voltage gives 5.0 milliamperes in the output circuit. Through the use of known input resistors, selected by a switch, the voltage drop across the chosen resistor is measured and the current is then known.

In measuring very small currents, in a high resistance input circuit, the grid current of the first tube becomes important. This has been kept as low as possible, through choice of type of tube and operating voltages, consistent with all other requirements. The grid current should not exceed 0.003 microampere with no voltage impressed on the grid circuit.

Current Through Input Resistance
for Full Scale on Meter

	Setting of Input Resistance Switch	2	3	4	5	6	7	Var. Gain (Maximum Position)
	Input Resistance in Ohms	100	1000	10,000	100,000	1 MΩ	10 MΩ	150,000
Range (volts)								
0.1		1.0 ma	0.1 ma	10 μa	1 μa	0.1 μa	.01 μa	2 μa
0.2		2.0	0.2	20	2	0.2	.02	4
0.5		5.0	0.5	50	5	0.5	.05	10
1.0		10.0	1.0	100	10	1.0	0.1	20

PART 4
INSTALLATION

1. Connect the amplifier to the 115-230-volt, 60-cycle mains by means of the attachment cord provided. See wiring diagram for instructions for changing connections from 115-volt to 230-volt supply.

2. Connect d-c voltage to be measured, or recorded, to input terminals. Terminal H should be negative, if possible, but can be the positive terminal if necessary. (See detailed instructions below.) Connect recorder, or external meter to output terminals. In case neither a recorder nor external meter is to be used, short-circuit the output terminals by means of the short-circuiting plug provided.

3. Install tubes, if not shipped in place, in accordance with the positions shown on socket tags (see also Figure 2). The following tubes are required:

2 - RCA 6J7G
1 - RCA 6F6G
1 - RCA VR-105-30 (or VR-90)
1 - Sylvania 4A1
1 - RCA 6X5G

4. Precautions: In setting up the amplifier for use on high input resistances, care must be taken to avoid a-c pickup from power circuits in the vicinity of the wires leading to the input terminals. The internal input wiring of the amplifier is shielded.

In industrial applications, particularly, interference from power or radio frequency circuits may be encountered. It is not possible to outline methods for overcoming pickup of this nature applicable in every case. The following suggestions may prove helpful as a guide.

Make certain that the instrument case is grounded to a point which is not at high interference level above ground. In some cases considerable experimentation will be necessary to arrive at the "best" ground.

Check for pickup on the power circuits feeding the amplifier. The internal by-pass condensers may not be sufficient in a given case; additional filtering in

the form of additional by-passes to ground, with or without chokes, may be required.

In many applications good quality condensers may be shunted across the element across which a d-c voltage is being measured. Such condensers may be placed at the amplifier input terminals, or at the element being measured, or both.

Shielded connecting leads, with shields grounded, either at the element being measured or at the grounded input terminal of the amplifier, are generally helpful.

PART 5
OPERATION

It simplifies the viewpoint to think of the amplifier as a calibrated d-c voltmeter, having a very high resistance. In use, for various purposes, known resistances may be inserted in the d-c circuit to be measured; the instrument then indicates the voltage drop across the known resistances. Since the resistances are known, the instrument can then be read as a milli- or micro-ammeter.

1. To start up, throw POWER SUPPLY switch to ON. The pilot lamp should light. The meter may indicate off-scale for a moment and then return on scale. (If it does not, see instructions for zero adjustment below.) It is best to let the instrument warm up 10 or 15 minutes before attempting the most accurate adjustments or readings.

2. Throw INPUT-POLARITY switch to H-. This signifies that the input terminal H is to be connected to the negative terminal of the d-c voltage to be measured, in turn applying a negative voltage to the first grid of the amplifier. This is the normal method of connection. Under these conditions, the maximum possible current, through the meter or recorder is about 11 milliamperes, regardless of the magnitude of the voltage impressed on the input terminals.

3. Select the desired input resistance by means of the switch provided. The switch positions indicate the resistance values in powers of 10, so that 100, 1000, 10,000 etc. ohms are available to a maximum of 10 megohms. The ZERO position places a direct-connection across the input terminals; the ∞ position signifies a direct connection to the first grid, with no shunting resistance. The VARIABLE GAIN position connects the amplifier to the output of the variable voltage divider controlled by the knob marked VARIABLE GAIN.

4. Select the desired voltage RANGE, by the switch. If the magnitude of the voltage applied to the amplifier is not even approximately known, select the 1.0-volt range, then successively adjust through more sensitive ranges until appropriate deflections are obtained.

5. The METER RESISTANCE control should be set to the value of the resistancy of any external device connected to the amplifier output, in order to maintain the accuracy of calibration. The amplifier is intended to operate into a constant load of 1000 ohms. If accuracy of calibration is not important, the amplifier functions perfectly well into output loads of any value between zero and 2000 ohms. Set the METER RESISTANCE control as follows:

External Load	Setting
For no external device.	Zero
For Esterline-Angus 5-milliampere graphic instrument.	550
For any load, zero to 1000 ohms.	Value of load
For maximum current in any load, zero to 2000 ohms; relative readings only.	1000

PART 6
SPECIAL INSTRUCTIONS AND PRECAUTIONS

Certain special instructions are included here and precautionary measures covering special applications.

A. DO NOT GROUND OUTPUT CIRCUIT

Both terminals of the output circuit are above ground by approximately 90 volts d-c, brought about by the bridge arrangement used for balancing out the steady plate current of the last tube.

B. THE "G" TERMINAL OF AMPLIFIER IS GROUNDED TO FRAME

The "ground" or low-potential side of the input circuit is grounded to the frame (and case, if the Esterline-Angus case is

used) of the amplifier. The grid of the first tube may be swung either above or below ground potential, in ordinary use. In cases where one terminal of the source being measured is at ground potential, the "G" terminal of the input of the amplifier should be connected to that terminal. Whichever polarity of applied voltage results, up-scale meter response is obtainable by throwing the INPUT POLARITY switch to the correct polarity.

C. USE ON D-C OUTPUT OF A RECTIFIER

In many applications the d-c voltage to be applied to the amplifier may be obtained from a rectifier, or may be of a pulsating form. For accurate results, such outputs must be reasonably well filtered. Filtering is included in the amplifier for the VARIABLE GAIN position ONLY. If the calibrated ranges are to be used, external filtering must be provided.

The peaks of a rectified wave may overload the amplifier, even though the average value of the voltage wave would give only a relatively small deflection.

In cases where no difficulty in circuit arrangements due to grounding can occur, a test for overloading can be obtained by reversing the input (and simultaneously reversing the INPUT POLARITY switch). If the resulting readings are not the same, overloading is occurring because of insufficient filtering.

D. ACCURATE ADJUSTMENT TO ZERO

In some work it is desirable to adjust the zero very carefully. In such cases it is sometimes convenient to adjust by throwing the INPUT POLARITY switch alternately to H+ and H-. This doubles the motion of the pointer, if the instrument is not on zero. Adjust zero controls for least motion.

E. USE OF EXTERNAL SENSITIVE METER

Under some circumstances, a more sensitive indicating instrument may be employed. When connected in the output, a short-circuiting switch should be provided so that the sensitive instrument may be cut in circuit only when the indications of the panel meter show that it is safe to do so.

A one-milliampere meter can be used advantageously in increasing the sensitivity without too great magnification of instabilities. It must be appreciated that unless the plate voltage balance adjustment, for example, is very carefully set, changes in output current which would be entirely negligible on the 5-milliampere meter, would be readily observable on the 1-milliampere instrument.

For observations of a minimum or a null type, such as detecting balance in a d-c bridge, the fluctuations observed on a more sensitive meter may not be troublesome.

F. OFFSETTING ZERO

The zero of the amplifier may be set when no voltage is applied to the input, in which case it is a "true" zero. In some cases, it is advantageous to offset the zero of the amplifier to cancel out a steady component of voltage applied to the input. The amplifier then indicates changes in input voltage above or below the steady value, corresponding to the offset or "false" zero.

Some care must be used in applying this zero shift, dependent on circumstances. If the zero is not offset by too large an amount, the amplifier will operate normally in all respects. If it is attempted to offset the zero by an amount which is comparable with the full range of the amplifier, then proper response can be obtained only for input voltage changes in one direction.

If this condition is reached, and circuit conditions permit, a battery may be connected, with suitable polarity in series with the input, thereby cancelling most of the steady voltage component. The remainder of the steady voltage component may then be cancelled out by the zero adjustment of the amplifier, with normal performance for changes in input voltage of either direction.

PART 7
DIRECTIONS FOR REALIGNMENT

The adjustments for voltage calibration of each range and for balancing out the effects of plate voltage changes are made at the factory. If it becomes necessary to make any changes in these adjustments, proceed as follows:

1. Refer to wiring diagram. For illustration, the adjustments for one range will be detailed. Adjustments for other ranges are made in a similar manner. Adjustments for one range are entirely independent of adjustments for any other range.

2. Withdraw the instrument from the case by removing the four screws in the corners of the panel and pulling the unit

straight forward. Connect power plug and get instrument warmed up. Provide a means for varying the supply voltage, such as a Variac, or a series resistor which may be cut in and out of circuit. Short-circuit the recorder (or external meter) terminals of the amplifier. Set the METER RESISTANCE control at zero. Set INPUT RESISTANCE at a value high enough not to load the d-c source. Usually Point 5, 100,000 ohms, is satisfactory.

3. Test first for lack of alignment on plate voltage balance by applying quick changes in line voltage, returning to normal each time. If the meter needle varies with the change in line voltage, readjust the plate voltage balance control for the range in use. The plate voltage balance controls for the different ranges are located as follows:

Range	Plate Balance Resistor	Location on Upper Shelf Just Behind Panel
0.1	R-16	Left
0.2	R-15	Left Center
0.5	R-14	Right Center
1.0	R-13	Right

(See also Figure 2)

While applying the rapid changes in supply voltage, watch the mater and carefully adjust the appropriate resistor to make the changes in meter reading as small as possible. A small readjustment is all that should be required.

4. Having adjusted the plate voltage balance, proceed to check the calibration. This is done by applying known d-c voltages to the input terminals, preferably through a reversing switch. Adjust the voltage applied to the full-scale value of the range to be checked. With input voltage off, check the zero adjustment of the amplifier. Then apply the input voltage. If the reading is not quite full scale, there is too much degeneration and the appropriate resistor should be reduced slightly. If the meter reading is slightly off-scale, there is too little degeneration and the appropriate resistor should be increased slightly.

5. On reversing the input voltage, and throwing the INPUT POLARITY switch, the meter readings should agree with those obtained before. Care should be taken to make certain that zero is correct in both cases, since any zero error in the first case is multiplied by two in the second case.

The positions of the degeneration control resistors are as follows:

Range	Degeneration Control Resistor	Location on Panel around Meter
0.1	R-9	Lower left
0.2	R-10	Upper left
0.5	R-11	Upper right
1.0	R-12	Lower right

6. Finally check the plate voltage balance again. Ordinary readjustments of the degeneration control resistances will not upset the plate voltage balance. If an unusual change is made, a second adjustment of plate voltage balance may be necessary.

PART 8
SUGGESTED APPLICATIONS

The following suggestions are given as illustrative of the many ways in which the amplifier may be applied in different problems.

1. Frequency Recorder. When used with the General Radio Type 834-A Electronic Frequency Meter, direct recording of frequency is possible. Connect recorder terminals of frequency meter to amplifier input; use VARIABLE GAIN control, for internal filtering. Adjust gain and choose voltage range to cover desired frequency range. Offset amplifier zero may be employed to expand the recorder range to cover a portion of the range of the frequency meter. This arrangement is adaptable to frequency and speed control systems.

2. Audio-Frequency Signal Recorder. Audio-frequency signals from a receiver, line, sound-level meter, or other source, may be rectified by a small oxide rectifier. Type 492-A Oxide Rectifier is satisfactory. Use the VARIABLE GAIN control, for internal filtering; adjust gain, and choose voltage range to cover desired signal range. The output of the amplifier may be used to operate signal recorders, relays, counters or other devices.

3. Photronic Cell Recordings. The output of the photronic cell may be connected directly to the amplifier input; either the VARIABLE GAIN control, or fixed resistance input circuits may be used. In the latter case the load on the cell may be adjusted to the desired value. There are evidently many applications for this combination, since the illumination of the photronic cell may be arranged to vary in accordance with a large number of factors.

4. Photo-Electric Recording. Usually the photo-electric tube circuit may be arranged to make use of the amplifier input resistance as a coupling resistance directly, without the use of an external amplifier. Where this is not feasible, the amplifier may be associated with the output of a single-stage amplifier following the photo-electric tube.

5. Recording D-C Voltages or Currents. Since the amplifier and recorder constitute a recording voltmeter, and, through the use of known input resistances, a recording milliammeter or microammeter, records of d-c voltages or currents may be obtained directly. In some cases, where relative values only are of interest, the VARIABLE GAIN position is convenient; also, when used with an offset zero, the recorder may be made to give an expanded record of changes in input voltage.

PARTS LIST

Resistors

R-1 = 100 Ω ± 0.1%
R-2 = 1000 Ω ± 0.1%
R-3 = 10 kΩ ± 0.1%
R-4 = 100 kΩ ± 0.1%
R-5 = 1 MΩ ± 1%
(2 - 0.5 MΩ in series)
R-6 = 10 MΩ ± 2%
(2 - 5 MΩ in series)
R-7 = 100 kΩ
R-8 = 50 kΩ
R-9 = 25 Ω
R-10 = 75 Ω
R-11 = 200 Ω
R-12 = 300 Ω
R-13 = 5000 Ω
R-14 = 2500 Ω
R-15 = 750 Ω
R-16 = 200 Ω
R-17 = 1 MΩ
R-18 = 1 MΩ
R-19 = 7500 Ω ± 1%
R-20 = 1 kΩ
R-21 = 5 kΩ
R-22 = 25 kΩ ± 1%
R-23 = 500 Ω
R-24 = 25 Ω
R-25 = 10 kΩ ± 1%
R-26 = 5 kΩ
R-27 = 50 kΩ
R-28 = 11.5 kΩ ± 1%
R-29 = 100 kΩ ± 1%
R-30 = 100 kΩ ± 1%
R-31 = 200 Ω

Condensers

C-1 = 1 μf
C-2 = 0.025 μf
C-3 = 0.01 μf
C-4 = 0.01 μf

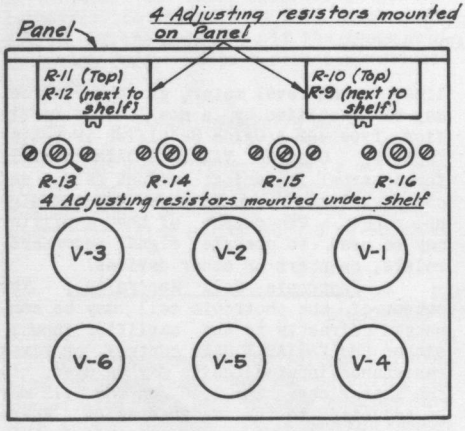

FIGURE 2. Location of Tubes and Adjusting Resistors

Tubes

V-1 = RCA Type 6J7G
V-2 = RCA Type 6J7G
V-3 = RCA Type 6F6G
V-4 = RCA Type VR-105-30 (or VR-90-Sylvania)
V-5 = Sylvania Type 4A1
V-6 = RCA Type 6X5G

Fuses

F-1 = 1 amp.
F-2 = 0.1 amp.

Transformers

T-1 = 485-407
T-2 = 345-412 "Saturated core regulating type"

Switches

S-1 = 2-Circuit, 9 points per circuit 139-994
S-2 = 3-Circuit, 4 points per circuit 139-995
S-3 = DPST 139-333
S-4 = DPDT 139-335

Pilot Light

P-1 = 6-volt pilot 139-939

Meter

M-1 = 0-5.0 ma Weston 301

PACKING LIST

1 - 110-Volt Cord
2 - Type 274-M Plugs
5 - 0.1-amp. Bussmann Fuses
5 - 1-amp. Bussmann Fuses
2 - Pilot Lamps (6-volt)
2 - RCA 6J7G Tubes
1 - RCA 6F6G Tube
1 - RCA VR-105-30 (or VR-90) Tube
1 - Sylvania 4A1 Tube
1 - RCA 6X5G Tube

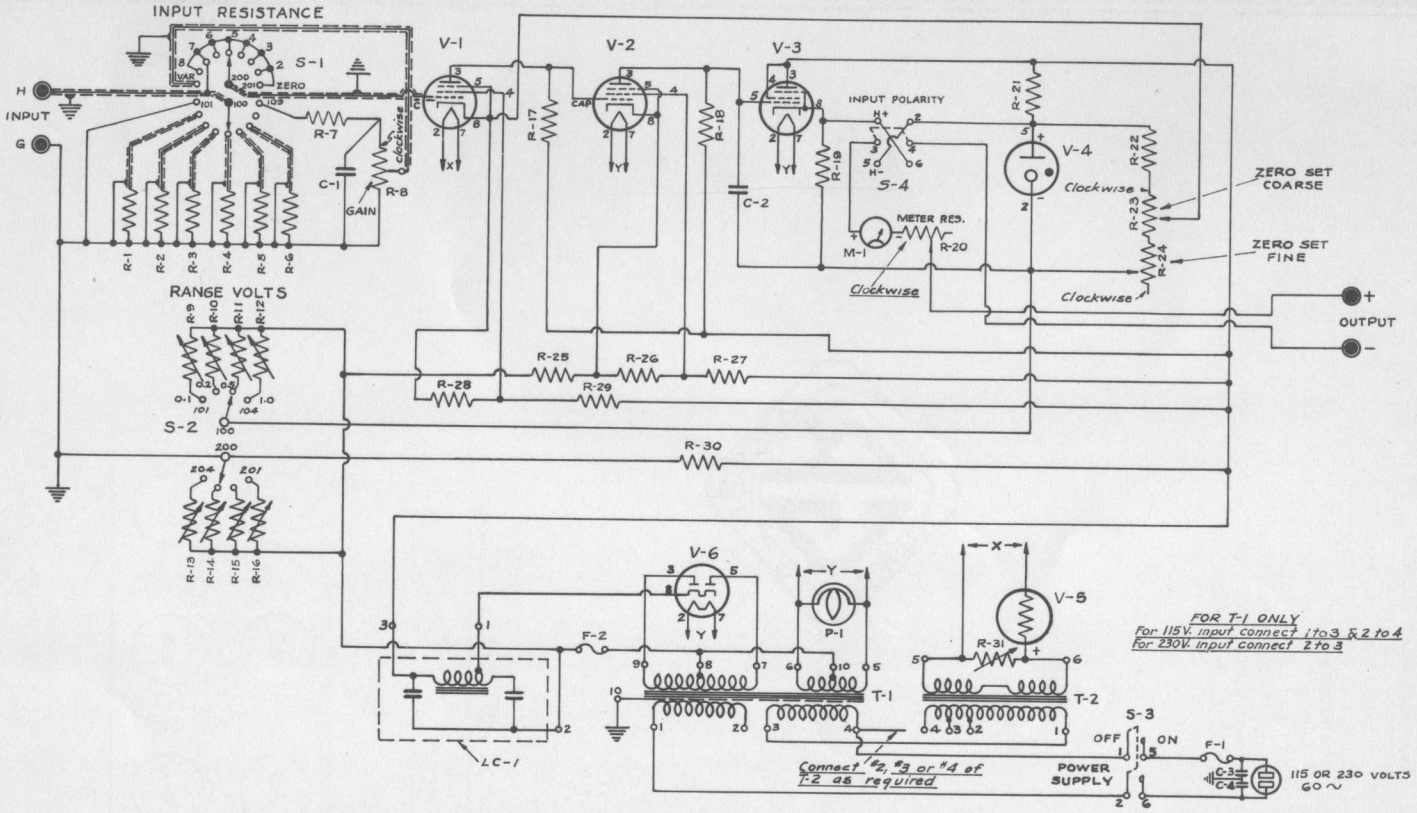

FIGURE 3. Wiring Diagram for Type 715-A Direct-Current Amplifier

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