Instruction Manual

JOHN FLUKE MFG. CO., INC.

ELECTRONICS FOR INDUSTRY

FLUKE

MODEL 801
DIFFERENTIAL VOLTMETER

INSTRUMENTS / COMPONENTS

John Fluke Mfg. Co., Inc.
P. O. Box 7428, Seattle 33, Washington

MODEL 801
DIFFERENTIAL VOLTMETER

Serial No. 66HD and above.

ADDENDUM

This instrument may utilize Amperex 7316 vacuum tube in place of 12AU7 for V104 only. Both tubes are directly interchangeable without circuit modification. Do not use the 7316 for V4.

MODEL 801 DIFFERENTIAL DC VOLTMETER

MODEL 801 PRECISION POTENTIOMETRIC DC VOLTMETER

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MODEL 801 PRECISION POTENTIOMETER DC VOLTMETER

CONVENTIONAL VTVM SPECIFICATIONS

RANGES	INPUT R	SCALES	*RANGES	INPUT R	SCALES
0 to ±500 V	10 megohms	500-0-500	0 to ±10V	10 megohms	10-0-10
0 to ± 50V	10 megohms	50-0-50	0 to ± 1V	10 megohms	1-0-1
0 to ± 5V	10 megohms	5-0-5	0 to ± 0.1V	1 megohm	0.1-0-0.1
0 to ± 0.5V	10 megohms	0.5-0-0.5	0 to ± 0.01V	1 megohm	0.01-0-0.01

Accuracy: 4% on all ranges. *These ranges obtained by setting NULL knob to desired sensitivity with 5 voltage knobs set to 0.

PRECISION POTENTIOMETER SPECIFICATIONS

INPUT	*RECOMMENDED 801 RANGES RANGE SETTING	NULL SETTING		INPUT RESISTANCE (RES. PER VOLT OF INPUT) AT NULL	AT 1% OFF NULL	
50-500	0-500	10-0-10	1-0-1	Inf.	100 meg	1000 meg
5-50	0-50	1-0-1	0.1-0-0.1	"	1000 meg	1000 meg
0.5-5	0-5	0.1-0-0.1	0.01-0-0.01	"	1000 meg	10,000 meg
0-0.5	0-0.5	0.1-0-0.1	0.01-0-0.01	"	1000 meg	10,000 meg

*Any null range may be used at any input voltage; recommended ranges are those most useful.

ACCURACY: ±0.05% of input voltage from 0.1V to 500 V.
±0.1% of input voltage or ±0.05 MV, whichever is greater, below 0.1 V.
These accuracies obtained when recommended ranges are used.

RESOLUTION:

RANGE	DIRECT VIA DIALS		MAX. METER RESOLUTION ON MOST SENSITIVE RECOMMENDED NULL RANGE	
500	0.01V	(10MV)	0.005V	(5MV)
50	0.001V	(1 MV)	0.0005V	(500 UV)
5	0.0001V	(100 UV)	0.00005V	(50 UV)
0.5	0.00001V	(10 UV)	0.00005V	(50 UV)

STABILITY OF REFERENCE SUPPLY:
0.01% for change in line voltage (105V to 130V)
0.01% per hour after warmup (adjustable via front panel CAL control)

STABILITY OF METER ZERO:
4% of full scale for 20% change in line voltage
2% per hour after warmup (adjustable via front panel MTR. ZERO control)

CALIBRATION: 500 volt reference supply calibrated against built-in standard cell

INPUT POWER: 100-130 volts, 60 cycles, 60 watts

DIMENSIONS: 9-3/4" wide x 13" high x 14" deep - standard model
19" wide x 8-3/4" high x 16-3/4" deep - rack mounting model

FINISH AND WEIGHT: Smooth grey baked enamel. Grey baked wrinkle case.
Cabinet model - 25 lbs.; rack mounting model - 28 lbs.

PRICE: $485 standard model; $505 rack mounting model; both f.o.b. factory, Seattle, Wash.

MODEL 801
PRECISION POTENTIOMETRIC DC VOLTMETER

INSPECTION

This instrument has been thoroughly checked and tested before being shipped from the factory. Upon receipt of the instrument, inspect carefully for damage which may have been incurred in transit. Reference should be made to the WARRANTY section of this instruction manual for the procedure to be followed if any shipping damage has occurred.

INITIAL OPERATION

Connect the instrument to 117 volt, 60 cycle source. Set VOLTS RANGE switch to "500" position, NULL switch to VTVM position, and all 5 voltage dials to zero. Throw toggle switch on right side of instrument to "ON". One decimal light should light and a buzzing noise should be heard to start; this comes from a 60 cycle chopper which is used to achieve stable DC amplification in the 0.1 and 0.01 volt null ranges. Allow instrument to warm up for approximately five minutes.

Adjust meter zero knobs. To do this, leave VOLTS RANGE switch in "500" position and NULL switch in VTVM position. Set meter needle on zero by adjusting "VTVM, 10V, 1V" knob. Turn NULL switch to 10V and then 1V positions. Meter should remain on zero. Then turn NULL switch to 0.1V position and set meter on zero by adjusting "0.1V, 0.01V" knob. Turn NULL switch to 0.01V position. Meter should remain on zero.

To calibrate the internal 500 Volt reference source: (1) turn the VOLTS RANGE switch to the CAL position; (2) press the CAL PUSH button; and (3) adjust the ADJ CAL knob until meter reads zero. Maximum accuracy is obtained with the Model 801 when this operation is carefully performed, resulting in the reference supply set to 500 Volts within 0.01%. The instrument is now ready for use.

TO MEASURE DC VOLTAGES

Determine approximate value of unknown voltage. With VOLTS RANGE switch set to 500 position and NULL switch set to VTVM position, connect voltage to be measured to plus and minus binding posts. If meter reads to the left, reverse connections. If reading is less than 50 volts, set VOLTS RANGE switch to 50; in other words, set VOLTS RANGE switch to the lowest range which will give an on-scale reading. With the NULL switch in the VTVM position, the 801 functions as a conventional 4 range VTVM with 10 megohms input resistance on all ranges. It is accurate to better than 4% and serves to locate approximately the unknown voltage in the 0 to 500 volt spectrum.

Determine precise value of unknown voltage. Set the five voltage dials to the approximate voltage indicated on the meter. Be sure to observe the decimal lights. For example, if the VOLTS RANGE switch is set to the 5 volt position the decimal light between the A and B knobs will be lit. If the meter indicates that the unknown voltage is 3.5 volts, set the A knob to 3 and the B knob to 5, leaving the C, D, and E knobs set on zero. Now turn the NULL knob to the 1 volt position (the 10 Volt position may be skipped when

measuring voltages of less than 50 Volts) and adjust last 4 knobs for zero meter deflection. Next turn NULL knob to the 0.1 Volt position and trim last 3 knobs for zero meter deflection. The unknown voltage may now be read directly from the 5 dials, accurate to 0.05% of the actual voltage.

TO OBSERVE EXCURSIONS OF A VOLTAGE ABOUT A NOMINAL VALUE

Set up the nominal voltage on the five voltage dials as outlined above and observe the excursions directly on the meter on one of the four null ranges. Use recommended null ranges where possible (see specification sheet). A right-hand deflection of the meter needle indicates that the voltage under observation has increased above the nominal value by the amount indicated by the meter reading; a left-hand deflection indicates that the voltage has decreased by the amount indicated.

RECORDER OUTPUT PROVISIONS

The Model 801 includes provisions for recorder monitoring or for recording the excursions of the unknown voltage from the voltage indicated by the dial settings.

WARNING

NOTE ONE: The leakage resistance between the recorder used and ground must be greater than 500,000 megohms or the accuracy of the 801 will be impaired. Therefore, the John Fluke Manufacturing Company recommends that the John Fluke A-70 Potentiometric Recorder (manufactured by the Texas Instrument Company) be used with the Model 801. In all cases, teflon leads should be used to connect the Model 801 to the recorder.

NOTE TWO: Do not ground either of the recorder output terminals to the chassis of the Model 801, if a grounding link is being used on the front panel of the instrument. The 1/200 Ampere fuse which is in series with the Model 801 Kelvin-Varley divider will be blown if such a short circuit occurs. This fuse is located at the rear of the front panel and on the lower left side. The instrument must be removed from its case if replacement of this fuse is required.

1. Connect Recorder. The output terminals at the rear of the Model 801 must be isolated from ground when connected to the recorder. Connect the recorder and make one or both of the following checks:

a. Check One

(1) Connect a standard cell to the input of the 801.

(2) Measure the standard cell potential.

(3) Alternately connect and disconnect the recorder leads at the rear of the 801. If there is more than one-quarter of a small division deflection of the meter needle, leakage has been introduced by the recorder and the accuracy of the 801 will be impaired.

b. Check Two

(1) Zero the VTVM circuit.

(2) Set the Range switch to 500 volts, turn all five voltage dials to zero, and place the NULL switch in the 1 volt position.

(3) Turn the voltage dials to register 400 Volts. A properly operating 801 should show less than one-quarter of a small division deflection from zero as indicated on the meter. If there is more deflection disconnect the recorder and repeat the operation to determine whether there is leakage in the VTVM circuit or whether leakage has been introduced by the recorder.

2. Operation. A signal of 15 millivolts maximum from the null detector is available at the recorder output posts at the rear of the Model 801. This signal may be varied by means of the Gain ADJ potentiometer immediately adjacent to these posts. Accordingly, the recorder deflection may be adjusted to suit the particular application involved.

For example, if it were desired that full-scale meter deflection would result in full-scale recorder deflection, the instrument could be set up as follows:

a. Zero the meter on the 801.

b. Place NULL switch in 10 volt range.

c. Turn Kelvin-Varley dials to register 0.1 Volt.

d. Short out the 801 input.

e. Adjust ADJ GAIN control for full -scale recorder deflection.

TO USE AS CONVENTIONAL VTVM ON THE FOUR NULL RANGES

In addition to the 500-0-500, 50-0-50, 5-0-5, and 0.5-0-0.5 Volt VTVM search ranges in the Model 801, four additional ranges are available. These are 10-0-10, 1-0-1 Volts at 10 megohms input resistance and 0.1-0-0.1, 0.01-0-0.01 Volts at 1 megohm input resistance. These four ranges are available by setting all five voltage dials to zero, connecting the voltage to be measured to the input binding posts and setting the NULL dial to the desired voltage range. The VOLTS RANGE knob is not used in this case and may be left in any position except CAL. Accuracy in these four additional VTVM ranges is ±4%.

TO MEASURE HIGH RESISTANCES (USE AS A MEGGER)

The Model 801 may be used to measure resistances between 1 megohm and 500,000 megohms quickly and conveniently. The unknown resistance can often be measured at any voltage between 0.01 and 500 Volts to simulate actual operating conditions Examination of the Model 801 circuitry and application of elementary circuit theory will produce the following equation for determining the value of an unknown resistance:

$$Rx - 10^7\left(\frac{E}{EM} - 1\right) \text{ where}$$

Rx is the unknown resistance.
E is the voltage setting of the 5 voltage knobs.
EM is the meter reading on the appropriate scale (either 10-0-10 or 1-0-1) as determined by the NULL switch setting.
10^7 is the input resistance of the VTVM in the 10 and 1 volt null ranges.

1. To measure a high value resistance set the VOLTS RANGE switch to 500 and NULL knob to either 10 V or 1 V position. Zero meter by means of "VTVM, 10, 1" knob.

2. Connect the unknown resistance between the plus and minus terminals. Leave link connected between minus and ground terminals. Avoid the use of long twisted leads since the Model 801 can easily measure the leakage resistance of the insulation on such leads. It is best to use very short isolated leads. Connect the negative terminals to the grounded side of the resistance under measurement (if one side happens to be grounded), or to the common-ground point if in a "floated" circuit.

3. Now adjust the five voltage controls to any desired value between 0.01 and 500 volts or to any voltage which allows convenient reading of the meter (that is, produces a reasonable, easily read meter deflection - say, 10% of full scale). The maximum resistance that can be used is approximately 500,000 megohms. With this resistance connected to the input posts, NULL switch set to 1V position and the five voltage dials set to 499.910 the meter will read 0.01 volts to the left of zero. (All resistance measurements cause a meter left deflection.)

4. Read the meter, the voltage dials, and the NULL switch setting and substitute these values in the equation given. Compute the value of the unknown resistance.

5. For rapid measurement of resistances up to 500 megohms without use of the formula, merely set NULL switch to the 10V position, adjust the 5 voltage dials for full scale meter deflection and subtract 10 from the reading of the voltage dials. This is the value of the unknown resistance in megohms.

6. For rapid measurement of resistances up to 5000 megohms without use of the formula set NULL switch to the 1 volt position and adjust the 5 voltage dials for full scale meter deflection. Subtract 1 from the reading of the voltage dials and multiply the difference by 10. This is the value of the unknown resistance in megohms.

NOTES ON MEASURING DC VOLTAGES

Reference to the Model 801 specification sheet will show the recommended VOLTS RANGE switch setting for obtaining maximum accuracy from the instrument. Since the accuracy of the Model 801 is governed chiefly by the linearity of the Kelvin-Varley five-dial attenuator, and since the highest accuracy resistors in the attenuator are used in the A and B decades (all resistors matched to ±0.005%), and the next highest accuracy in the C, D, and E decades (all resistors matched to ±0.025%), it is obviously best to use these most accurate decades at all times.

Therefore, when measuring a voltage of 3.52 volts for example, do so by setting the VOLTS RANGE switch to the 5 position and using all 5 knobs rather than setting the VOLTS RANGE switch to the 500 position and using only the last 3 knobs. Better absolute accuracy will thus be obtained as well as two additional figures in the readout.

Reference to the Model 801 specification sheet will also indicate certain recommended NULL ranges to be used with each setting of the VOLTS RANGE knob.

The 0.01 volt NULL range is not recommended for use in the 50 to 500 volt range for three reasons. First, unless the voltage being measured is an even multiple of 0.01 volts, it will be impossible to obtain a null, since the last voltage dial is calibrated in 0.01 volt steps when operating in the 500 volt position of the VOLTS RANGE switch; one step of this switch causes full scale meter deflection with NULL switch at 0.01V. Second, it is unlikely that a voltage of say 450 volts will be stable to 10 millivolts, and third, the Model 801 will tend to meter the regulation of its own 500 volt reference supply. The regulation of this reference supply is approximately 0.01% for a 30% change in line voltage. While this figure is more than adequate for the instrument when used in recommended fashion, it may cause some meter rattle if the line voltage fluctuates badly while the instrument is used in the 0.01 volt null range for metering excursions at several hundred volts.

EFFECT OF AC COMPONENT

The Model 801 employs four null ranges. Two of these, the 10 volt and 1 volt ranges, employ a cathode follower type vacuum tube voltmeter circuit. This type of VTVM is not particularly sensitive to an AC component in the DC being measured. Accordingly, an AC component of several volts may be present on the DC signal being measured and the 801 will still read within specs as long as only the 10 and 1 volt null ranges are used. This is not true with the 0.1 and 0.01 volt null ranges. Here a chopper amplifier precedes the cathode follower VTVM. The chopper contacts are driven at power line frequency, 60 cycles. Any signal appearing at these contacts, whether DC or AC, is passed to the grid of the first amplifier stage during the time the contacts are open. It is amplified and rectified by the back contact of the chopper on alternate half cycles. Obviously any AC which appears at these contacts will appear as DC after amplification and rectification just as a DC off-null signal would.

A two section low pass filter comprised of R123, R124, C109, and C110 is used at the input to reduce any AC present on the DC being measured. This filter has an attenuation ratio of 330 to 1 at 60 cycles. A one-half volt 60 cycle component will therefore be reduced to slightly over one millivolt. This may still cause a reading of as much as 10% of full scale when operating in the 0.01 volt null range however, and may be positive or negative depending on the phase relationship between the AC component and the chopper driving coil source. If large AC components are present and the chopper null ranges must be used, additional filtering may be required. If the AC is of a single frequency, a twin T filter is extremely effective and has the advantage of low total series resistance. If the AC is of variable frequency, an ordinary low pass filter may be used. In either case the capacitors used should be high quality units of extremely high leakage resistance.

MEASUREMENT OF NEGATIVE VOLTAGES

Voltages which are negative with respect to ground may be measured with the 801 as well as the more commonly encountered positive variety. However, when the 801 positive binding post is connected to the G post (metal case), either at the posts themselves or at the source under measurement, and the negative side of the 801 is connected to the "hot" side of the source, certain circuit conditions are changed and must be taken into consideration.

First, a 0.1 MFD capacitor (C7) is connected directly across the source under measurement. In certain circuits this capacitance may affect the source EMF. If this capacitor were removed there would still be considerable capacity, in the form of transformer winding capacitance and wiring strays, between the 801 input posts.

Second, a small 60 cycle signal appears between the 801 input posts (across C7) when a shorting link is connected between the plus and G posts. This comes about by slightly unbalanced transformer high voltage winding-to core capacitances. By careful transformer design this signal has been kept to less than 50 millivolts. Nevertheless, it may still affect the 801 reading and/or the DC voltage under measurement under the following conditions:

1. If the most sensitive null range (0.01 volt) is being used, a fraction of a millivolt will get through to the chopper contacts and appear as a DC off null reading. If the DC voltage under measurement is quite small, some inaccuracy may result.

2. If the source under measurement contains unilateral conducting elements, such as the diodes used in limiter circuits, together with high internal resistance, this spurious 60 cycle signal may be rectified by these diodes and appear across the source as DC, which either adds to or subtracts from the true EMF of the source. The 801 will of course read this false voltage. Therefore, if the source under measurement does contain diodes, choppers, or other unilateral circuit elements, some additional filtering may be necessary to prevent this spurious 60 cycle signal from reaching the voltage source under measurement. A twin T is extremely effective and will reduce the signal to a few millivolts of 180 cycles, which are handled with a sinple low pass filter if still objectionable. Or, one or more sections of low pass filter alone may be used between the 801 and the source. The twin T has the advantage of low series resistance. This is only important if off-null voltage excursions are being observed. Since the chopper input resistance is 1 megohm, series resistance of greater than 100K may cause objectionable full scale off-null error. At null, of course, the input resistance of the 801 is infinite, so the filter resistance has no affect.

Third, connecting the shorting link from the + post to G post leaves C7, a 0.1 MFD capacitor, connected across the input. With nothing connected to the input posts and the NULL switch in the more sensitive null ranges, the meter will flop around wildly as the settings of the five voltage dials are changed. This comes about because C7 charges and discharges to the level set on the 5 voltage dials, through the input resistance of the VTVM channel (10 megohms for the 10 and 1 volt ranges, and 1 megohm for the 0.1 and 0.01 volt ranges). Since the entire change in voltage appears across the R in an RC current at the instant the change occurs, the meter needle will pin hard at the instant the voltage dials are changed (providing the change is greater than that required for full scale meter deflection). The solution is obvious - do not tweek the voltage dials with the null switch in other than the VTVM position when the input is unterminated, since no useful purpose is so served anyway.

NOTES ON USE OF .1 VOLT AND .01 VOLT NULL RANGES

Use care when operating in the 0.01 and 0.1 volt null ranges. Do not inadvertently apply several hundred volts to the instrument with the VOLTS RANGE switch set in the 0.5 volt position as the chopper will be seriously overloaded. While the chopper used in the Model 801 is an extremely rugged unit whose contacts are rated 100 volts maximum, repeated applications of several hundred volts will have an adverse effect on it.

Do not check calibration without first disconnecting the voltage being measured from the plus binding post. This is particularly important when operating in the 5 and 0.5 volt ranges where the NULL switch is usually set in the 0.1 or 0.01 volt ranges.

The reason for this is that when the VOLTS RANGE switch is rotated from the 0.5 position counterclockwise back toward the CAL position, the voltage developed between the minus binding post and the output of the 5 dial divider (rotar of "E" switch) is multiplied by 10, 100, and 1000 as the VOLTS RANGE switch successively passes through the 5, 50, and 500 positions on the way back to the CAL position. This voltage connects to the negative bus of

the VTVM channel, up through the input divider resistors to the plus input binding post, thence through the internal resistance of the voltage being measured to the minus binding post, through the 5 dial divider resistors and back to the negative bus of the VTVM channel. If a 0.45 volt unknown signal were being observed with VOLTS RANGE and NULL switches in the 0.5 and 0.01 volt positions respectively, rotating the VOLTS RANGE switch back to check calibration would momentarily impress 450 volts across this network of dividers and voltage sources. Reference to the circuit diagram will show that current through the voltage source being measured is limited to around 450 ma by the 1 megohm resistance of R130 and R131, and current through the chopper contacts is limited to about 120 ma by this 1 megohm resistance plus the 2.6 megohm resistance of R123, R124, and R125. While this probably would not damage either the chopper or the unknown voltage source, it should definitely not be done. If it is necessary to check calibration of the internal reference supply, remove the lead connecting the voltage being measured to the plus input binding post before rotating the VOLTS RANGE knob.

If a large voltage is accidentally applied to the chopper amplifier, either by having the 5 voltage dials set much too low or much too high with respect to the voltage being measured, or by checking calibration without first disconnecting one lead from the voltage under measurement as discussed above, it may be found that the meter will not come back to zero in the absence of any input signal. This is caused by temporary polarization of the two 0 22 mfd capacitors C109 and C110 which comprise part of the filter at the input of the chopper amplifier. These may charge to a relative high voltage and may require some time to discharge completely (a 1 millivolt charge on these capacitors will cause the meter to deflect 10% of full scale when using the 0.01 V null range). The quickest way to restore the instrument to normal operation is to remove it from the case and connect clip leads across both capacitors. Leave these connected for a few seconds, then remove and replace instrument in case, after which operation will be found normal. Usually this is not necessary and the capacitors will discharge completely in a matter of minutes.

CIRCUIT DESCRIPTION

The Model 801 Precision Potentiometric DC Voltmeter operates on the potentiometer principle wherein an unknown voltage is measured by bucking it against an adjustable known voltage and the difference read on a sensitive null detector. When zero displacement current flows in the null detector, the unknown voltage is exactly equal to the known voltage and the impedance presented to the unknown voltage source by the known voltage source and null detector is infinite.

The circuit consists of six main elements which are:

1. A super regulated, extremely stable 500 volt reference source.
2. Means for setting this reference source to 500 volts within ±0.01%.
3. A range switch for dividing the 500 volts down to three lower reference voltages of 50, 5, and 0.5 volts.
4. A calibrated 5 decade Kelvin-Varley precision attenuator for dividing the reference voltage down to the exact level of the unknown voltage.
5. A calibrated multi-range VTVM which is used both as a conventional VTVM for determining the approximate value of the unknown voltage and also as a calibrated null detector for measuring the difference between the unknown voltage and the known voltage derived from the 5 decade calibrated attenuator.
6. Appropriate attenuators for reducing the signal input to 0.5 volt maximum for the 4 VTVM ranges and the first 2 null ranges (10V and 1V) and to 0.01 volt maximum for the last 2 null ranges (0.1V and 0.01V).

Element 1 consists of an unregulated 900 volt DC supply (V1, R1, C10, C11, C12, R71, R72, R73) a pre-regulator delivering 625 volts at 1% regulation (V2, 3, 5, and associated components), and a super-regulator delivering 500 volts at 0.01% regulation (V4, 6, 7, 8, and associated components). The super-regulator used the highly stable type 5651 reference tubes, a carefully balanced differential amplifier as the equating element, and precision wirewound resistors in the sampling circuit. The stability of this 500 volt supply is better than 0.01% per hour after a short warm up period.

Element 2 consists of P1, S7, a standard cell B2, a precision wirewound divider (R15, R19, R16, and !2) across the 500 volt supply from which is derived a voltage exactly equal to the EMF of the particular standard cell used when the output is exactly 500.00 volts, a 50-0-50 microamp meter, M1, and VOLTS RANGE switch sections S8C and S8D for connecting the standard cell and 1 volt sample of the 500 volt output to the chopper amplifier, V100.

To calibrate, S7 CAL PUSH switch is pushed and P1 ADJ CAL knob is rotated until there is no deflection of the meter needle.

Element 3 is comprised of S8A and S8B, precision wirewound resistors R142 through R148, rheostats P3, P4, and P5, and the 200,000 ohm 5-dial Kelvin-Varley type attenuator since this attenuator always shunts the lower portion of the range divider string (portion between switch S8B rotor and the negative bus).

Element 4 is made up of S1, S2, S3, S4, S5, and associated matched precision wirewound resistors, R20 through R68. The resistors on the A and B switches are matched to be within ±0.005% of each other; those on the C, D, and E switches to within ±0.025%. If any of the resistors in this dial attenuator become defective, send resistor value and serial number of the instrument to John Fluke Mfg. Co., Inc., where a record is kept of the exact values used in each instrument shipped. In this way a replacement can be obtained which will not upset the matching of the other resistors on the particular switch.

Element 5 consists of a cathode follower type VTVM, V104, and associated components R109, R110, R111, C102, P101 (meter zero control for VTVM, 10V, and 1V ranges), M1 and VOLTS RANGE switch sections S8C and S8D for switching the meter from the CALIBRATE function to the VTVM function. This VTVM has a basic full scale sensitivity of 0.5 volt; that is, a 0.5 volt dc signal applied between pin 2 of V104 and the 0 volt bus of the voltmeter channel, with everything to the right of R111 cast loose, will cause the meter to deflect full scale right or left, depending on whether the signal is positive or negative respectively (pin 2 with respect to 0 volt bus).

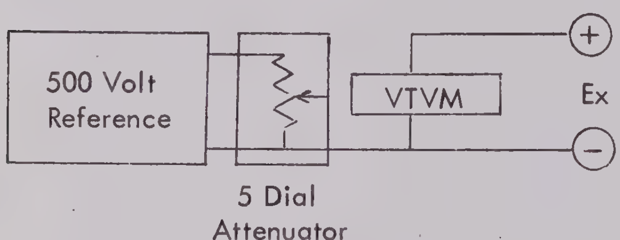
In order to provide the more sensitive null ranges (0.1 volt and 0.01 volt) a chopper amplifier is used to amplify the signal by a factor of 5 or 50 respectively (gain of the amplifier is constant; input signal is attenuated by factor of 10). This amplifier consists of V100, V105, a break-before-make type single pole double throw 60 cycle chopper, and associated components, R112 through R125 and C103 through C112. Both heater and plate voltage on both the cathode follower VTVM tube and the two chopper amplifier tubes are regulated. V101 is an Amperite regulator tube for maintaining heater voltage at 6.3 volts ±0.2 volt in the face of 20% line voltage change. V102 and V103 are cascaded voltage regulator tubes which provide 105 volts at better than 0.1% regulation and less than 2 millivolts ripple to V100, V104, and V105.

The gain of the chopper amplifier is stabilized by a feedback network consisting of C106, R119, P103 and R122 and is so adjusted that a 10 millivolt dc signal applied between the top of R123 and the 0 volt bus of the voltmeter channel will appear as a 0.5 volt dc signal across C103. R123, R124, C109, and C110 serve as a 2 stage low-pass filter for removing any unwanted ac from the dc signal input. The armature and upper contact (pin 6) of the chopper converts the dc signal to square wave ac and the two halves of V100 amplify it. V105 serves as a phase inverter so that a positive going input signal will, after rectification, appear as a positive going dc voltage and cause an up scale meter reading. (When the unknown voltage is larger than the voltage set up on the 5 voltage dials, the meter reads upscale). After amplification and phase inversion, the ac output signal is synchronously rectified by the armature and lower contact pin l of the chopper. R112 and C103 form a low-pass filter for removing the ripple component from the rectified signal; the resulting dc is then applied to the cathode follower VTVM. The purpose of the chopper-amplifier section, of course, is attainment of stable, drift free dc amplification for signals in the microvolt to millivolt region.

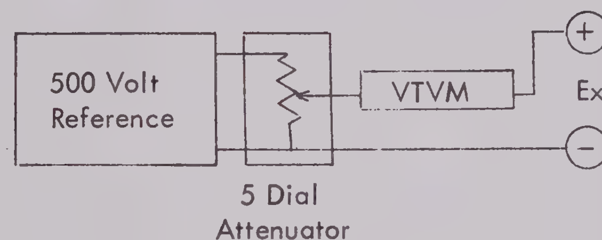
Element 6 consists of the appropriate sections of VOLTS RANGE switch S8 and NULL switch S9, together with their associated resistors R128 through R139. VOLT RANGE switch section S8E and resistors R136 through R139 divide the unknown voltage down to 0.5 Volts from either 500, 50, or 5 Volts depending on the setting of the switch. VOLT RANGE switch section S8F and resistors R133 through R135 are used to maintain the resistance between input grid of VTVM (pin 2 of V104) and negative side of voltmeter channel constant at 11 megohms.

In order to use the instrument as a straight VTVM., the negative input binding post is connected directly to the negative side of the voltmeter channel via NULL switch S9A; the positive input binding post is connected to the VOLTS RANGE switch divider via NULL switch S9B and the VTVM input grid is connected to the output of the VOLTS RANGE switch divider via NULL switch S9E. This is illustrated in block diagram below.

In order to use the instrument in the differential mode, the entire voltmeter channel is floated between the output of the 5-dial attenuator and the positive input binding post. The block diagram below illustrates this.



STRAIGHT VTVM



DIFFERENTIAL VTVM

This is effected via NULL switch sections S9A and S9B. NULL switch sections S9B and S9C serve to attenuate the 10 Volt or 1 Volt out-of-balance signal to 0.5 Volts for application directly to the cathode follower VTVM input grid (pin 2, V104). In the last two positions of the NULL switch the 0.1 Volt and 0.01 Volt out-of-balance signals are attenuated to 0.1 Volt for application to the chopper amplifier. NULL switch section S9D serves to switch the output of the NULL attenuator either straight into the VTVM (in 10 and 1 Volt positions) or into the chopper amplifier (in 0.1 and 0.01 Volt positions). R126 and R127 are used to maintain the resistance between the input grid of VTVM (pin 2 of V104) and negative side of voltmeter channel constant at 11 megohms.

Capacitor C111 is a high grade polystyrene 1 mfd 200 Volt capacitor used to eliminate the hash picked up by the wirewound resistors in the 5 dial attenuator and provide a return path to the negative binding post for the chopper input filter (C109, C110, R123, R124).

Screwdriver adjust control P104 is adjusted so that full scale meter deflection results when exactly 0.5 Volt is applied to the input binding posts with NULL switch set to VTVM position and VOLTS RANGE switch set to 0.5 Volt position. Screwdriver adjust control P103 is adjusted after P104 has been adjusted. It is set so that full scale meter deflection results when exactly 0.01 Volt is applied to the input binding posts with NULL switch set to 0.01 V position, VOLTS RANGE switch set to any position except CAL, and all 5 voltage dials set to zero. A simple

method of making these adjustments is to set the VOLTS RANGE switch to the 5 volt position, NULL switch to 1 volt position, and A switch to the 1 position (other 4 voltage switches must be set to 0). Next connect a resistor of approximately 40,000 ohms across plus and minus binding posts (this approximates the resistance of the 5 dial divider when dials set at midpoint) and adjust P104 for full scale left deflection. Turn NULL switch to 0.01V. Then set "C" switch to 1 and other 4 voltage switches to zero, leaving 40,000 ohm resistor connected across input posts, adjust P103 for full scale left meter deflection. Slide instrument back into case and recheck meter deflection, since the chopper amplifier is subject to stray fields and this adjustment is one which must be made with instrument withdrawn part way out of case.

This concludes the circuit description. Should trouble occur, an orderly, step by step servicing procedure should locate the source. If trouble connot be isolated, write us giving full details of the difficulty and include serial number. On receipt of this information we will send service data or shipping instructions.

CAUTION: IT IS RECOMMENDED THAT THE PLUG TO THE STANDARD CELL BE REMOVED WHEN TROUBLE SHOOTING TO PREVENT ACCIDENTAL SHORTING AND DAMAGING OF THE CELL.

MAINTENANCE NOTES

1. TUBE REPLACEMENT. All tubes used in the Model 801 are, with the exception of the Amperite type 9-7, common receiving types. Only two of the 14 tubes used are at all critical - these are V6 in the 500 volt reference supply and V104 in the VTVM channel. Should replacement of these be necessary, the following procedure should be followed to insure optimum performance of the instrument. We recommend replacement of these two with factory pretested tubes.

   V6 - this tube is a high mu dual triode, type 12AX7, used as a differential amplifier. This connection insures maximum stability and minimum effects from line voltage change. Some tubes have poor balance between halves, however, causing poor regulation against line voltage. Check for this by allowing 5 minutes for tube to heat and then varying line voltage from 100 to 130 volts and checking reference supply output voltage with another Model 801 or 800. The 500 volts must not change by more than 50 millivolts (0.01%) over this range of line voltage. If regulation exceeds this figure, discard tube in favor of another. Such discards may work very well for V100 in the chopper amplifier since it is an AC coupled amplifier not dependent upon the DC tube characteristics for proper performance.

   V104 - this tube is a medium mu dual triode used in a cathode follower type VTVM circuit. The two requirements of V104 for satisfactory performance are good balance between halves and low grid current. These can be checked by setting RANGE switch to 500, NULL switch to 1V and all 5 voltage dials to zero. Allow a few minutes for tube heating and then check for ability to zero meter. At zero, the top meter zero knob pointer should lie within ±90° of vertical. If outside these limits remove tube and

try another. If okay, vary line voltage from 105 to 130V and check stability of meter zero. Meter should not offset more than ±4% (2 small scale divisions). If it does, check the heater voltage to determine whether the Amperite 9-7 ballast tube is okay. Heater voltage at 117 volts line should measure between 5.5 and 6.5 volts and should change less than 0.5 volt for a line voltage change from 105 to 130 volts. If outside these limits, replace. If the ballast tube is functioning properly but the meter offset exceeds 2 small scale divisions for a 30 volt change in line voltage, discard V104 in favor of another with better balance.

To check for excessive grid current in V104, set RANGE switch to 500, NULL knob to 1V, the five voltage knobs to zero and line voltage to 117 volts. Zero meter and then short the input binding posts. Meter offset must not exceed 1/4 of one small scale division. If it does, replace V104. Shorting the input posts changes the resistance in the grid circuit of the right half of V104 from 10 megohms to 8 megohms. Assuming the small grid current to be constant (which is not strictly true) this changed grid resistance appears as a change in grid voltage which causes a small meter offset to the left. The average Amperex 12AU7 produces offset of from 0 to 1/2 of one small scale division. It is important that this offset be kept to a minimum in order that slight errors not result from measuring EMF's with widely varying internal resistances. This is not error due to external circuit loading since the 801 at null presents infinite resistance to the external circuit. Rather it is error due to shunting of the normal 10 megohms VTVM grid circuit resistance by the internal resistance of the voltage source under measurement.

The John Fluke Mfg. Company's sales representative in your area maintains a stock of aged replacement tubes selected for optimum performance in these two critical spots - V6 and V104. If replacement becomes necessary, contact him and advise tube type required. This is usually simpler than selecting tubes from stock on hand.

Replacement of V100, the 12AX7 chopper amplifier tube, should be made with one which is not microphonic. The Westinghouse type 12DF7 is a low microphonic version of the 12AX7 and may be used if desired. A microphonic or otherwise noisy tube may cause meter rattle in the 0.01 and 0.1 volt null ranges. Another possible source of meter rattle in these ranges is a defective type OB2 (V103).

Should the ballast tube V101 burn out or otherwise fault, it may in an emergency be replaced with a 10 ohm, 10 watt resistor. Remove tube and solder resistor across pins 2 and 7 on the printed circuit board. Voltage at the heaters of the tubes on the VTVM board should then run around 6 volts at 117 volts line voltage. If a resistor is not available there is a 6.3 volt transformer tap taped back to the bundle of transformer leads coming out the right side of transformer (VTVM printed circuit board side). This is a yellow sleeved lead. Unsolder the green lead (15 volt end of this winding) and tape it back out of the way using plastic tape since any leakage from any point on the VTVM board to chassis will cause meter offset. Solder the yellow lead to the board in place of the green lead and jumper pins 2 and 7 of the V101 socket. This runs the tubes on the VTVM board at 6.3 volts unregulated. As soon as replacement is available,

restore circuit to its original condition being sure to remove the jumper from across pins 2 and 7 of V101. Failure to do this will almost certainly damage the tubes and chopper since they will be running at 15 volts instead of 6.3 volts.

2. STANDARD CELL AND BIAS CELL REPLACEMENT. The standard cell, B2, used in the Model 801 is an Eppley type MIN 1. This is a miniature low hysteresis unit which has excellent long term stability and negligible temperature hysteresis. (Hysteresis is a temporary increase in EMF immediately following a decrease in temperature. This effect should not be confused with temperature coefficient). Under normal conditions this cell should last from 8 to 15 years. End of life is usually heralded by a marked increase in the temperature hysteresis effect. That is, reading errors in excess of 0.05% will result when the same voltage is read with the 801 hot and cold. Should replacement of the cell become necessary for any reason, the instrument must be recalibrated (basic 500 volt range only), since the EMF of different cells may be different by as much as 0.05% and each instrument is calibrated to its own particular standard cell. Refer to the recalibration instructions for this. Nominal EMF of a new Eppley type MIN 1 cell at average room temperature is 1.0193 volts.

   Do not subject the standard cell to below freezing temperatures. The electrolyte will freeze at -17° C and operation below 0° C is definitely not recommended. The life of the cell will be greater if the 801 is not operated at elevated temperatures. The 8 to 15 year figure holds for operation of the instrument in normal room temperature ambients.

   The mercury cell B1 in this instrument is used solely as a source of tube grid bias voltage. It is located on the smaller of the two printed circuit boards and should last from 2 to 4 years since no current is drawn from it. Replacement should be made when its voltage falls below 1.2 volts measured directly across the cell terminals. A defective cell is often the cause of inability of zero the meter by the 0.1, 0.01V MTR zero control.

3. GENERAL CLEANING. The Model 801 is extremely sensitive to the slightest amount of electrical leakage from the VTVM channel, particularly the input grid of V104 (pin 2) all its associated wiring, to the negative side of the input. Leakage resistance of 40,000 megohms between this grid circuit and the negative input will cause a 10% left meter deflection in the 1volt null range when voltage dials are set to 400 volts; lower values of leakage resistance will cause larger no signal meter deflection. An analysis of the 801 circuitry will show that it meters its own internal leakage resistance. Therefore, the instrument should be cleaned occasionally to remove dust and foreign matter, particularly from the two Plexiglass strips which insulate the VTVM chassis from the metal frame of the instrument, the positive binding post and the ceramic NULL and RANGE switches. Blow the instrument out with a low pressure air hose (be sure air is dry) and wipe strips off with a clean dry rag. If necessary, wipe the Plexiglass strips with a rag saturated in Metriclene Solvent M-4 (manufactured by the John B. Moore Corp., Nutley, New Jersey). This is a high grade, non-toxic solvent for use on delicate electrical equipment. Many other solvents have very poor electrical properties and leave a residue which might be slightly conductive. Switches may be washed using a small stiff bristled brush dipped in Metriclene. After washing, the ceramic surfaces must be recoated with a 10% solution of Dow Corning 200 Fluid (100 viscosity grade) in Metriclene. This prevents moisture collecting across the ceramic surfaces.

If the instrument is stored for a considerable period of time in a hot humid atmosphere, considerable leakage may be noted upon initial operation. This is evidenced by large meter offsets in the null ranges as the voltage dial settings are increased. This usually clears up as the instrument warms up and dries out. If not, remove from case and wipe above mentioned surfaces with clean dry cloth.

If necessary to clean the binding post insulators, do not use Metriclene. Use only pure denatured alcohol and a clean cloth, since the insulator material is slightly solvent in Metriclene.

TROUBLE SHOOTING HINTS

1. Excessive drift in 500 volt reference supply - this is evidenced by having to recalibrate the unit every five or ten minutes for an hour or more. Trouble is usually a defective reference tube V7 or V8, or a faulty equating tube V6. A leaky feedback capacitor C6 may cause either drift or unstable output.

2. Excessive drift in VTVM - drift should stop after a few minutes operation. If it persists, replace V104.

3. Inability to calibrate instrument - if meter deflection cannot be reduced to zero by following step 2 under "Initial Operation" trouble is in one of the following:

   A. Either R17 or R18 has shifted, making it impossible to bring output of super-regulator to 500 V. Replace out of tolerance unit.

   B. V7 and/or 8 have aged to the point where their running voltage is too low. Replace them if this is the case. Their running voltage should lie between 85 and 87 volts. Screwdriver adjust control P6 may be adjusted to bring the front panel CAL ADJ control to the approximate center of its rotation at the point meter deflection has been reduced to zero. <u>Under no conditions attempt replacement with ordinary power resistors, Nichrome resistors, carbon or deposited carbon resistors, or matal film resistors. This statement applies to every single precision wirewound resistor in the instrument.</u>

   C. One of the three wirewound resistors in the standard cell sampling string has changed value. These are R15, R16, and R19. If replacement of any of these is necessary <u>the instrument must be recalibrated</u>. See recalibration instructions.

D. The standard cell may have shifted value very badly. It should measure between 1.0190V and 1.0196V. Use only a Model 801 or a Leeds & Northrup Type K potentiometer (or other similar potentiometer) to make this measurement. DO NOT USE A VOLTOHMMETER. If replacement is necessary instrument must be recalibrated. See recalibration instructions

E. Failure of either the rectifier filter (V1, C10, C11, C12), the super-regulator power supply (V4, V6, V7, V8) or the pre-regulator (V2, V3, V5). Output of the rectifier filter should run approximately 900 volts at a line voltage of 117 volts. Output of the pre-regulator should run 610 to 640 volts and be regulated to better than 1% over range of 100 to 130 volts line. Output of the super-regulator must obviously be 500 volts and should have a range of adjustability of at least 5 volts either side of 500. Regulation must be 0.01% or better over range of 100 to 130 volt line.

4. Error in excess of specified values - this is caused either by the instrument being out of calibration or by a defective resistor in the 5 dial Kelvin-Varley voltage divider

A. A quick check to determine whether this divider is okay consists of setting the 5 voltage dials to 400.00 and applying an EMF from an extremely stable high resolution DC power supply, such as the John Fluke Models 301C, 406, or 407. Adjust supply until a null is obtained in the 1 volt range. Then remove voltage from input and reset the 5 voltage dials to 399.910. Reconnect the 400 volts to the instrument again with NULL switch in 1V position. Meter should null within 80 millivolts (0.02%). Repeat this check applying 50 volts and setting up 050.00 first on the voltage dials and then 049.10. Difference in the two readings must be less than ±25 millivolts (0.05%).

Non-linearity is usually traceable to one defective wirewound resistor on one of the five switches. Since these are matched units the drops across each resistor on a particular switch should lie within 0.01% of each other on X100, 0.025% on X10, and 0.05% on the other three. If replacement of any resistor is necessary, wire serial number of instrument to factory where a stock of matched replacements is maintained.

B. To determine whether instrument is still in calibration proceed as follows:

Since this is a four range instrument, there are four calibration adjustments. The basic adjustment concerns the 500 volt range and employs a screwdriver adjust rheostat P2. It affects not only the 500 volt range but each of the other three ranges as well. The other three ranges, 50V, 5V, and 0.5V, employ individual screwdriver adjust rheostats P3, P4, and P5, respectively, which are completely independent adjustments. That is, adjustment of any one of the three has no effect on the other two ranges, not on the basic 500 volt calibration.

Obviously then, the first range to check is the 500 volt range. If this is out of calibration then all three of the lower ranges will also be out of calibration. To check the basic 500 volt range calibration perform the calibration operation as outlined in paragraph 2 under INITIAL OPERATION. Then apply a KNOWN 500 volts - this voltage must be accurate to 0.01% or better - to the instrument and measure it. It must read between 499.90 and 500.10 volts (±0.02%). If outside these limits follow recalibration instructions.

NOTES: A 500 volt EMF accurate to 0.01% is extremely difficult to obtain. If there is any doubt in your mind as to the accuracy of your 500 volts, do not use it. Instead, contact our field representative in your area. Most of them have in their repair stations a John Fluke approved precision calibration set-up and therefore can perform this important check to the accuracy required. Refer also to the RECOMMENDED CALIBRATION SET-UP section of this manual.

If the error appeared in one of the three lower voltage ranges and the basic 500 volt calibration was found to be off and recalibration performed, recheck the lower range to see whether the recalibration of the basic 500 volt range corrected the error. If not, proceed as follows: Let us assume the error appears in the 5 volt range. Set the VOLTS RANGE knob to the 5-volt position, apply a KNOWN 5 volts - this voltage must be accurate to 0.01% or better - to the instrument and measure it. It must read between 4.999 and 5.001 volts (±0.02%). If outside these limits follow recalibration instructions.

NOTE: Any EMF accurate to 0.01% is extremely difficult to obtain. If there is any doubt in your mind as to the accuracy of the 5 volts, do not use it. Instead contact our field representative in your area. Most of them have in their repair stations a John Fluke approved precision calibration set-up and therefore can perform this important check to the accuracy required. Refer also to the RECOMMENDED CALIBRATION SET-UP section of this manual.

5. Error in the VTVM readings - if meter reads off in all four VTVM ranges as well as the 10 and 1 volt null ranges, adjustment of P104 is probably required. This is the upper screwdriver adjust potentiometer on the smaller printed circuit board. If the error lies in only certain ranges the trouble is probably in one of the dividers - S8E for the VTVM ranges and S9C for the null ranges.

   If there is error in the 0.1 or 0.01 volt null ranges the trouble is either a defective 12AX7 chopper amplifier tube V100 (if both ranges are off), or the NULL divider in switch section S9C. Also cehck adjustment of P103.

   NOTE: DO NOT POKE AROUND THE SWITCH DIVIDERS WITH A SHARP POINTED TOOL. IF A DEPOSITED CARBON RESISTOR COATING IS SCRATCHED DEEPLY ENOUGH, THE RESISTOR WILL OPEN UP.

6. Meter needle offsets to the left as voltage dials settings as increased (NULL switch in 1 volt position, VOLTS RANGE switch in 500 position, nothing connected to input posts). This indicated leakage between grid pin 2 of V104 and ground. See MAINTENANCE NOTES under "General Cleaning" for discussion of this.

7. Excessive error which appears only at low voltages when operating in the 1 volt null range. This is caused by either a defective wirewound resistor on S4 or S5 (the "D" or "E" switch), or by excessive grid current in V104. See MAINTENANCE NOTES, last paragraph on page 13, for discussion of grid current. See TROUBLE SHOOTING HINTS, heading 4A, for discussion of Kelvin-Varley non-linearity.

8. Meter needle rattle. Trouble may lie in the source under measurement which is not steady or in the bucking voltage developed in the 801, or in the VTVM in the 801. To check the first two possibilities apply an absolutely steady voltage and see if meter needle wobble ceases. If it does, trouble was in the source. If wobble is still present, remove signal from input posts altogether. If wobble still is present trouble is in VTVM. If wobble disappears trouble is either in 500 volt reference supply, Kelvin-Varley divider, or one of the three range dividers (if operating in other than the 500 volt range).

   To track down trouble in 500V reference, use another Model 801 or 800 and monitor the output of the 500 volt reference supply of the defective 801. If 500 volts is steady, trouble is in Kelvin-Varley or range dividers. If 500 volts is not stable, trouble may lie in R17, R18, R7 or any of the tubes in this supply. Also may be a leaky feedback capacitor C6. May also be caused by trouble in the 625 volt pre-regulator.

9. Meter needle rattle with no signal applied. This occasionally occurs in the two most sensitive null ranges - 0.1V and 0.01V, and is usually caused by a microphonic 12AX7 (V100) or a defective regulator tube V103. Occasionally this rattle will appear periodic, occurring at a low frequency rate, perhaps once a second and of amplitude equal to one small meter scale division. This is often caused by a defective V103 and occasionally cured by replacement of V100.

   NOTE: DO NOT APPLY GREASE OR OTHER LUBRICANTS TO SWITCH WAFERS. Some lubricants may be slightly conductive; all will collect dust and dirt. The result will be leakage which can cause considerable error particularly if the leakage occurs in the NULL switch S9. Lubricate the detent mechanism and shaft bearing if necessary, but keep the lubricant off the wafers. Refer to MAINTENANCE NOTES, page 15, under GENERAL CLEANING for instructions on switch wafer cleaning and recoating.

10. Inability to bring meter needle to zero in the 0.1 and 0.01 volt null ranges. This can be caused by overloading the chopper input filter badly - see discussion on pages 7 and 8 concerning this. If this wasn't the cause, check the mercury bias cell B1, also V100, the chopper amplifier tube. Replacement of these often clears trouble up, particularly B1. Another cause may be simple DC leakage from some higher DC (or AC) potential point on the VTVM printed circuit board to the chopper input contact or the input filter. A thorough scrubbing of this board with Metriclene M4 solvent (John B. Moore Co., Nutley, N. J.) particularly in the area of the chopper input filter, will sometimes correct trouble.

RECALIBRATION INSTRUCTIONS

If it has been positively determined that the instrument is out of calibration (see heading 4 (B) on page 17), proceed as follows:

1. To calibrate basic 500 volt range, first adjust meter zero controls as outlined under INITIAL OPERATION. Then apply a known 500 volts (accurate to 0.01% or better) to the instrument. Set 5 voltage dials to 499.910 and turn NULL dial to 1 volt position. Bring needle to zero by adjustment of the ADJ CAL control. Then withdraw instrument part way out of the case to gain access to P2, a screwdriver adjust control located at the bottom of the large printed circuit board. Now turn VOLTS RANGE knob to CAL position and push the CAL PUSH button, at the same time checking for meter needle movement. With a screwdriver adjust P2 until meter needle reads zero when the CAL PUSH button is pushed. This operation should be performed in a draft free room since a strong draft blowing across the wirewound resistors in the various dividers could cause some slight error. When meter needle movement has definitely been eliminated the instrument is in calibration. Push back in case and recheck calibration one more time. If okay, apply a dab of Duco Household Cement to P2.

2. To calibrate the other three ranges, first be sure the basic 500 volt range is in calibration. Then apply a known voltage equal to the full scale value of the range being calibrated. As an example, consider the 5 volt range. Set VOLTS RANGE knob to the 5 volt position and apply a known 5 volts (accurate to 0.01% or better) to the instrument and turn NULL dial to the 0.01 volt position. Withdrawn instrument part way out of case to gain access to P3, P4, and P5, the range adjustment rheostats located on the Plexiglass strip at the top front of the instrument. The left hand control adjusts the 50 volt range; themiddle control adjusts the 5 volt range, and the right hand control adjusts the 0.5 volt range (viewed from front). With a screwdriver adjust the middle control to bring the needle to zero on the meter scale (assuming the meter needle lies on zero with nothing connected to the input posts). The 5 volt range is now in calibration.

   If it is impossible to bring the meter to zero one of the precision wirewound resistors in the 5 volt range divider has probably developed shorted turns. These resistors are R142, R143, R145, and R147. If either R142 or R143 has become defective all three of the lower ranges will be affected. R145 and R147 affect only the 5 volt range.

   A very effective independent check of the entire instrument, particularly the 5 volt range, consists of measuring the EMF of a standard cell which has been recently certified by the Bureau of your own standards group. This furnishes a known EMF of a value which will read out nicely on all 5 dials in the 5 volt range. Measure this cell with the 801. It should read well within 0.03% of the certified value.

A recommended setup for calibrating Model 800 and 801 instruments is discussed in the next section of this book.

RECOMMENDED CALIBRATION SET-UP

The hook-up of equipment required for final calibration of Models 800 and 801 is shown in Figure 1. The heart of this set-up is the precision voltage divider, ESI #194, built by Electro Scientific Industries in Portland, Oregon. This divider is so constructed that when the left hand knob is set to the exact EMF of the Eppley standard cell shown at the extreme left and the 301C output voltage controls are adjusted until the Leeds & Northrup galvo comes to null with both COARSE and FINE buttons pushed, the EMF applied to the precision divider will be 500 volts within plus or minus 0.005%. The precision of this divider is such that the three divided down EMF's of 50, 5, and 0.5 volts will also be accurate to within plus or minus 0.005%. These figures obtain at 72^{o} F and the accuracy will be maintained within plus or minus 0.01% providing room temperature does not deviate more than plus or minus 5^{o} F from this figure.

It is necessary, of course, that the EMF of the particular standard cell being used be known to an accuracy of plus or minus 0.002%. This means certification by some group who has a bank of saturated standard cells. The Eppley Model 100 standard cell is encased in a special phenolic housing which is thermally insulated and lagged. We strongly recommend that it be further insulated and lagged by housing it in an aluminum box inside of a wooden box with three inches of glass wool between cell and aluminum box and another three inches between boxes. While the Eppley 100 cell is of the unsaturated type which the Bureau of Standards will certify only to 0.01%, it will nevertheless maintain an extremely constan EMF if treated with care and not subjected to sudden temperature changes. Many groups will read an unsaturated cell's EMF down to the fifth place so that if you use this value in setting the standard cell knob of the ESI divider and treat the cell with care, you can be reasonably sure that you are within plus or minus 0.002% (20 parts per million) of the true EMF of the cell. Overall accuracy of the system then is plus or minus 0.005% plus or minus 0.002% or somewhere between 0.003% and 0.007%, which is quite adequate for calibrating a 0.05% instrument.

MODEL 801
LIST OF REPLACEABLE PARTS

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
C10, 11, 12	Capacitor, electrolytic 20 mfd, 450 v	CE65
C3	Capacitor, paper 0.1 mfd, 600 v	CP5
C5, 103 - 106	Capacitor, paper 0.047 mfd, 400 v	CP6
C6	Capacitor, paper 0.01 mfd, 1600 v	CP1
C7,8	Capacitor, mylar 0.1 mfd, 600 v	CP20
C9	Capacitor, paper 0.1 mfd, 600 v	CP4
C100	Capacitor, paper, grounded case 0.01 mfd, 600 v	CP7G
C101	Capacitor, electrolytic 2 section 10/10 mfd, 450 v	CE13
C102	Capacitor, mylar 0.022 mfd, 600 v	CP18
C107	Capacitor, paper, grounded case 0.047 mfd, 400 v	CP6G
C109, 110	Capacitor, mylar 0.22 mfd, 400 v	CP19
C111	Capacitor, polystyrene 1 mfd, 200 v	CO22
C112	Capacitor, ceramic 220 mmfd, 500 v	CT1
C113	Capacitor, electrolytic 200 mfd, 6 v DC	CE30
R1	Resistor, composition 390 Ω, ±10%, 1 w	GB3911
R2	Resistor, composition 470 k, ±10%, 1/2 w	EB4741
R3A-F, R4A, B	Resistor, composition 22 k, ±10%, 2 w	HB2231

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
R5	Resistor, deposited carbon 500 k, ±1%, 2 w	DR620
R6	Resistor, deposited carbon 144 k, ±1%, 1 w	DR67
R7	Resistor, precision wirewound 149 k, ±0.5%, 1 w	PR611
R8, 12, 14, 111 112, 116, 117, 120	Resistor, composition 1 m, ±10%, 1/2 w	EB1051
R9, 10	Resistor, deposited carbon 300 k, ±1%, 1 w	DR614
R13	Resistor, deposited carbon 250 k, ±1%, 1 w	DR613
R15. 19	Resistor, precision wirewound 125 k, ±0.1%, 1 w	PR610
R16	Resistor, precision wirewound 509 Ω, ±0.1%, 1/2 w	PR37
R17	Resistor, precision wirewound 320 k, ±0.5%, 1 w	PR614
R18	Resistor, precision wirewound 158 k, ±0.5%, 1 w	PR620
*R20 thru 25	Resistor, precision wirewound 40 k, ±0.02%, 1/2 w matched	PR512
*R26 thru 36	Resistor, precision wirewound 8 k, ±0.05%, 1/2 w matched	PR48
*R37 thru 47	Resistor, precision wirewound 1.6 k, ±0.1%, 1/2 w matched	PR46
*R48 thru 58	Resistor, precision wirewound 320 Ω, ±0.1%, 1/2 w matched	PR39
*R59 thru 68	Resistor, precision wirewound 64 Ω, ±0.1%, 1/2 w matched	PR24

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
R69, 114, 115	Resistor, composition 39 k, ±10%, 1 w	GB3931
R70	Resistor, wirewound 10Ω, 5%, 5 w	R10WA
R71,72,73	Resistor, composition 220 k, 10%, 1 w	GB2241
R101	Resistor, composition 56Ω, ±10%, 1 w	GB5601
R102A,B	Resistor, composition 2.7 k, ±10%, 1 w	GB2721
R104A,B R106A,B, 108	Resistor, composition 4.7 k, ±10%, 1 w	GB4721
R109, 110	Resistor, deposited carbon 8.2 k, ±1%, 1/2 w	DR411
R113	Resistor, composition 10 k, ±10%, 1/2 w	GB1031
R118, 125	Resistor, composition 2.2 m, ±10%, 1/2 w	EB2251
R119	Resistor, deposited carbon 2.2 m, ±1%, 1/2 w	DR73
R121	Resistor, composition 10 m, ±10%, 1/2 w	EB1061
R122	Resistor, deposited carbon 5 k, ±1%, 1/2 w	DR49
R123, 124	Resistor, composition 220 k, ±10%, 1/2 w	EB2241
R126	Resistor, deposited carbon 4.4 m, ±1%, 1/2 w	DR74
R127, 128	Resistor, deposited carbon 4.5 m, ±1%, 1/2 w	DR75
R129	Resistor, deposited carbon 500 k, ±1%, 1/2 w	DR618
R130, 137	Resistor, deposited carbon 900 k, ±1%, 1/2 w	DR622

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
R134	Resistor, deposited carbon 9.9 m, ±1%, 1 w	DR79
R135	Resistor, deposited carbon 9.99 m, ±1%, 1 w	DR711
R131	Resistor, deposited carbon 103.5 k, ±1%, 1/2 w	DR63
R132	Resistor, deposited carbon 4.99 m, ±1%, 1/2 w	DR76
R133, 136	Resistor, deposited carbon 9 m, ±1%, 1 w	DR78
R138	Resistor, deposited carbon 90 k, ±1%, 1/2 w	DR513
R139	Resistor, deposited carbon 10 k, ±1%, 1/2 w	DR51
R140	Resistor, composition 270Ω, ±10%, 1 w	GB2711
R141	Resistor, composition 27 k, ±10%, 1 w	GB2731
R142, 143	Resistor, precision wirewound 112,375 Ω, ±0.05%, 1 w	PR615
R144	Resistor, precision wirewound 28,571 Ω, ±0.05%, 1/2 w	PR515
R145	Resistor, precision wirewound 2531.7 Ω, ±0.05%, 1/2 w	PR49
R146	Resistor, precision wirewound 250.31Ω, ±0.05%, 1/2 w	PR311
R147	Resistor, precision wirewound 22.5 k, ±0.1%, 1/2 w	PR513
R148	Resistor, precision wirewound 24.75 k, ±0.1%, 1/2 w	PR514
P1 ✓	Potentiometer, wirewound 2 k, ±10%, 2 w	P2KB
P101, ✓ 104 ✓	Potentiometer, wirewound 5 k, ±10%, 2 w	P5KA
P105	Resistor, Variable 300Ω, ±10%, 2 w	P300A

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
P3, 4, 5	Rheostat, wirewound 600Ω, ±20%, 2 w	P600A
P2	Rheostat, wirewound 5Ω, ±20%, 2 w	P5A
P6	Potentiometer, wirewound (Trimit) 10 k, 10%, 1/4 w printed circuit type	P10KTA
P102, 103	Potentiometer, wirewound 10 k, ±10%, 2 w	P10KA
V1	Tube, high vacuum rectifier Type 5AR4	5AR4
V2	Tube, pentode Type 6AQ5	6AQ5
V3	Tube, pentode Type 6AU6	6AU6
V4, 104	Tube, dual triode Type 12AU7	12AU7
V5, 102	Tube, voltage regulator Type OA2	OA2
V6, 100	Tube, dual triode Type 12AX7	12AX7
V7, 8	Tube, voltage reference Type OG3	OG3
V101,9	Tube, current regulator Type 9-7	9-7
V103	Tube, voltage regulator Type OB2	OB2
V105	Tube, triode Type 6C4	6C4

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
C[illegible] 2	Diode, silicon 600V, PIV, 0.75 amp	RE17
CR3, 4	Diode, silicon 400 V, PIV, 300 ma	2E4
S1	Switch, rotary 2 pole, 5 position, shorting	SR40
S2, 3, 4	Switch, rotary 2 pole, 10 position, shorting	SR41
S5	Switch, rotary 1 pole, 11 position, shorting	SR42
S6	Switch, toggle SPST 3A/250 V	ST5
S7	Switch, push button DPST	SP1
S8	Switch, rotary 8 pole, 5 position	SR28
S9	Switch, rotary 6 pole, 5 position	SR29
B1	Mercury cell 1.35 V bias type	X44
B2	Standard cell, non-saturated, low hysteresis	X223
CK1	Chopper, SPDT, BBM 6.3 V, 60 C coil	X100
F1	Fuse - cartridge 2 Amperes	F2
F2	Fuse, 1/200 Amp. 250 Volt	F1/200A

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
M1	Meter, 50-0-50 microamp with special scale	M31
PL1 thru 4	Lamp - 6.3 v - 0.25 ampere Min. bayonet base	X34
T1	Transformer, power	801-601 801R-601
	Fuse holder, bayonet type	X12
	Binding post	X219
	Binding post insulator, black	X218
	Binding post insulator, red	X217
	Binding post spacer	X220
	Knob, 2 inch, no pointer	X233
	Knob, 1-1/2 inch, pointer	X207
	Knob, 1 inch, pointer	X231
	Cable, power, 3 conductor #18	X27D
	Bushing, line cord strain relief	X138
	Feet, ruber mounting	X224
	Handle, leather (801 only)	X373
	Washer, flat insulated for potentiometer mounting	X93
	Washer, shoulder insulated for potentiometer mounting	X93A

* These 49 resistors are factory matched for each instrument. When ordering, specify instrument serial numbers for each resistor ordered. See page 9, paragraph 4, of the manual for additional information.

WARRANTY

The JOHN FLUKE MFG. CO., INC. warrants each instrument manufactured by them to be free from defects in material and workmanship. Their obligation under this Warranty is limited to servicing or adjusting an instrument returned to the factory for that purpose, and to making good at the factory any part or parts thereof; except tubes, fuses, choppers and batteries, which shall, within one year after making delivery to the original purchaser, be returned by the original purchaser with transportation charges prepaid, and which upon their examination shall disclose to their satisfaction to have been thus defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at a nominal cost. In this case, an estimate will be submitted before work is started, if requested.

If any fault develops, the following steps should be taken.

1. Notify the John Fluke Mfg. Co., Inc., giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the Warranty.

SHIPPING

All shipments of John Fluke Mfg. Co., Inc. instruments should be made via Railway Express prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

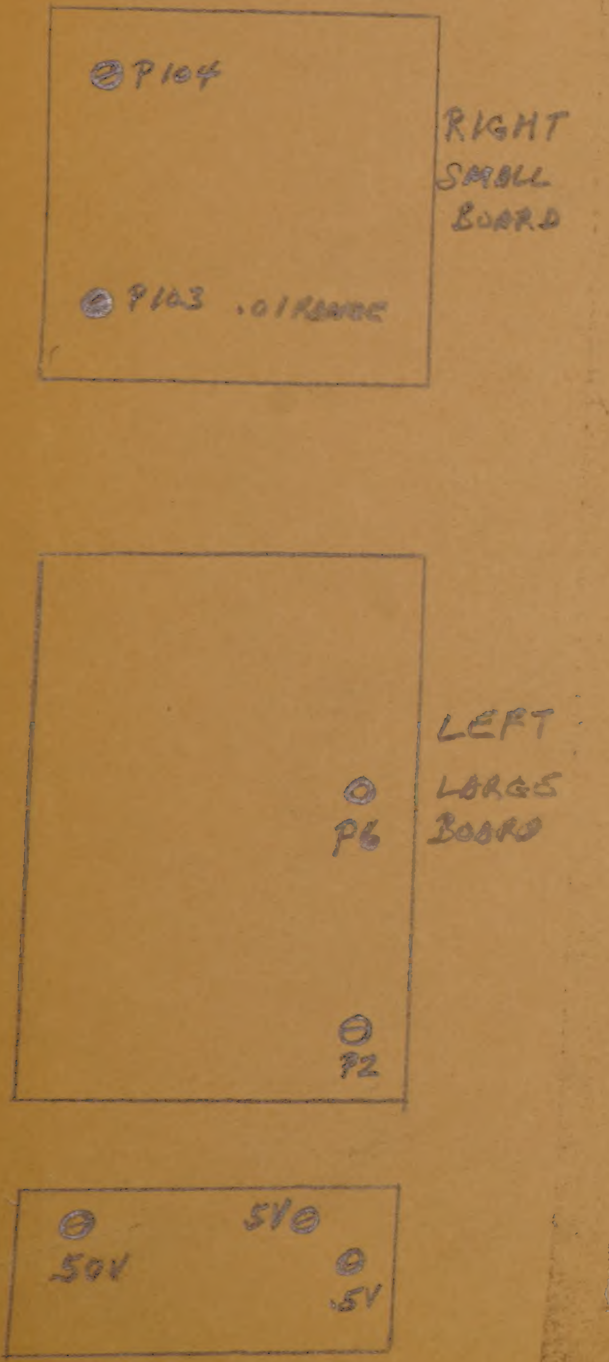
CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to John Fluke Mfg. Co., Inc. Upon receipt of this report you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

The John Fluke Mfg. Co., Inc. will be happy to answer all application questions which will enhance your use of this instrument. Please address your requests to:

JOHN FLUKE MFG. CO., INC., P. O. BOX 7428, SEATTLE 33, WASHINGTON

P-2 CAL.
P-104 VTVM ADJ.
P-103 - GAIN (CHOP AMP.)
P-101 - ZERO VTVM - 10 - 1V (PANEL)
P1 - ADJ. CAL - (PANEL)
P-102 - .1V - .01V PANEL
P3-4-5 -
P-6 ZERO CAL ADJ.

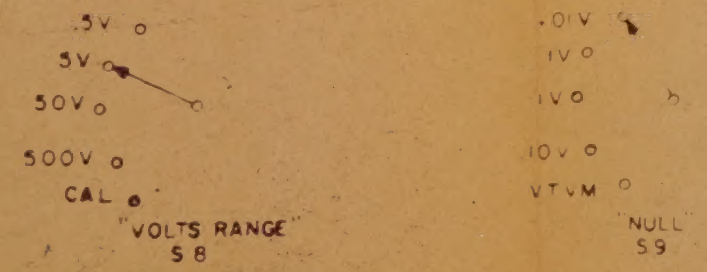


NOTES

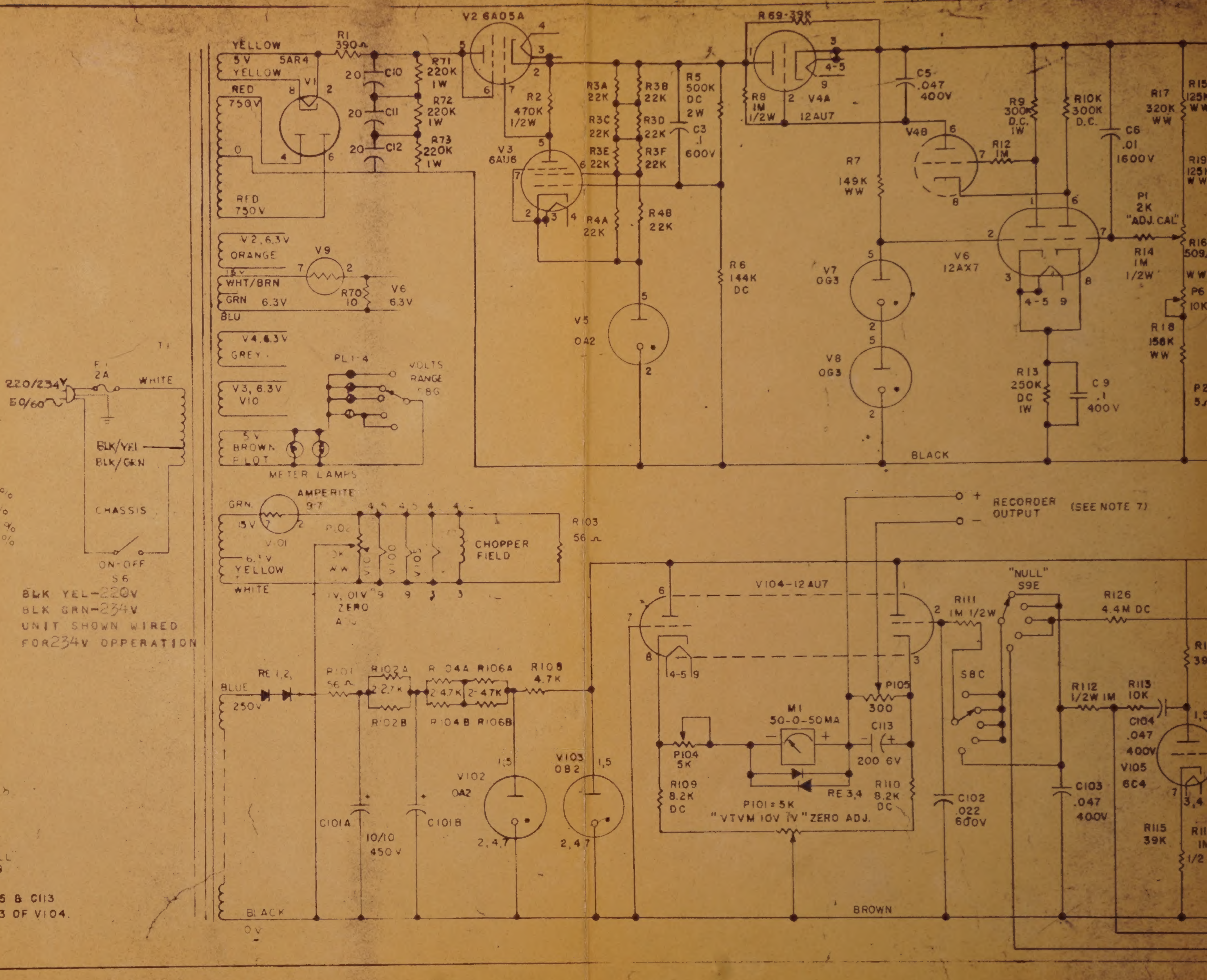
1. ALL CAPACITORS SHOWN IN MFD UNLESS OTHERWISE NOTED.
2. ALL RESISTORS ARE COMPOSITION 10% TOL 1W UNLESS OTHERWISE NOTED.
3. ALL DEPOSITED CARBON RESISTORS ARE 1% TOL 1/2 W UNLESS OTHERWISE NOTED
4. ALL POTS & RHEOSTATS ARE WIREWOUND.
5. PRECISION WIREWOUND RESISTORS RATED AS FOLLOWS:

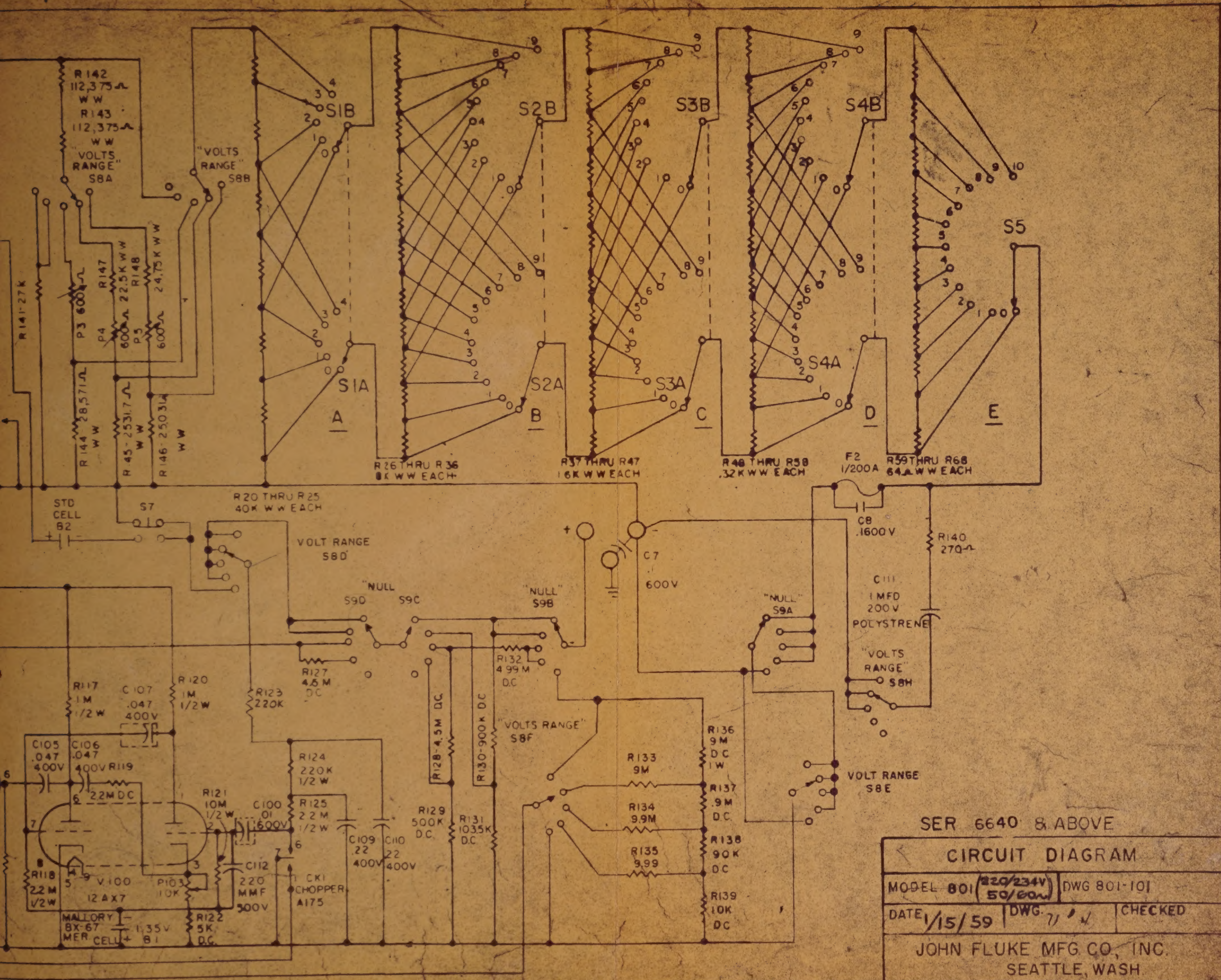
R7 = 149K - 0.5% 1W
R15, R19 = 125K - 0.1% 1W
R16 = 509 OHMS - 0.1% 1/2 W
R17 = 320K - 0.5% 1W
R18 = 158K - 0.1% 1W
R20 THRU R25 = 40K - .02% 1W - MATCHED TO 0.01%
R26 THRU R36 = 8K - 0.05% 1/2 W MATCHED TO 0.025%
R37 THRU R47 = 16K - 0.1% 1/4 W MATCHED TO 0.05%
R48 THRU R58 = 320 OHMS - 0.1% 1/2 W - MATCHED TO 0.05%
R59 THRU R68 = 64 OHMS - 0.1% 1/2 W MATCHED TO 0.05%
R142, R143 = 112,375 OHMS - 0.05% 1W
R144 = 28,571 OHMS - 0.05% 1/2 W
R145 = 2,531.7 OHMS 0.05% 1/2 W
R146 = 250.31 OHMS 0.05% 1/2 W
R147 = 22.5K - 0.1% 1/2 W
R148 = 247.5K - 0.1% 1/2 W

6. S8 & S9 SWITCH POSITION SEQUENCE AS FOLLOWS



7. WHEN RECORDER OUTPUT PROVISION IS OMITTED, P105 & C113 ARE OMITTED. M1 IS CONNECTED DIRECTLY TO PIN 3 OF V104.





SER 6640 & ABOVE

CIRCUIT DIAGRAM		
MODEL 801 (220/234V 50/60~)	DWG 801-101	
DATE 1/15/59	DWG.	CHECKED
JOHN FLUKE MFG. CO., INC. SEATTLE, WASH.		