OPERATING AND SERVICING MANUAL

HP Part No. 405C-901

MODEL 405C/CR

SERIALS PREFIXED: 243-, 402-
219-, 120-, 114-, 101-

AUTOMATIC DC DIGITAL VOLTMETER

00518-3

Printed JUNE 1963

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I
GENERAL DESCRIPTION

1-1 IDENTIFICATION

The ℌ Model 405C Automatic DC Digital Voltmeter measures positive or negative voltages from 1 millivolt to 999 volts. It can select range and polarity automatically to display voltages from 100 millivolts to 999 volts to three significant figures.

1-2 COOLING

The 405C uses forced-air cooling to maintain tolerable temperatures within the cabinet. Exhaust fan and air outlet are located on the instrument rear air intakes, on the sides. Allow at least 2 in. clearance about instrument sides and rear for proper ventilation.

1-3 STEPPING SWITCH

The 405C uses a relay-operated stepping switch for ranging. Although the switch requires infrequent service, it is important to service it when due. See Section IV, Maintenance.

1-4 POWER LINE VOLTAGE

The 405C is normally wired for use from a 115-volt, 50-60 cps power source. To convert it for use from a 230-volt power source, change the dual 115-volt primary windings of the power transformer from a parallel combination to a series combination. See the schematic diagram for details. At the time of conversion, change the line fuse from a 2-ampere, slow-blow type to a 1-ampere, slow-blow type.

1-5 THREE CONDUCTOR POWER CABLE

This instrument is equipped with a three conductor power cable terminated with a polarized connector recommended by the National Electrical Manufacturers' Association (NEMA). The third green conductor is terminated in a round pin added to a standard two-blade connector. With the NEMA connector plugged into an appropriate receptacle, the third lead grounds the instrument cabinet for the protection of operating personnel. To use the NEMA connector in a two-contact receptacle, you should use a three-prong to two-prong adapter. The ground lead emerges from the adapter as a short green lead which should be connected to a grounded receptacle box.

1-6 DAMAGE IN SHIPMENT

Inspect and operate this instrument upon receipt. Section IV contains a performance check which is a good test as part of incoming quality control inspection. If there is any damage, see the "Claim for Damage in Shipment" sheet in this manual.

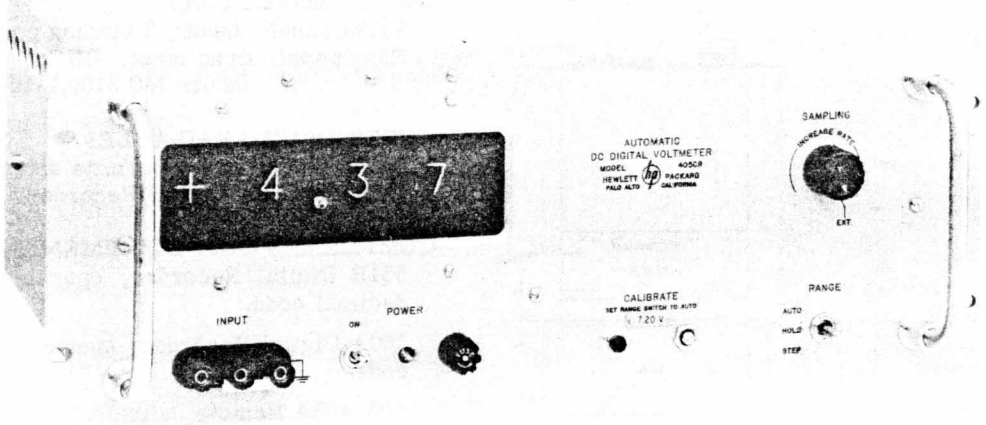


Figure 1-1. Model 405CR Automatic DC Digital Voltmeter

00518-2

Table 1-1. Specifications

RANGE:
.001 to 999 volts dc. Voltages 100 mv and higher are presented by three significant figures.

ACCURACY:
Within ±0.2% of reading +1 count.

FLOATING INPUT:
Permits measurements of systems operating within ±500 vdc of power line ground.

RANGE AND POLARITY SELECTION:
Automatic. A hold control disables the automatic selection and permits manual range selection.

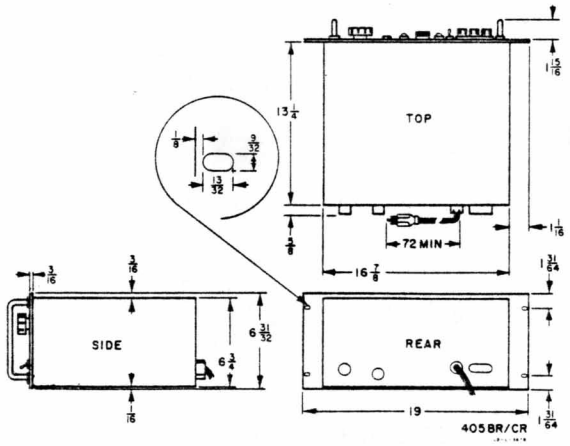
RANGING TIME:
1/5 second to 2 seconds depending on range change required.

INPUT IMPEDANCE:
11 megohms to dc on all ranges.

INPUT FILTER RESPONSE TIME:
Less than 1 second to step function.

INPUT FILTER AC REJECTION:
3 db at 1.5 cps, nominally 44 db at 60 cps

DIMENSIONS:



WEIGHT:
Net 31 lbs. Shipping 46 lbs.

POWER:
115/230 volts ±10%, 50-60 cps, 180 watts

SAMPLE RATE:
Internal: Maximum, more than 4 but less than 5 per second
Minimum, 5 seconds or more between samples

External: By 20 volt positive pulse, maximum rate of 5 per second

OUTPUT:
1) 10-line decimal code for operating ⓗⓟ Model 561B Digital Recorder or K05-405A Remote Indicator.

2) Single-line voltage coded decimal (staircase). For operating ⓗⓟ Model 560A Digital Recorder, use the 405A-95C Adapter.

3) A print command for ⓗⓟ Digital Recorders is issued after every sample except when the 405CR is ranging.

HOLD-OFF:
Internal hold-off circuit will operate from an external contact-closure.

INPUT CONNECTORS:
Front panel: Input: 3 binding posts
Rear panel: Sync Input: BNC
Input: MS 3102A-10SL-3P

ACCESSORIES AVAILABLE:
405A-95C Adapter, permits direct connection to ⓗⓟ Model 560A Digital Recorder.

COMPLEMENTARY EQUIPMENT:
561B Digital Recorder; operates from 10-line decimal code.

560A Digital Recorder; operates from staircase code.

K05-405A Remote Indicator

K07-405A Cable (100 ft max) for connecting K05-405A to 405CR.

SECTION II
OPERATING INSTRUCTIONS

2-1 AUTOMATIC OPERATION

1) Turn instrument ON. Instrument can be used within 1 minute of turn on, but requires 15 minutes warm up before calibration against internal standard brings it within specified accuracy. See paragraph 2-3.

2) Set RANGE switch to AUTO.

3) Set SAMPLING control to desired sampling rate. To control sampling rate externally, set SAMPLING control to EXT and connect triggering signal to EXT TRIGGER connector on instrument rear. Trigger must be a positive step at least 20 volts peak and have repetition rate no greater than 5 per second.

NOTE

The instrument requires about 1 second to fully respond to sudden input-voltage changes (see paragraph 2-4); therefore delay the external trigger about 1 second after any sudden change in applied voltage.

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4) Connect voltage to be measured to INPUT connector and read its value. A parallel INPUT connector is located on instrument rear.

CAUTION

When measuring voltage between two points which are both off ground potential, remove the shorting strap between power-line ground and chassis-ground terminals of front-panel INPUT connector.

2-2 MANUAL OPERATION

Manual operation permits manual selection of range and is intended for measuring voltages which produce readings of 999 or 100 regardless of decimal position. In either case, a varying input voltage might cause the instrument to continuously change ranges if it is operating automatically.

Manual operation permits measurement of some voltages to four figures, for the instrument can measure to about 150% of full scale. By holding the instrument on the range just below the correct range, you obtain the second, third, and fourth figures from the readout; the first figure, which is lost, is always 1. However, instrument accuracy deteriorates above full scale.

Manual operation is convenient for measuring a series of voltages quite close in value, for the instrument will not cycle through its ranges as you move the probe from one test point to another.

1) Set RANGE switch to HOLD. Instrument will remain on its displayed range.

2) To change ranges, set RANGE switch to STEP. This is a spring-loaded position, and switch returns to HOLD when released. Instrument steps to next more positive range each time you release RANGE switch from STEP except that three blank positions occur between +9.99 and +99.9 volt ranges. The decimal point is not lighted on the blank ranges.

2-3 CALIBRATION

The 405C has an internal secondary voltage standard to check its calibration. The push-button CALIBRATE switch, located on the front panel, applies this voltage to the instrument and disconnects the INPUT connector. Calibrate the instrument, after sufficient warm up, each time you turn it on. Once set, calibration need seldom be checked. Proceed as follows:

1) Turn instrument ON and allow 15-minute warm up.

2) Set SAMPLING control to maximum sampling rate (full clockwise but not to EXT).

3) Set RANGE switch to AUTO.

4) Note voltage indicated below CALIBRATE engraving on front panel. This is the internal secondary standard voltage.

5) Press CALIBRATE switch and adjust CALIBRATE control until readout agrees with internal secondary standard voltage.

2-4 INPUT FILTER

The 405C measures instantaneous dc voltages. To avoid readout variations due to superimposed ac signals, the instrument has a low-pass RC filter at its input. The filter has a sharp cutoff and attenuates 60-cps signals about 50 db. Thus a 60-cps signal with a peak value equal to full scale of the displayed range typically causes a readout variation of ±4 counts.

Since the filter is at the input, it becomes charged to the full value of the input voltage. With the input open-circuited (probe lifted off test point), the filter capacitors must discharge through the input attenuator, and after 2 seconds they still have about 37% of their original charge. (You can see the discharge by watching the readout decrease after the probe is removed from a voltage source.) Therefore, if you quickly change the probe from a high-voltage point to a low-voltage point, you will apply nearly the full high voltage stored in the filter capacitors to the low-voltage point through 500K resistance. If the low-voltage point happens to be a high-impedance point such as a vacuum tube grid or, possibly, a transitor element, the voltage applied through the probe may upset circuit operation to the point that the circuit will damage itself. A GOOD OPERATING PRACTICE IS TO TOUCH THE PROBE TO GROUND BRIEFLY OR ALLOW THE FILTER SUFFICIENT TIME TO DISCHARGE WHEN CHANGING THE PROBE FROM HIGH-VOLTAGE POINTS TO LOW-VOLTAGE POINTS. In any case be sure the readout is less than the expected voltage before connecting the probe into a low-voltage circuit.

The input filter makes instrument response to step functions about 0.75 second compared to about 0.2 second between successive samplings at maximum sampling rate. If you require a response time compatible with maximum sampling rate, remove C1 and replace C2 with two 0.02-μf, 600-vdcw, polystyrene-dielectric capacitors in series.

CAUTION

Since the two capacitors are in series, one will be off ground potential. Be sure to insulate the off-ground capacitor from the chassis.

Response time will then be about 50 msec. However, ac rejection will be much less than with the standard filter. For example, a 60-cps signal with a peak value equal to full scale of the displayed range will cause readout variations as much as ±200 counts.

2-5 OPERATION WITH DIGITAL RECORDERS

With hp Model 560A or 561B Digital Recorder you can obtain permanent printed records of 405C measurements. An example of printed records is shown below. The 3rd, 4th and 5th columns from the right show the digits that appear on the 405C. The 2nd column from the right indicates polarity, blank for positive and (-) for negative. The right-hand column indicates decimal location from the right.

Voltmeter Indication	Printed Record
+ 3.48	348 2
- 565.	565-0
+ .283	283 3

The 405C can drive the 561B directly; the standard 561B cable makes the necessary connections between the voltmeter and recorder. However, the 405A-95C Digital Recorder Adapter is required to connect the 405C to the 560A. The adapter mates with the 100-pin output connector on the rear of the 405C and is held in place by two machine screws. The standard 560A cable connects to the adapter. When connecting either recorder to the 405C, be sure both the recorder and 405A are turned off.

CAUTION

The 405C chassis is connected to power-line ground through the adapter/550A system. Do not connect the voltmeter common lead to an off-ground potential while the 560A is connected to the voltmeter. This caution also applies when using 405C with Models 561, 562 with dual input couplers.

2-6 ELECTRICAL OUTPUT INFORMATION

You can use the electrical information provided by the 405C for other purposes than operating a recorder. For example, you might use the information to operate a remote readout identical to the one in the instrument or to record voltage information on punched cards or tape. Table 2-1 gives full details of the information available.

TABLE 2-1. J3 OUTPUT CONNECTOR CHART

Connector A (upper)		Connector B (lower)	
Pin	Function	Pin	Function
1	999-v range	1	0
2	99.9-v range	2	1
3	9.99-v range	3	2
4	999-v range — Decimal information[1]; stepping switch stator; also see pin 44, J3A.	4	3
5-11	No connection	5	4
12	Jumpered to pin 38, J3A.	6	5 — Ten-line code, tens counter[3].
13	+120v ±10%[2]	7	6
14	Polarity information: 0 volt on positive ranges, +110 volts on negative ranges; maximum external load: 100K.	8	7
15	Polarity information: +110 volts on positive ranges, 0 volt on negative ranges; maximum external load: 20K	9	8
16-25	No connection	10	9
26	0	11	No connection
27	1	12	Jumpered to pin 13, J3B
28	2	13	Jumpered to pins 12 and 14, J3B
29	3 — Ten-line code, units counter[3]; lighted numeral: <+40 volts	14	Jumpered to pin 13, J3B
30	4	15	No connection
31	5 — dark numeral: approx. +100 volts	16	9
32	6 — maximum load per pin: 500K	17	8
33	7 — with pin 13, J3A as reference	18	7
34	8	19	6 — Ten-line code,
35	9	20	5
36	No connection	21	4 — hundreds counter[3]
37	Jumpered to pin 38, J3A	22	3
38	Jumpered to pins 37 and 12, J3A	23	2
39	No connection	24	1
40	+300v ±10% for remote control. Connect to J3A pin; 47 externally for remote control of 405C.	25	0
41-43	No connection	26-38	No connection
44	Decimal information[1]; stepping switch rotor; also see pins 1-4, J3A	39	Staircase, units counter[4]; +135 volts at count of zero, equal steps to +55 volts at count of nine; external load does not affect counting but will affect staircase voltage levels; internal imped. 700K.
45-46	No connection	40	Staircase, tens counter[4]
47	Remote holdoff (see J3A pin 40)	41	Staircase, hundreds counter[4]
48	Print command: -20 volt pulse	42	405C chassis ground (10 ohms to chassis ground when K4 energized).
49	Differential print command load: 100K (R107) to 405C chassis	43	+300 volts regulated from external source; necessary only when regulated staircase required.
50	Power-line ground	44	±110 volts dc from external source to energize K4, which then connects +300 volts supplied at pin 43 to decade counters.
		45	6.3 volts ac
		46-50	No connection

[1] Decimal information can be either four-line code or staircase code. For four-line decimal information, apply a voltage to pin 44, J3A; this voltage is then connected to pin 1, 2, 3, or 4 of J3A depending on the selected range. For staircase decimal information, apply different voltages to pins 1 through 4, J3A; the voltage corresponding to the range selected is then connected to pin 44, J3A.

[2] Pin 13, J3A is the ten-line code reference. Avoid applying any load between this pin and ground; use the voltage as a reference or bias voltage only.

[3] To utilize ten-line code information, use pin 13, J3A, as the common return; that is, any load on pins 26-35 of J3A, 1-10 and 16-25 of J3B must return to pin 13, J3A. It is best to connect any external chassis to pin 13, J3A; however, the external chassis will then be about 120 volts positive with respect to power-line ground and so must have no common connection with power-line ground. The dark-numeral ten-line code voltages require a finite time to reach the final +120 volts; however, they are at least +50 volts at the time of the print command.

[4] The +300 volts internally supplied to the counter units is not regulated; thus the staircase voltages are not normally regulated. To obtain regulated staircase voltages, supply regulated +300 volts at 45 ma to pin 43, J3B, and ±110 volts at 12.5 ma to pin 44, J3B, to energize relay K4, which then applies the external +300 volts to the counter units.

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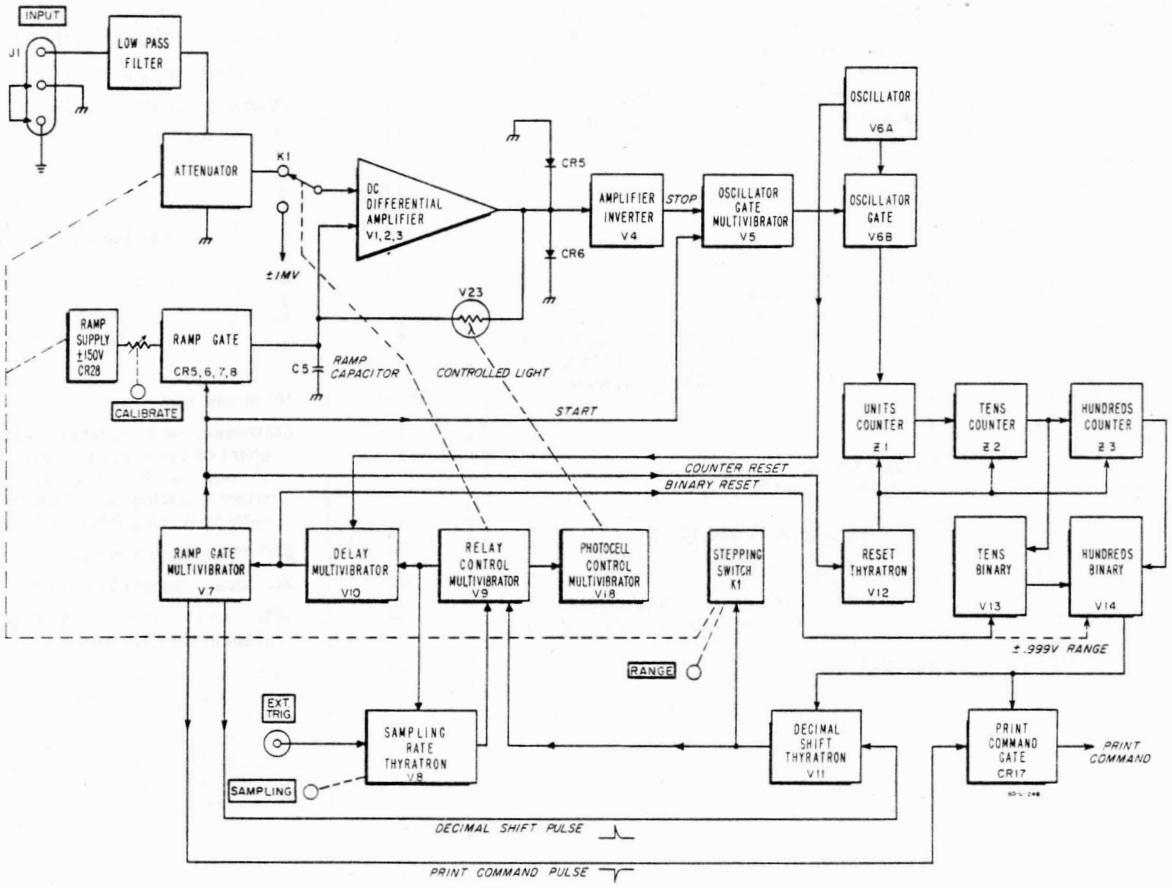


Figure 3-1. Model 405C Block Diagram

SECTION III
THEORY OF OPERATION

3-1 INTRODUCTION

The 405C is a voltage-to-time converter. It measures the time required for an internally generated voltage (ramp) to increase from essentially zero to the value the input voltage has after passing through an input filter and attenuator. Three decade counters indicate elapsed time by totalizing the output of a 50-kc oscillator for the duration of the time interval. Thus the readout is a number of time units or periods of the 50-kc signal. Ramp slope is such that the readout equals the input voltage.

The 405C requires about 0.2 second to make a single measurement; it does not continuously monitor its input voltage as do meter-movement types of voltmeters. During the measurement time, the 405C zero-sets itself, makes a measurement, checks range, and if necessary, changes range. The SAMPLING control determines the rate at which measurements are repeated except that if the instrument is on the wrong range, it will shift range and remeasure at its maximum rate until it finds the correct range.

Figure 3-1 is an over-all block diagram of the Model 405C.

3-2 INPUT CIRCUIT

The input circuit consists of a Low-Pass Filter and an Attenuator. The Low-Pass Filter attenuates any ac voltage superimposed on the dc voltage being measured. Cut-off characteristics of the filter are such that a 60-cps signal with a peak value equal to full scale of the displayed range causes a readout variation of about ±4 counts.

Four series resistors make up the Attenuator and provide 1:1, 10:1, 100:1, and 1000:1 attenuation. Stepping switch K1, controlled automatically or by the front-panel RANGE switch, selects the appropriate degree of attenuation for the displayed range. Since the Low-Pass Filter introduces some attenuation even to dc voltages, the output of the Attenuator is less than ±0.999 volt when the displayed range is correct.

3-3 VOLTAGE-TO-TIME CONVERSION

The 405C measures the time required for the ramp voltage to increase from essentially zero to the value of the attenuated input voltage. The ramp voltage is the voltage developed across the ramp capacitor as it charges through a series resistance toward ±150 volts. The polarity of the 150 volts is the same as the polarity of the selected range. The CALIBRATE control permits some adjustment of the series resistance to allow adjustment of the ramp slope.

Ramp Gate Multivibrator V7 starts the time measurement when it opens the Ramp Gate (CR5, CR6, CR7 and CR8) and triggers Oscillator Gate Multivibrator V5. The Oscillator Gate Multivibrator opens the Oscillator Gate, V6B, and the counters start totalizing the output of Oscillator V6A.

A DC Differential Amplifier (V1, V2 and V3) ends the time measurement by producing a voltage step when ramp voltage equals the attenuated input voltage. The amplifier has two input grids and amplifies the difference between the two applied voltages a thousand times. Two crystal diodes limit the voltage swing at the output of the amplifier to about 1 volt; thus there is no change in amplifier output until the ramp voltage is within about 0.5 millivolt of the attenuated input voltage. As the ramp voltage equals and becomes greater than the attenuated input voltage, the amplifier output quickly goes from one limit to the other, producing the voltage step. Amplifier Inverter V4 amplifies this voltage step and inverts it, if necessary, to provide a negative-going input to the Oscillator Gate Multivibrator. This multivibrator then closes the Oscillator Gate,

and the counters display the total number of pulses which passed through the gate.

The Ramp Gate Multivibrator returns to its stable condition, closing the Ramp Gate, about 30 milliseconds after it starts the ramp; and should there be no output from the amplifier, the Oscillator Gate Multivibrator returns to its stable condition at about the same time. Thus the instrument can count to about 1-1/2 times full scale.

3-4 ZERO-SETTING THE VOLTMETER

To insure that the ramp always starts from the correct voltage, the ramp is zero-set prior to each measurement. Two multivibrators, Relay Control Multivibrator V9 and Photocell Control Multivibrator V18 zero-set the ramp. The Relay Control Multivibrator energizes a relay which applies a voltage of approximately ±1 mv to the signal input grid of the amplifier. The polarity of the voltage is always opposite to the polarity of the displayed range. The Photocell Control Multivibrator illuminates a photocell V23 in a feedback loop around the amplifier. When the photocell is illuminated its resistance drops to a low value, and full negative feedback is applied to the amplifier. Thus any voltage at the amplifier output is fully fed back to the input and essentially cancelled. Because of the internal unbalance and drift in the amplifier, plus the ±1 mv applied to the signal input grid, cancellation is not complete. This feedback brings the amplifier output and the corresponding ramp grid input down to less than ±100 mv. The ramp is zero-set at this time, since the ramp capacitor is connected to the ramp grid of the amplifier and charges to the feedback voltage. Amplifier drift is not fast enough to upset the balance in the time of a single measurement. Thus the ramp always starts from the same zero-set value.

The Photocell Control Multivibrator opens the feedback loop (by turning off the light shining on the photocell) before the Relay Control Multivibrator de-energizes the relay. Thus the input signal voltage is applied to the amplifier after the feedback loop opens and cannot upset the ramp zero level. Amplifier output has been reduced to less than ±100 mv as explained in the previous paragraph. With no input the output remains at this level. However, the amplifier gain has gone up to approximately 1000 when the photocell is not illuminated. Since the signal at the output remains at less than ±100 mv, the effect of this additional gain is to reduce the apparent input to the amplifier by the amount of the gain. Thus the apparent input level has been reduced to less than ±100 μv. Therefore the voltmeter is zero-set to within 100 μv of zero.

3-5 THE MEASUREMENT PROCESS

Sampling Rate Thyratron V8 starts the measurement process by triggering the Relay Control Multivibrator, V9. The Relay Control Multivibrator immediately triggers Photocell Control Multivibrator V18, and these two multivibrators zero-set the ramp. After about 80 msec, the Photocell Control Multivibrator returns to its stable condition, darkening the photocell. Some 30 msec later the Relay Control Multivibrator returns to its stable condition, de-energizing the relay and triggering Delay Multivibrator V10. The Delay Multivibrator allows the relay to completely de-energize before the start of the ramp. The delay is about 4 msec.

When the Delay Multivibrator returns to its stable condition, it triggers the Ramp Gate Multivibrator, V7, to start the ramp and open the Oscillator Gate, V6B. Oscillator V6A synchronizes the return of the Delay Multivibrator to its stable condition. Thus there is no count ambiguity at the start of the ramp. When the ramp voltage equals the attenuated input voltage, the DC Differential Amplifier closes the Oscillator Gate, and the readout indicates the voltage applied to the instrument.

3-6 CHECKING RANGE

During each measurement the 405C checks the range by monitoring the output of the Tens and Hundreds Counters. If there is no output from the Tens Counter, the range is too high, for the ramp voltage equals the attenuated input voltage before the counters register 100 counts. If the Hundreds Counter produces an output, the range is too low, or the displayed polarity is wrong, for the counters count off scale before the ramp voltage equals the attenuated input voltage. Thus the range is correct only when the Tens Counter produces at least one output pulse, while the Hundreds Counters produce none. However, on the most sensitive ranges, (±. 999 v), the Tens Counter is effectively bypassed. This action permits the counters to display levels of less than 100 counts, during which time the Tens Counter is unable to produce an output pulse.

Tens Binary V13 and Hundreds Binary V14 do the monitoring. The Tens Binary is reset by Delay Multivibrator V10 when that multivibrator triggers the Ramp Gate Multivibrator. The Tens Binary in turn resets the Hundreds Binary. (Binaries have two stable conditions. Hereafter, condition 0 is the reset condition; condition 1, the non-reset condition.) With no output from the Tens Counter, both binaries remain in condition 0. The first output pulse from the Tens Counter switches the Tens Binary to condition 1, and the Tens Binary immediately switches the Hundreds Binary to condition 1 also. Succeeding pulses from the Tens Counter

have no effect. The first output pulse from the Hundreds Counter switches the Hundreds Binary back to condition 0. Succeeding pulses have no effect. Therefore, if the measurement ends with the Hundreds Binary in condition 1, the range is correct; if the measurement ends with the Hundreds Binary in condition 0, the range is wrong.

There is a direct reset line from the Delay Multivibrator to the Hundreds Binary (not shown in Figure 3-1); so the Delay Multivibrator directly resets the Hundreds Binary in the event the Tens Binary is in condition 0 and the Hundreds Binary in condition 1, should this combination occur. Also, on the ±. 999 v range, when no logic pulse is available from the now by-passed Tens Binary, this line serves to reset the Hundreds Binary to condition 0, where it remains. However, if the range is too low, an output pulse will be produced by the Hundreds Counter which immediately resets the Hundreds Binary to condition 1.

3-7 DECIMAL SHIFT CONTROL

The Hundreds Binary determines whether or not the 405C shifts range by controlling Decimal Shift Thyratron V11 and Print Command Gate CR17. When in condition 1 (correct range), the Hundreds Binary holds the Decimal Shift Thyratron off and opens the Print Command Gate. When in condition 0 (wrong range), the Hundreds Binary lets the Decimal Shift Thyratron fire if triggered and closes the Print Command Gate.

When the Ramp Gate Multivibrator returns to its stable condition and closes the Ramp Gate, it applies a positive pulse to the Decimal Shift Thyratron and a negative pulse to the Print Command Gate. If the range is correct, the negative pulse passes through the Print Command Gate to be used as a trigger for a remote recorder. The Decimal Shift Thyratron is held off. If the range is wrong, the Print Command Gate is closed, but the positive pulse fires the Decimal Shift Thyratron. The Decimal Shift Thyratron then shifts the instrument to the next more positive range (by moving Stepping Switch K1 one step) and triggers Relay Control Multivibrator V9 to start another measurement.

When triggered, the Relay Control Multivibrator triggers Sampling Rate Thyratron V8. The Sampling Rate Thyratron then cannot fire during a measurement started by the Decimal Shift Thyratron.

To prevent continual recycling when the 405A measures voltages from +0. 099 to -0. 099 volt, the Hundreds Binary is reset to condition 1 on the +. 999 and -. 999 volt ranges. Thus the instrument shifts from these ranges only after off-scale counts.

SECTION IV
MAINTENANCE

4-1 INTRODUCTION

This section contains maintenance and servicing information for the 405C with the exception of its decade counter units. Information covering these units is contained in the AC-4 Decade Counter Manual.

Included in this section is a performance check to verify instrument operation. The check can be made with the instrument in its cabinet and is a good test as part of preventive maintenance and incoming quality control inspection.

The stepping switch used for ranging requires periodic cleaning and lubrication. It is important to service it when due. See paragraph 4-9.

4-2 TEST EQUIPMENT

The following is a list of recommended test equipment for servicing and trouble shooting your 405C:

1) A dc voltmeter having an input resistance of at least 100 megohms. Recommended hp equipment: 410B Vacuum Tube Voltmeter or 412A DC Vacuum Tube Voltmeter.

2) Trigger generator to provide a 20-volt positive pulse for triggering the 405C externally. Recommended hp equipment: 202A Low Frequency Function Generator.

3) Calibration generator to check calibration and tracking of the 405C. Generator output should be adjustable in steps of millivolts, tenths of volts, and volts, and should be accurate within 0.1%. Recommended hp equipment: Model 738AR Voltmeter Calibrator.

4) Oscilloscope to check circuit waveforms. The oscilloscope should have an upper frequency limit of at least 200 kc. Recommended hp equipment: 120A Oscilloscope.

5) Ohmmeter. Recommended hp equipment: 410B Vacuum Tube Voltmeter or 412A DC Vacuum Tube Voltmeter.

6) Variable power transformer to vary line voltage between 103, 115 and 127 volts. The transformer should have a current capacity of at least 3 amps, and its output voltage should be monitored by a voltmeter accurate within ±1 volt.

4-3 PERFORMANCE CHECK

A. TRACKING AND RANGING CHECK

1) Turn instrument on, set line voltage to 115 volts, and allow 5-minutes warm up.

2) Set RANGE switch to AUTO and SAMPLING control to maximum (clockwise) but not to EXT.

3) Connect calibration generator to 405C INPUT connector and adjust generator output to +0.8 volt. Adjust 405C CALIBRATE control to produce readout of +.800.

4) Check 405C readout against calibration generator output voltages listed below; 405A indication should be within 0.2% ±1 count of generator output at all voltages.

000	+.1	+.8	+20
+.001	+.2	+.9	+30
+.002	+.3	+1	+50
+.003	+.4	+2	+100
+.010	+.5	+3	+200
+.02	+.6	+5	+300
+.03	+.7	+10	

5) Repeat step 4 for negative voltages.

6) Repeat step 4 and 5 at line voltages of 103 and 127 volts.

B. EXTERNAL TRIGGER CHECK

1) Set SAMPLING control to EXT.

2) Connect trigger generator to EXT TRIG connector on rear of 405C.

3) Adjust trigger generator output for positive pulse (square wave will do) 20 volts peak. Set trigger repetition rate to 5 per second and observe 405C readout. If it is not apparent that 405C is sampling five times per second, vary voltage applied to INPUT connector and watch rate at which readout changes.

C. CALIBRATION STANDARD CHECK

(Instrument must have 15 minutes warm up before you make this check.)

1) Set SAMPLING control to maximum (clockwise) but not to EXT, and set RANGE switch to AUTO.

2) Connect calibration generator to 405C INPUT connector and adjust generator output to +0.8 volt.

3) Adjust 405C CALIBRATE control to produce readout of +.800.

4) Press CALIBRATE switch; readout should agree with voltage stamped on tag under CALIBRATE engraving on front panel.

D. MANUAL RANGING CHECK

1) Set RANGE switch to HOLD. Range should remain constant regardless of voltage applied.

2) Set RANGE switch to STEP and release. Instrument should step to next more positive range except that three blank positions occur between +9.99 and +99.9 volt ranges. The decimal point is not lighted on the blank ranges.

4-4 CABINET REMOVAL

The 405C has top and bottom dust covers. Each cover is held by two screws in the rear. When sliding either cover off, you may have to lift the front edge of the cover to clear internal components.

NOTE

Turn the 405C off before removing or replacing the dust covers.

4-5 POWER SUPPLIES

Check power supply voltages and regulation as part of routine maintenance and as a first trouble-shooting step. If the voltages are essentially correct and properly regulated (the +300 and +120 supplies are not regulated), the supplies are operating properly.

You can check regulation of the power supplies by monitoring their voltages while varying line voltage between 103 and 127 volts. The regulated voltages should vary only slightly, if at all, from the value measured at a 115-volt line. Figure 4-5 shows convenient points to measure the voltages.

The 250-volt supply is the only adjustable supply, and it should seldom require resetting. If you do adjust it, use a voltmeter accurate within 3% of full scale and following the adjustment check amplifier balance (paragraph 4-6) and neutralization (paragraph 4-7).

4-6 BALANCING THE AMPLIFIER

1) Remove top dust cover.

2) Set line voltage to 115 volts, turn instrument on and allow 5-minutes warm up.

3) Set RANGE switch to AUTO and SAMPLING control to maximum (clockwise) but not to EXT.

4) Connect calibration generator to 405C INPUT connector and set generator output to +0.8 volt (any convenient voltage will do provided you can change its polarity without changing its amplitude).

5) Adjust CALIBRATE control until voltmeter reads +.800.

6) Change calibration generator output to -0.8 volt.

7) Adjust Coarse Bal R14 until 405C reads -.800.

8) Repeat steps 4 through 7 until 405C reads +.800 and -.800 without adjustment.

4-7 NEUTRALIZING THE AMPLIFIER

1) Remove bottom dust cover.

2) Set line voltage to 115 volts, turn instrument on, and allow 5-minutes warm up.

3) Set RANGE switch to AUTO and SAMPLING control to maximum but not to EXT.

4) Connect direct short across 405C INPUT.

5) Adjust Amp Neut control C10 to set readout to ±.000. This control is mounted on socket of V3.

4-8 405A-95C ADAPTER ADJUSTMENT

The only adjustment required by the 405A-95C Digital Recorder Adapter is the adjustment of the staircase voltages for range indication on the Model 560A Digital Recorder. Proceed as follows:

1) Connect Adapter to Recorder only and turn Recorder on.

2) Adjust R302 (A) and R308 (B) in Adapter until voltages at pins 1 and 4 of P301A are +169 and +119 respectively. Use the 405C to measure the voltages, for they should be set as close as possible to their correct values.

4-9 STEPPING SWITCH MAINTENANCE

The stepping switch should be kept clean and well lubricated. Inspect the switch according to the schedule below and add lubricant or clean and relubricate as necessary.

1) After 30,000 revolutions or three months, whichever is first.

2) After each additional 150,000 revolutions or six months, whichever is more frequent.

To obtain the best results from maintenance lubrication, first wipe the parts as clean as possible. If the switch is excessively dirty, clean it with a high-quality cleaner such as xylene which does not leave a film upon evaporation.

A lubrication kit consisting of three types of lubricant, each in a small bottle, is included with your instrument. Each bottle has a geometric figure (and the switch manufacturer's specification number) on it for easy identification in the lubrication procedure below. Each bottle cap has attached to it the type of brush best suited for the particular lubricant.

When lubricating the stepping switch, it is important to apply the right amount of lubricant. Too much can be as bad as not enough. To assure the proper amount, the term "dip" will be used as a guide. To obtain one "dip" of lubricant, dip the brush into the lubricant, then wipe the brush against the side of the bottle to remove the drop that forms at the end of the brush. In most cases one dip will be enough to lubricate several parts. Brush the lubricant lightly over the parts. Do not scrub the brush on the parts because such action usually results in too much lubricant on the first part and too little on the others.

During manufacture the undercut portion of the wiper shaft is filled with ANG-3-A grease, and a small portion of this grease is applied to the end of the shaft opposite the mounting hub before the shaft is assembled into the hub. This lubrication is good for the life of the switch and needs replacing only when the wiper assembly is replaced.

A. EXPOSING THE SWITCH FOR LUBRICATION

1) Remove stepping switch cover. See Figure 4-4.

2) Remove nuts that hold stepping switch mounting bracket to deck.

3) Remove screws holding switch to bracket and remove bracket.

4) Lift switch up through deck. You may have to remove relay K2 to make room. Reverse procedure to replace switch.

B. LUBRICATING THE STEPPING SWITCH

The lubricating points for the stepping switch are shown in Figure 4-1.

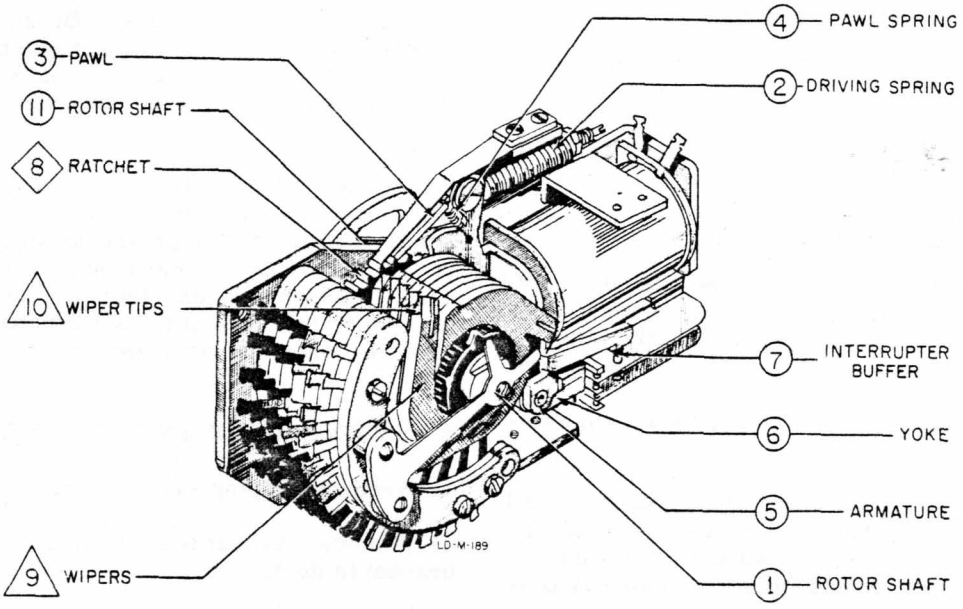
4-10 TUBE AND DIODE REPLACEMENT

A. TUBE REPLACEMENT

In many cases of instrument malfunction, the cause is a weak or defective tube. Locate the trouble as nearly as possible and check the tubes in the suspected circuits.

The best tube checker is the circuit in which a tube must operate. Check tubes by substitution and replace the original one if a new one does not restore proper circuit operation. However, if circuit condition (burned resistor, etc.) indicates that the original tube may be shorted or otherwise mechanically defective, check the tube on a "tube tester" before returning it to the circuit.

STEPPING SWITCH LUBRICATION DIAGRAM



○ USE BLENDED LUBRICATION OIL SPEC.5684

1. Apply one dip of oil on rotor shaft at point (1) and another at point (11). (Point (11) is not visible on the figure but is between the ratchet and the frame.)

2. Press on pawl pin to push pawl away from armature, and wipe parts of a dip between pawl (3) and armature.

3. Press sideways on pawl to push head of pawl pin away from armature, and wipe brush between head of pawl pin and armature. Spread rest of this dip through coils of pawl spring (4) and driving spring (2) and into holes in armature and pawl where pawl spring is engaged.

4. Push armature sideways, away from mounting frame, and wipe a dip between armature (5) and yoke (6), and around armature pin where it passes through yoke near mounting frame.

5. Push armature sideways toward mounting frame and wipe lubricant between armature and yoke on mounting-frame side of yoke, and around armature pin where it passes through yoke away from mounting frame.

6. Brush rest of this dip on interrupter-spring buffer where it strikes armature (7).

◇USE SWITCH LUBRICANT SPEC.5232-C

Wipe one dip over and between ratchet tooth on one half of ratchet, ◇8◇, and wipe second dip on other half of ratchet.

△USE WATCH OIL SPEC.5228

1. Using one dip per wiper pair, apply oil near the center of each wiper, △9△, at a point where it will contact tip of brush spring. The brush spring is part of first switch contact and makes permanent contact with wiper. Rotate wiper to distribute oil.

2. Using one dip for each group of wiper tips, apply oil between the wiper tips △10△. Oil the switch contacts by rotating the wipers. Oil all wiper tips.

Following lubrication, wipe lubricant from all parts and surfaces you did not intend to lubricate.

Figure 4-1. Stepping Switch Lubrication Diagram

You can use any tube with corresponding EIA (JEDEC) characteristics for replacement. If you replace any of the DC Differential Amplifier tubes (V1, V2 or V3) check both the coarse balance and amplifier neutralization adjustments (paragraphs 4-6 and 4-7).

B. DIODE REPLACEMENT

The crystal diodes used in the 405C are special high-performance, junction-type silicon diodes. These diodes are manufactured by Hewlett-Packard Company and are available from your hp Representative. Whenever possible use hp diodes for replacement.

You can check the diodes either by replacement or by measuring forward and reverse currents. With 1 volt forward bias at 25°C (77°F), the diodes should pass at least 3 ma. With 5 volts reverse bias at 25°C, the Ramp Gate diodes (CR5, CR6, CR7 and CR8) should pass 10 mμa or less, and all other diodes should pass 200 mμa or less.

CAUTION

Do not apply more than 5 volts reverse bias to these diodes. Excessive reverse bias may destroy them.

4-11 TROUBLE SHOOTING

The following is a systematic procedure for locating trouble in the 405C:

1) Visually check instrument for obvious indications such as open tube heaters. If there is no obvious defect, proceed to step 2.

2) Check power supply voltages and regulation. Proceed to step 3 only if the power supplies operate properly.

3) Check front-panel symptoms against those of Table 4-1, and/or check waveforms against those of Table 4-2B. Unless symptoms point to specific circuits, check waveforms in the order given in the table.

4) Check tubes, voltages, and resistances throughout suspected circuits to locate faulty components. See Figures 4-6 and 4-7 for typical voltages and resistances. If the counter units are at fault, see AC-4 Decade Counters manual.

To locate the trouble first check all supply voltages. After all supply voltages are correct refer to Table 4-2A and check the waveforms in the instrument against those shown. When a faulty waveform appears in the instrument find the faulty component in that section of the instrument by standard troubleshooting methods. After the waveforms are correct refer to Table 4-2B, troubleshooting the Amplifier, if the instrument still malfunctions.

TABLE 4-1. TROUBLE-SHOOTING AID
Set RANGE switch to AUTO and SAMPLING control for about one sample per second

Symptom	Possible Cause	Symptom	Possible Cause
Readings unstable except near zero	Ramp supply regulator V15	Changes range continuously except when .999 volt or less applied	Tens binary V13
Readout zero regardless of voltage applied	Oscillator V6	Changes range continuously regardless of voltage applied, readout changes with range	Hundreds binary V14
Range and readout constant regardless of voltage applied	Timing chain: V7, V8, V9 or V10	Range constant regardless of voltage applied	Decimal shift thyratron V11
Counters do not return to zero before each sampling (set RANGE switch to HOLD to prevent range changing)	Reset thyratron V12	Changes range continuously regardless of voltage applied, readout approximately constant	Amplifier V1,V2,V3
Counters count continuously (all numbers lighted)	Oscillator gate multivibrator V5		Amplifier inverter V4

TABLE 4-2A. WAVEFORMS

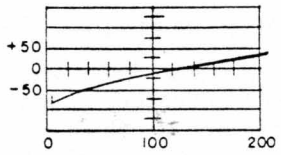
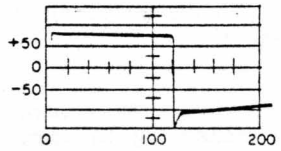
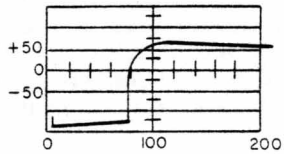
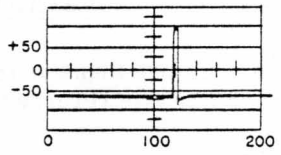
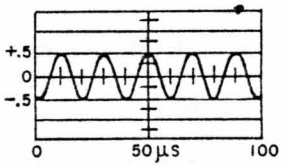
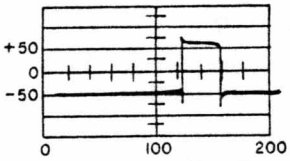
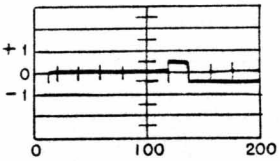
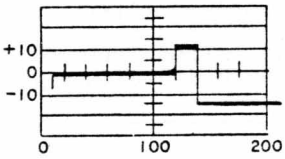
Conditions of measurement: Instrument on +9. 99 volts range RANGE switch to HOLD		SAMPLING control to maximum (not EXT) INPUT shorted	
Test Point	Oscilloscope Synchronization	Oscilloscope Sweep Speed	Normal Indication
1 Junction R61, R64	External at Junction R61 R64 (negative-going part of waveform)	20 ms/cm	
2 Pin 6, V9	Same as 1	20 ms/cm	
3 Pin 6, V18	Same as 1	20 ms/cm	
4 Pin 6, V10	Same as 1	20 ms/cm	
5 Pin 2, V10	Internal	10 μsec/cm	
6 Pin 1, V7	External at Junction R61, R64 (negative-going part of waveform)	20 ms/cm	
7 Pin 7, V4	External at Junction R61 R64 (negative-going part of waveform) - press 405C CALIBRATE switch	20 ms/cm	
8 Pin 1, V4	Same as 7	20 ms/cm	

TABLE 4-2A. WAVEFORMS (CONT'D)

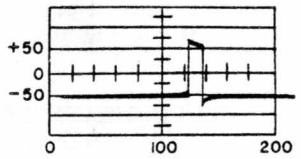
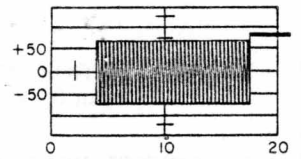
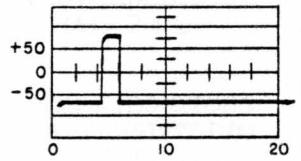
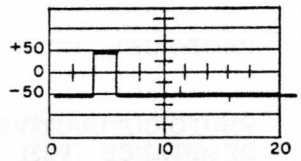
Test Point	Oscilloscope Synchronization	Oscilloscope Sweep Speed	Normal Indication
9 Pin 6, V5	Same as 7	20 ms/cm	
10 Pin 3, XZ1A	External at pin 1, V10 with input (negative-going part of waveform)	20 ms/cm	
11 Pin 1, V13	Same as 10	20 ms/cm	
12 Pin 1, V14	Same as 10	20 ms/cm	

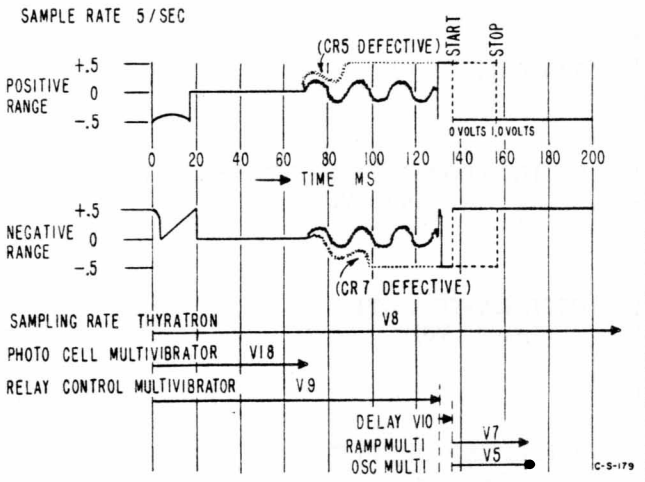
TABLE 4-2B. TROUBLESHOOTING THE AMPLIFIER

Make sure all waveforms agree with those shown in Table 4-2A before proceeding further.

1) Connect an oscilloscope for external synchronization (negative input) from pin 6, V8 of the Model 405C. Connect vertical input to pin 7, V4 of Model 405C.

2) Momentarily depress the RANGE switch until the instrument is on the +1 volt range (polarity sign and decimal light lit as shown in the title page photograph).

3) Compare waveforms. If different, trouble is in amplifier. Determine where waveform first deviates from that shown. Arrows at bottom show time relationship of the operation cycle of the tubes called out by V numbers. Comparison of point of deviation of waveform and time relationships will determine faulty section. If you obtain proper waveform but instrument still malfunctions, check decade counters, oscillator gate multivibrator or oscillator.



The following represent all the major waveshapes in the instrument in proper time relationship.

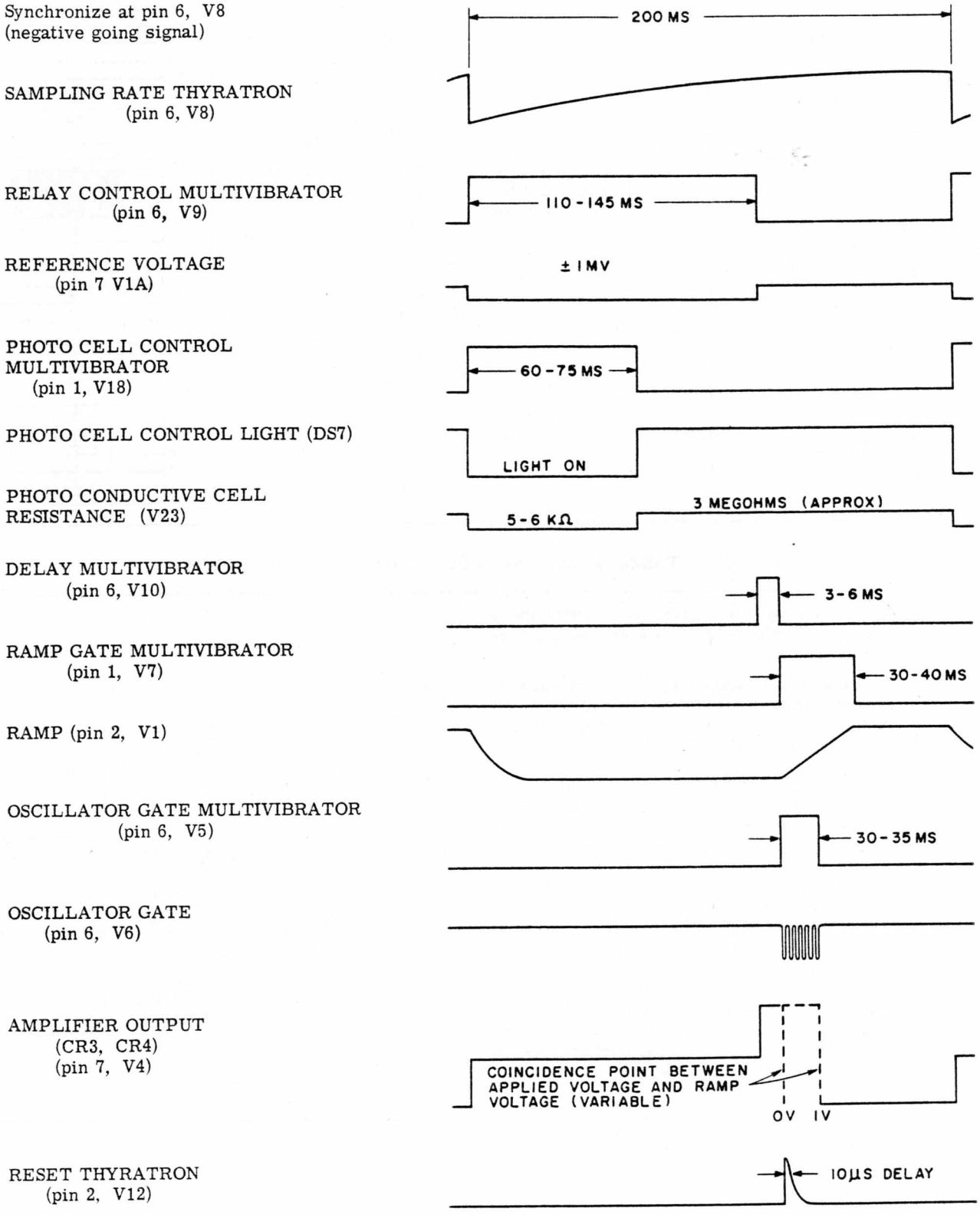
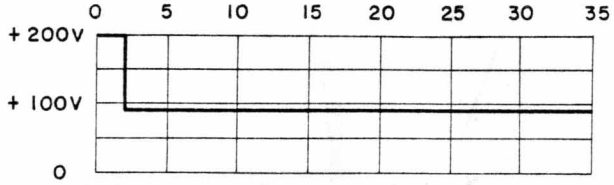


Figure 4-2. Troubleshooting Waveform Time Sequence

The following are normal waveshapes which will enable you to find trouble in the automatic ranging section of the instrument.

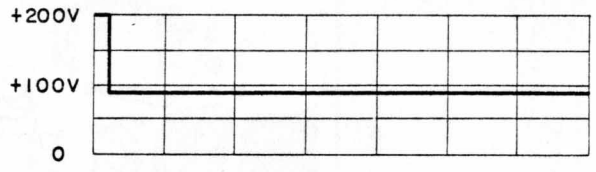
Connect vertical input of oscilloscope to pin 1 V14 (Hundreds Binary). Synchronize (negative going dc coupled) on pin 6 of V10 (Delay Multivibrator) with RANGE switch on HOLD. Sweep speed 5 milliseconds per centimeter.

Range ± 1 to 9.99V.
Input greater than 1V, but less than 10 volts.
(± indicates both either + or -)



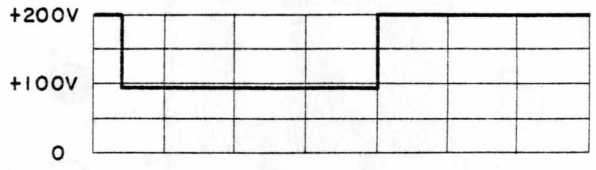
Model 405 should not range in AUTO position.

Range ± .0001 to .999V.
Input less than ± 1 volt.



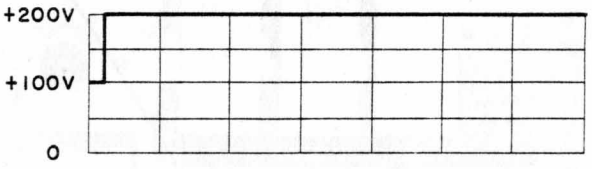
Model 405 should not range in AUTO position.

Range ±1 to 9.99V.
Input greater than ± 10 volts.



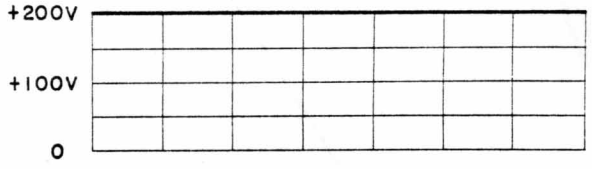
Model 405 should range in AUTO position.

Range +1 to 9.99V.
Input +0.9 volts.



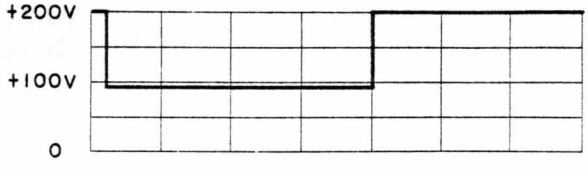
Model 405 should range in AUTO position.

Range +1 to 9.99V.
Input +0.4 volts



Model 405 should range in AUTO position.

Range ± .001 to .999V.
Input greater than ±1 volt.



Model 405 should range in AUTO position.

Figure 4-3. Ranging Troubleshooting Waveforms

00518-1

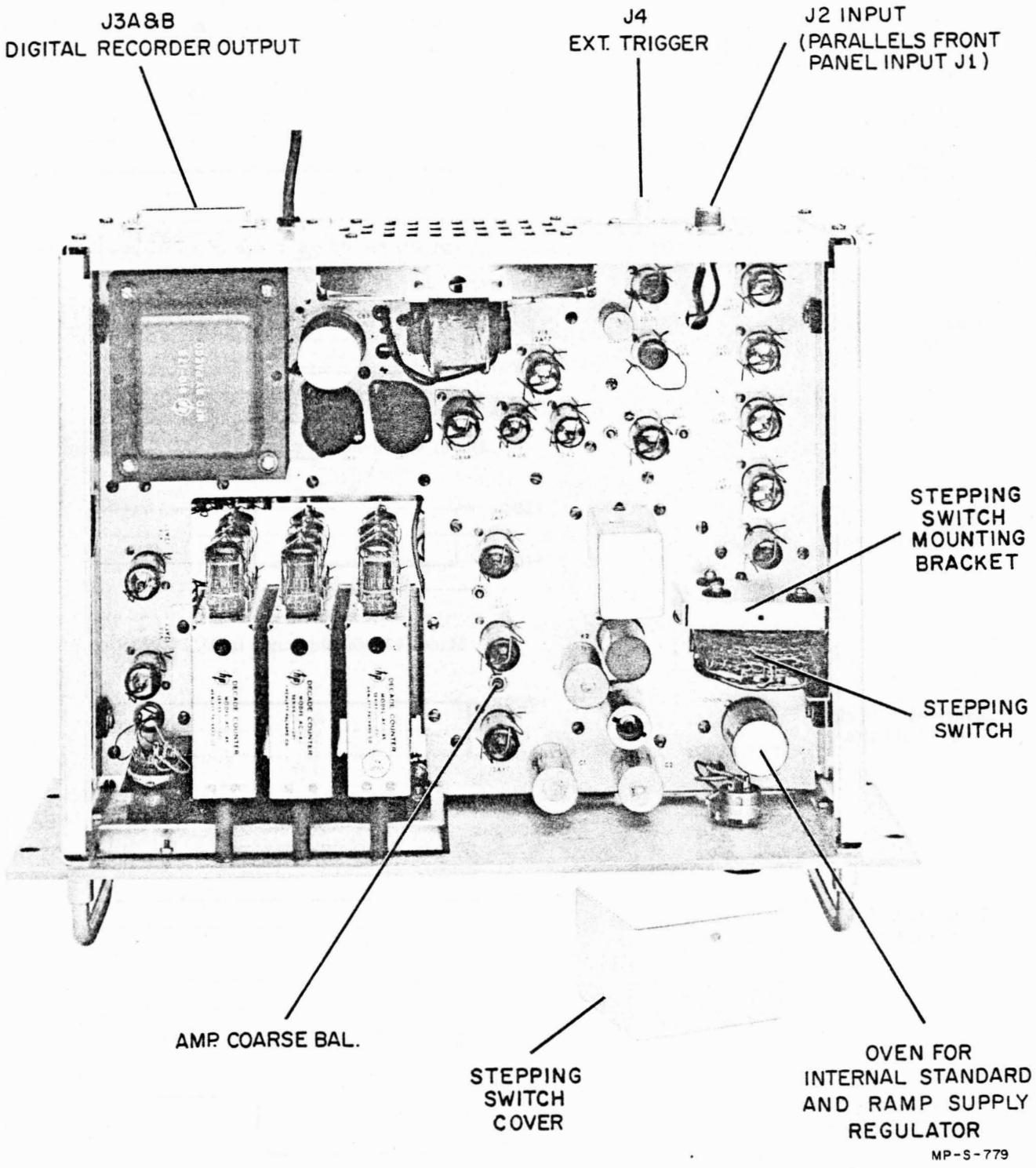


Figure 4-4. Top Internal View of Model 405C

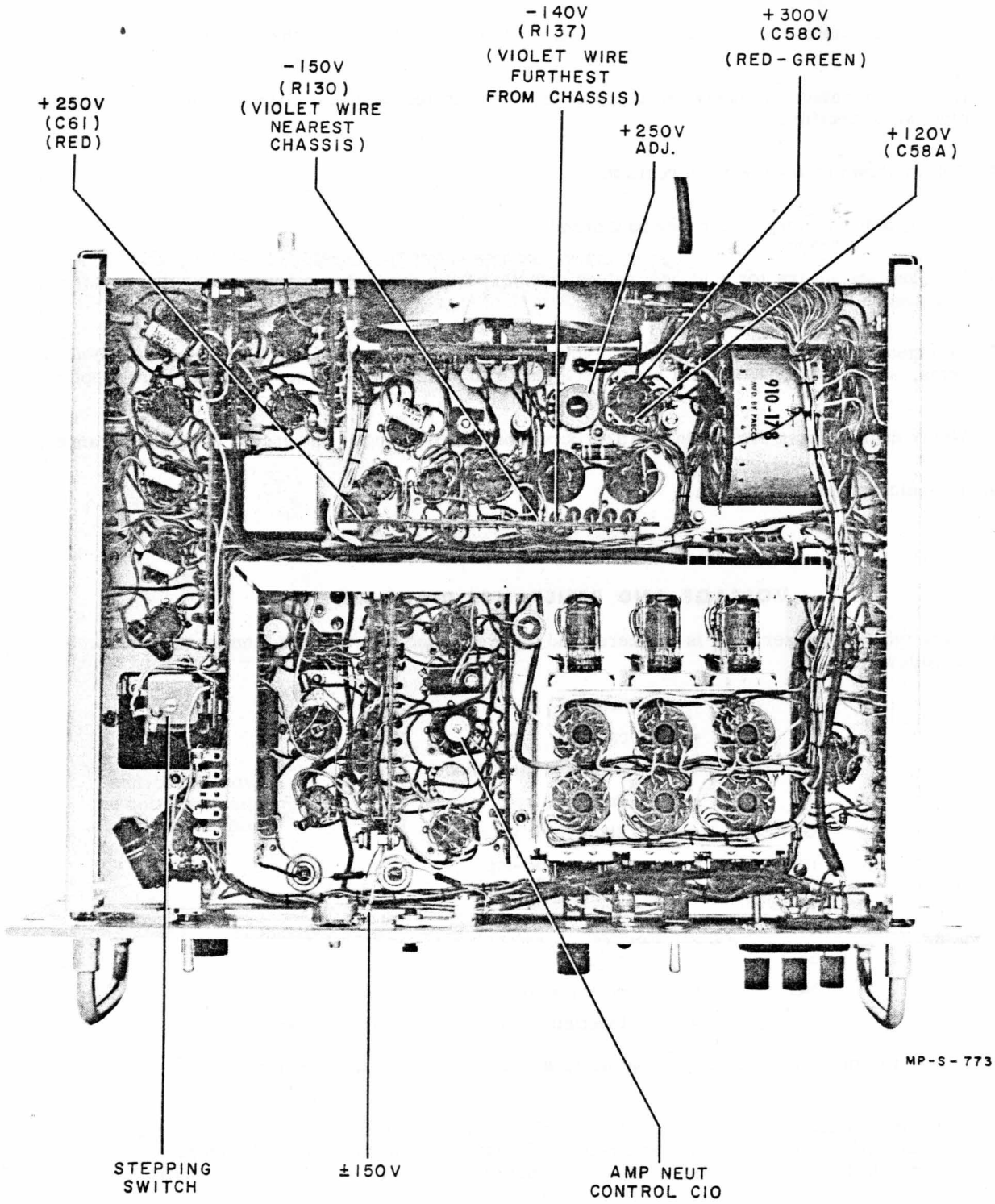


Figure 4-5. Bottom Internal View of Model 405C

SCHEMATIC DIAGRAM NOTES

1. Heavy box indicates front-panel engraving.

2. Arrows on potentiometers indicate clockwise rotation as viewed from the shaft end.

3. Resistance values in ohms, inductance in microhenries, and capacitance in picofarads unless otherwise specified.

4. Relays shown in de-energized position.

5. * Adjusted at factory. Part may be omitted.

6. Voltages shown are for guidance; values may vary from those shown due to tube aging or normal differences between instruments.

7. Voltages measured with an electronic voltmeter having an input resistance greater than 100 megohms, with SAMPLING control set to EXT, and with no input voltage or triggering signal applied.

8. Where dual voltages are shown, the first occurs on positive ranges; the second on negative ranges.

9. ⏚ indicates floating ground.

VOLTAGE AND RESISTANCE DIAGRAM NOTES

1. Each tube socket terminal is numbered and lettered to indicate the tube element and pin number, as follows:

H	=	heater
K	=	cathode
G or G_1	=	grid nearest cathode
G_2	=	2nd grid from cathode
G_3	=	3rd grid from cathode
Hm	=	heater mid-tap
IS	=	internal shield
P	=	plate
Sh	=	shield
NC	=	no external connection to socket
∓	=	indefinite reading due to circuit (see 2)

Letter subscripts indicate section of multi-section tubes.

The letter subscript to tube-element designators indicates the tube section.

2. Voltage values shown are for guidance; values may vary from those shown due to tube aging or normal differences between instruments. Resistance values may vary considerably from those shown when the circuit contains potentiometers, crystal diodes, or electrolytic capacitors.

3. Voltage measured at the terminal is shown above the line, resistance below the line; measurements made with an electronic multimeter, from terminal to chassis ground unless otherwise noted.

4. Measurements made with SAMPLING control set to EXT and with no input voltage or triggering signal applied.

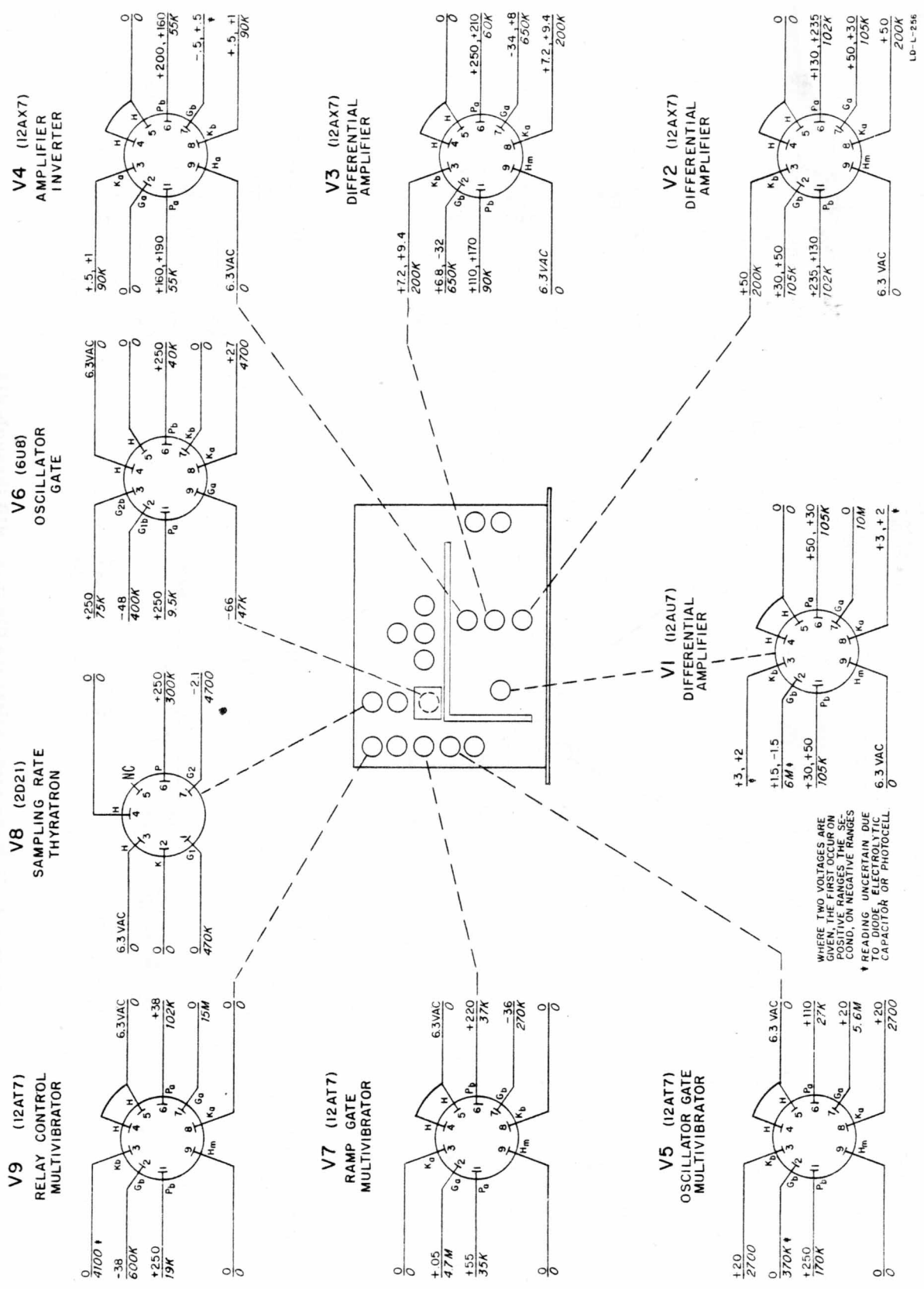


Figure 4-6. Voltage and Resistance Diagram, V1 through V9

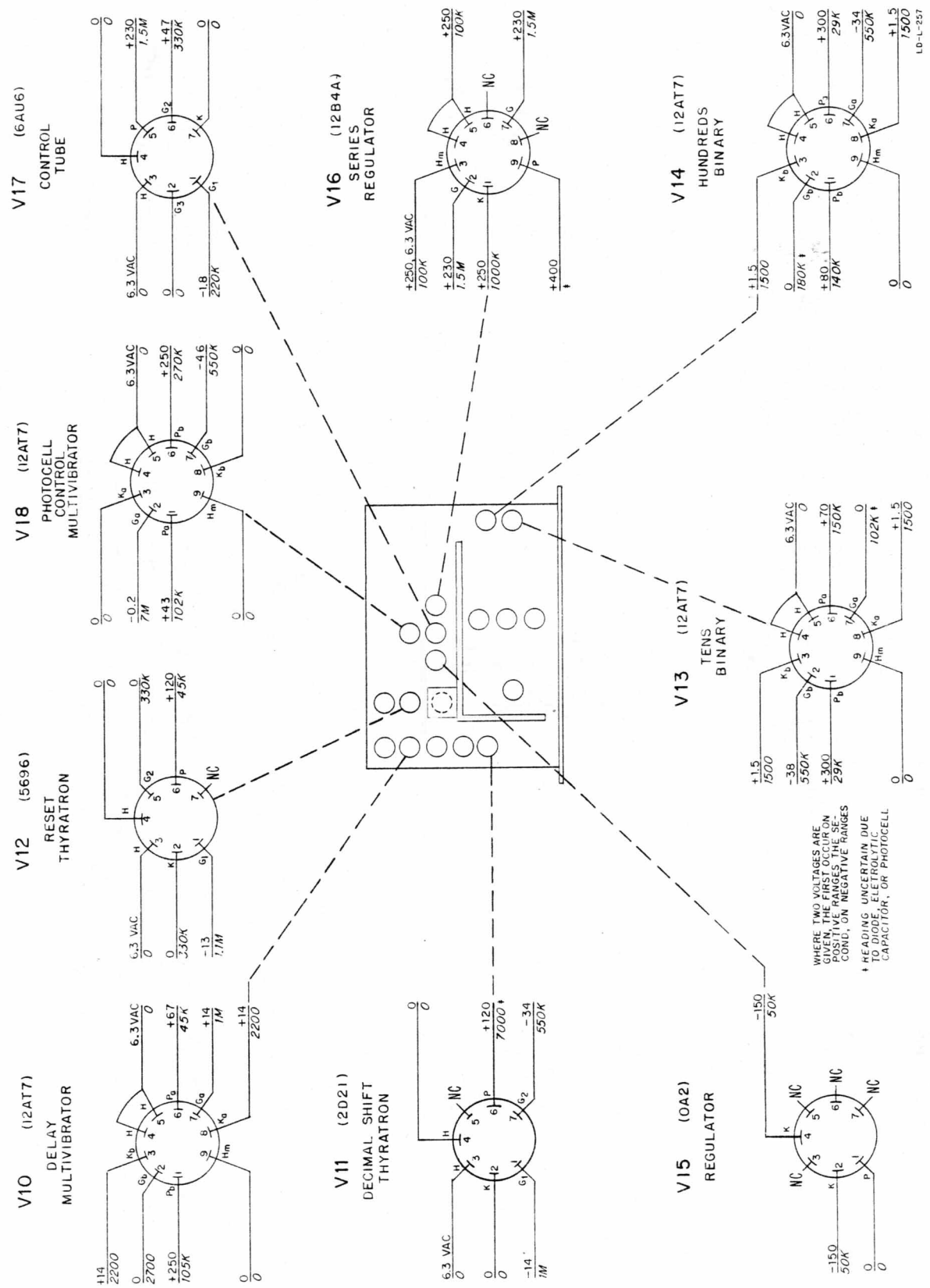


Figure 4-7. Voltage and Resistance Diagram, V10 through V18

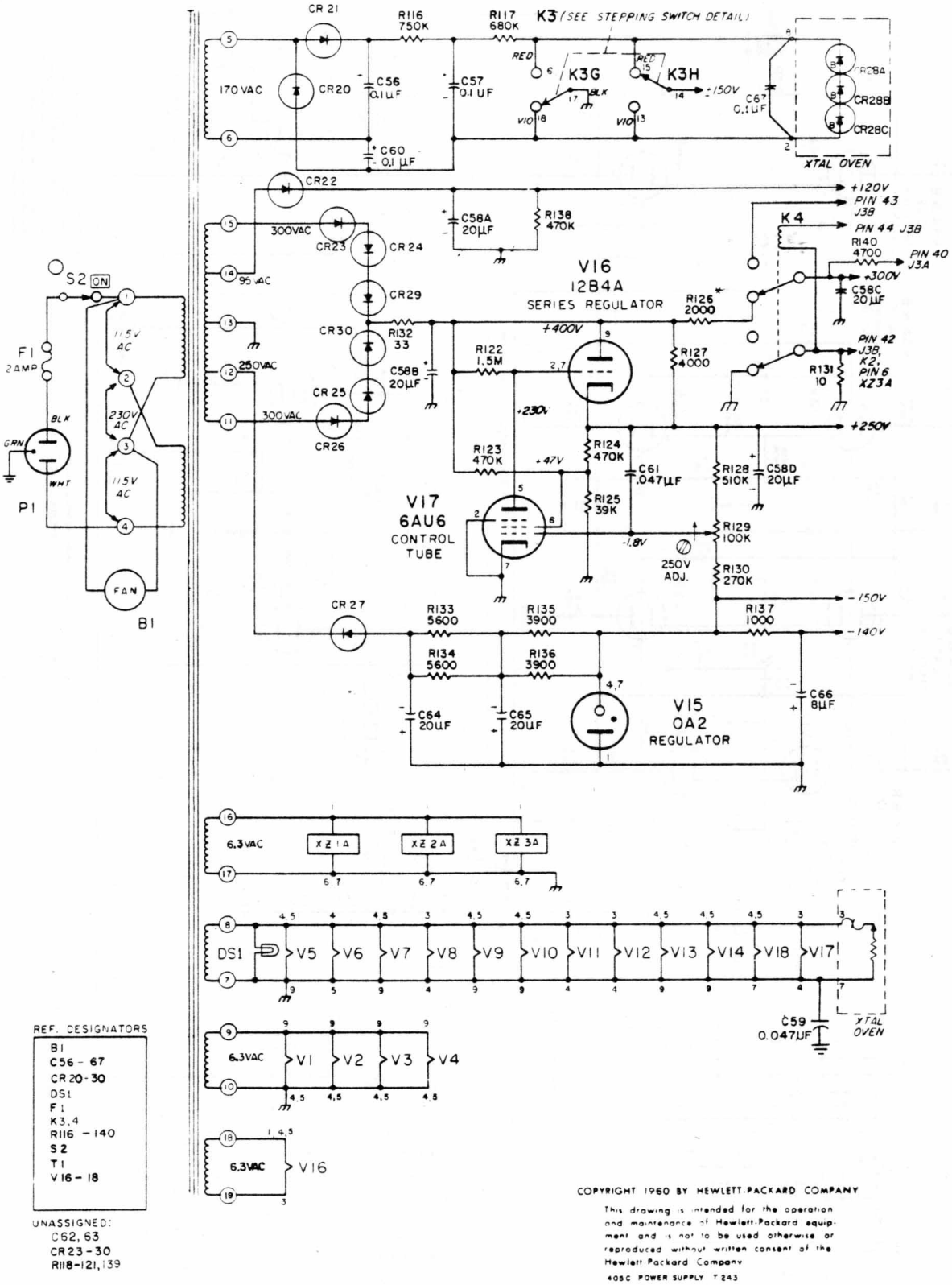


Figure 4-8. Power Supply

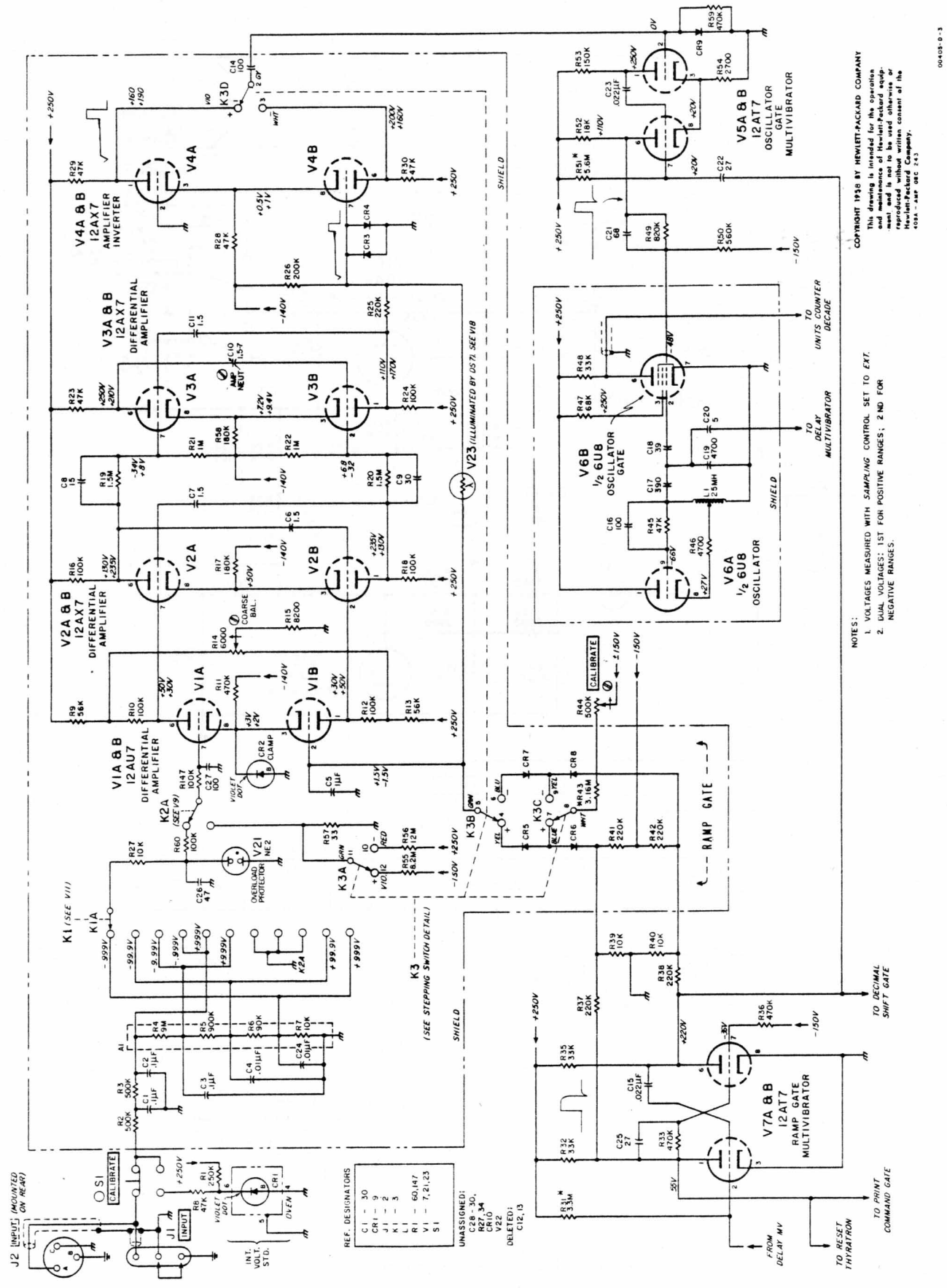


Figure 4-9. Amplifier/Oscillator Section

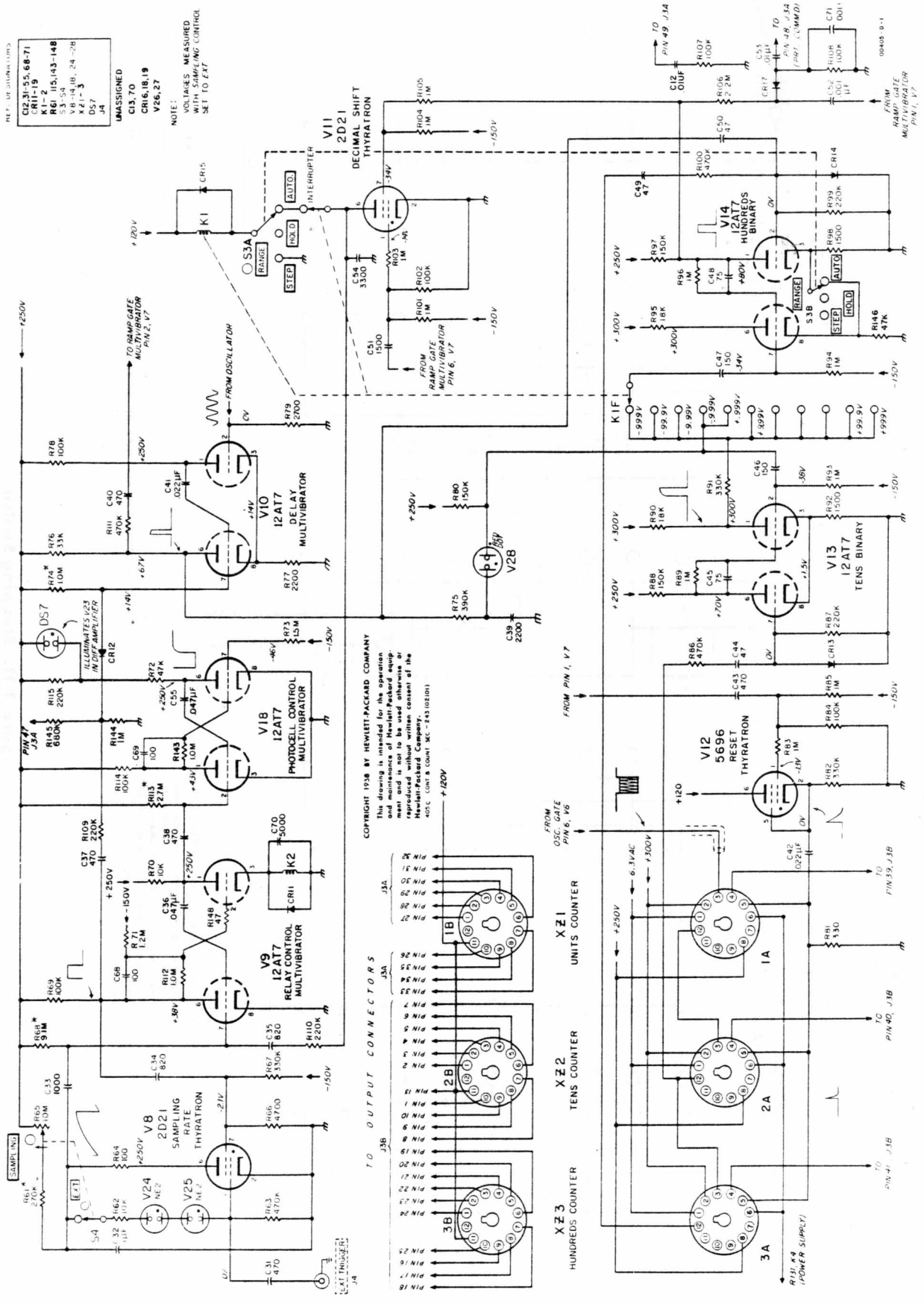


Figure 4-10. Control/Counter Section

00518-3

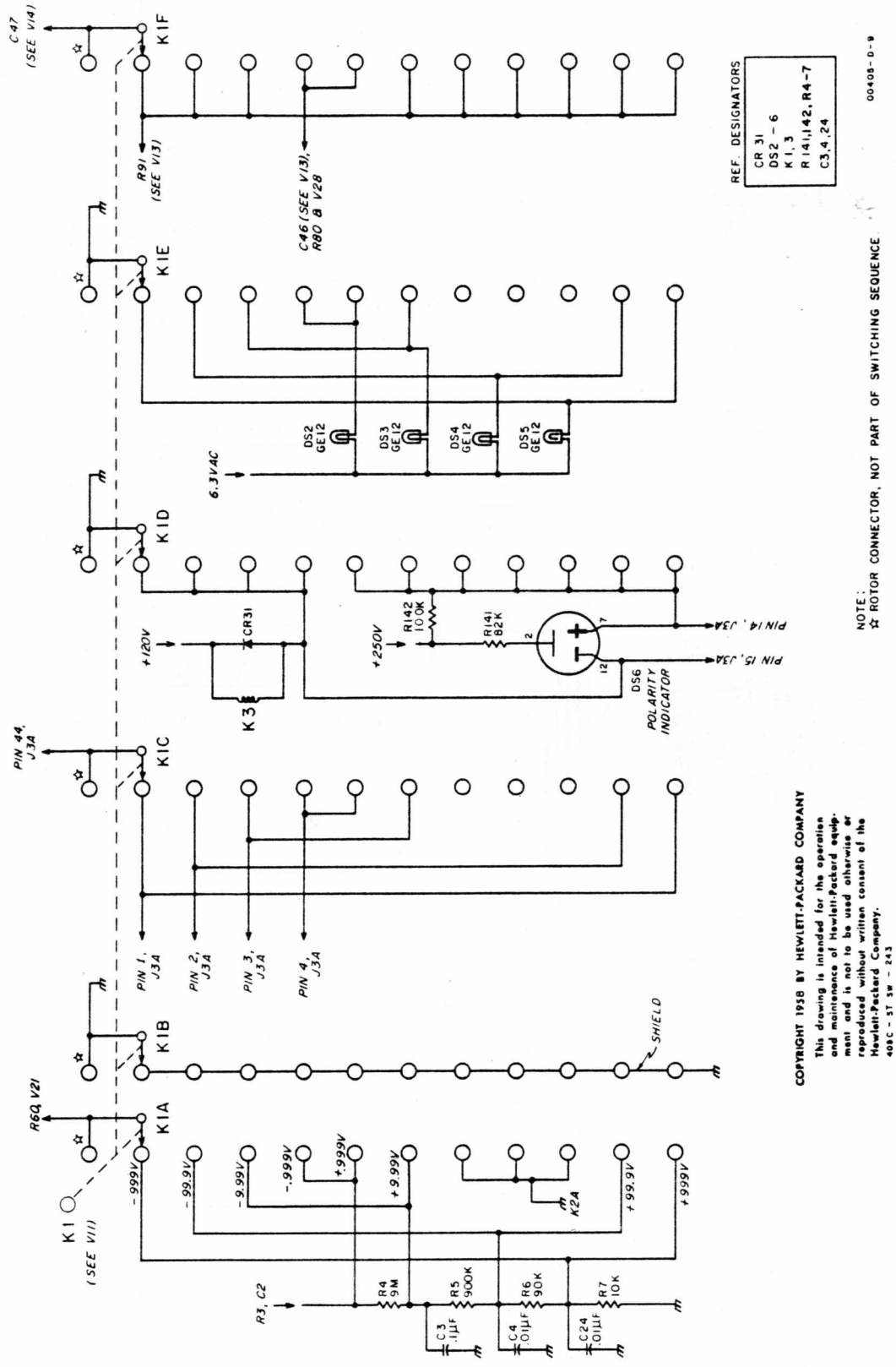


Figure 4-11. Stepping Switch

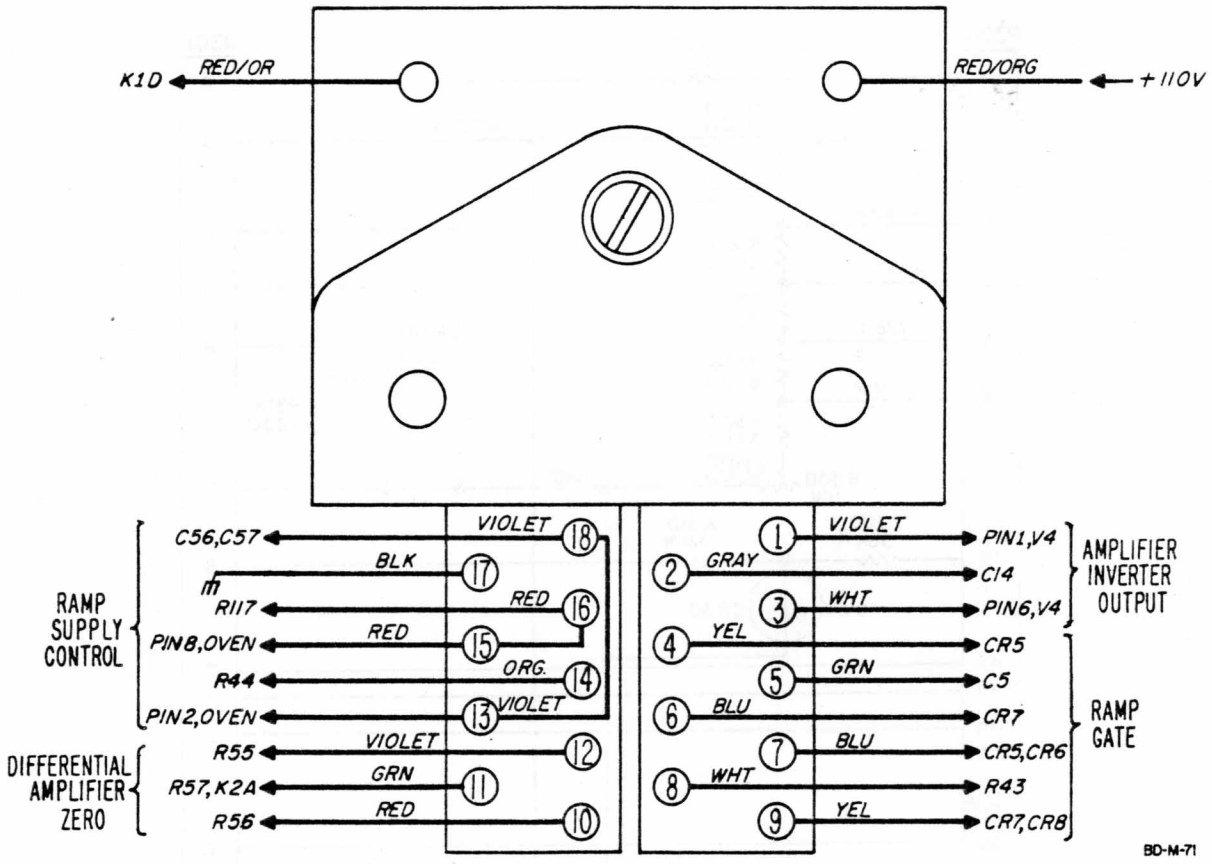


Figure 4-12. Polarity Relay Wiring

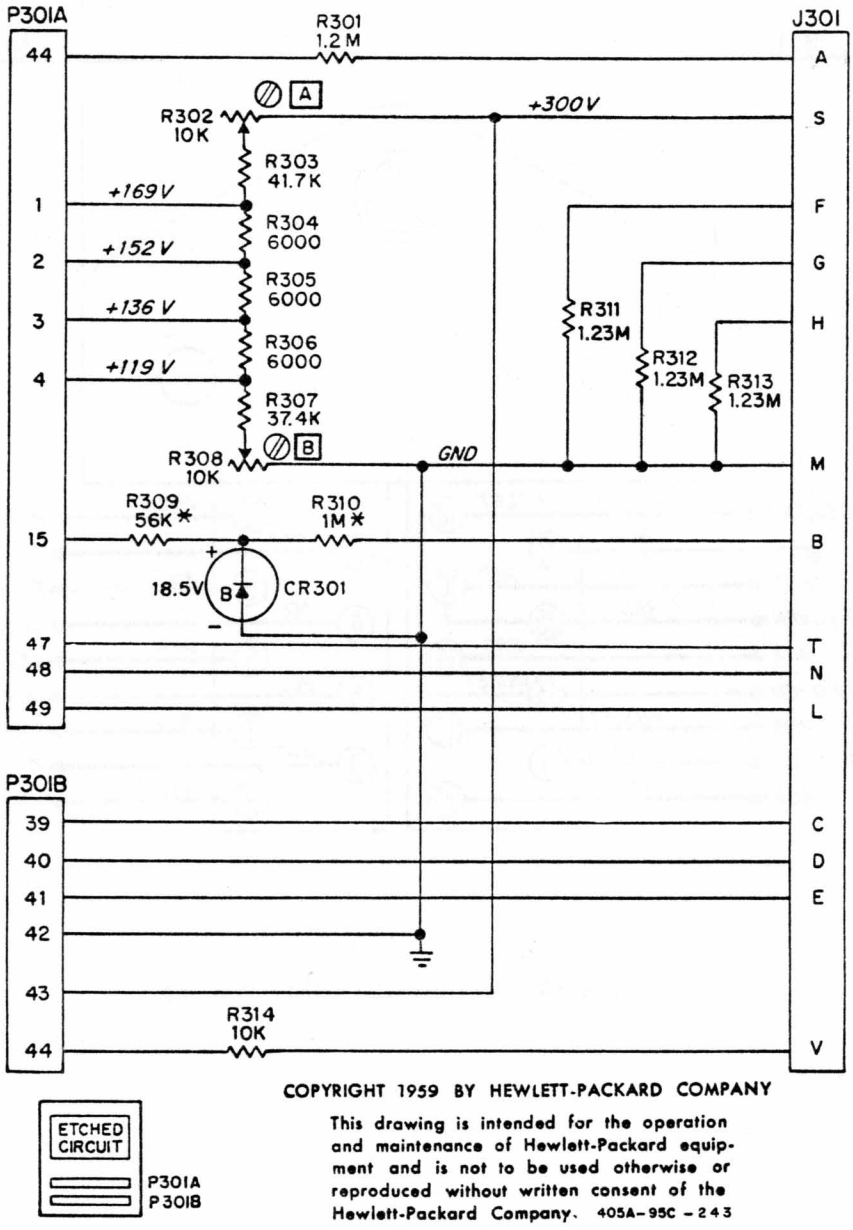


Figure 4-13. 405A-95C Digital Recorder Adapter

SECTION V
REPLACEABLE PARTS

5-1 INTRODUCTION

This section contains information for ordering replacement parts for the 405C Automatic DC Digital Voltmeter.

5-2 TABLE OF REPLACEABLE PARTS

Table 5-1 lists replaceable parts in alpha-numerical order of their reference designators. At the end of the table are listed miscellaneous items such as knobs which have no assigned reference designators. Table 5-2, Digital Recorder Adaptor (hp stock no. 405A-95C).

Detailed information on a part used more than once in the instrument is listed opposite the first reference designator applying to the part to appear in the table. Other reference designators applying to the same part reference the initial designator. The detailed information includes the following:

1) Full description of the part.

2) Manufacturer of the part in a five-digit code -- see list of manufacturers in appendix.

3) Total quantity used in the instrument (TQ column).

4) Recommended spare quantity for complete maintenance during one year of isolated service (RS column).

5-3 ORDERING INFORMATION

To order a replacement part, address order or inquiry either to your authorized Hewlett-Packard sales office or to

CUSTOMER SERVICE
Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California

or, in western Europe, to

Hewlett-Packard S. A.
Rue du Vieux Billard No. 1
Geneva, Switzerland

Specify the following information on a part:

1) Model and serial number of the instrument. Be sure to include the three-digit serial prefix.

2) ℗ stock number.

3) Circuit reference designator.

4) Description.

To order a part not listed in table 5-1, give a complete description of the part including its function and location in the circuit.

Table 5-1. Replaceable Parts (Sheet 1 of 12)

Ckt Ref.	Description	Mfr *	℗ Stock No.	TQ*	RS*		
A1	Resistor Network: consists of R4 thru R7	28480	405A-65B	1	1		
B1	Motor, AC: 2800 RPM	73793	3140-0010	1	1		
	Blade, fan	06812	3160-0012	1	1		
C1, 2	Capacitor: fixed, polystyrene, 0.1 μf ±20%, 1000 vdcw	56289	0170-0041	2	1		
C3	Capacitor: fixed, mylar, 0.1 μf ±20%, 600 vdcw	84411	0170-0022	4	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 2 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
C4	Capacitor: fixed, mylar, .01 μf ±5%, 400 vdcw	84411	0170-0017	2	1		
C5	Capacitor: fixed, polystyrene, 1 μf ±20%, 50 vdcw	56289	0170-0037	1	1		
C6, 7	Capacitor: fixed, titanium dioxide, 1.5 pf ±20%, 500 vdcw	78488	0150-0011	3	1		
C8	Capacitor: fixed, mica, 15 pf ±10%, 500 vdcw	76433	0140-0004	1	1		
C9	Capacitor: fixed, mica, 30 pf ±5%, 500 vdcw	00853	0140-0105	1	1		
C10	Capacitor: variable, ceramic, 1.5-7 pf	72982	0130-0011	1	1		
C11	Same as C6						
C12	Capacitor: fixed, paper, 0.01 μf ±20%, 400 vdcw	56289	0160-0054	2	1		
C13	Not assigned						
C14	Capacitor: fixed, mica, 100 pf ±10%, 500 vdcw	76433	0140-0054	2	1		
C15	Capacitor: fixed, mylar, 0.022 μf ±10%, 400 vdcw	84411	0170-0043	4	1		
C16	Capacitor: fixed, mica, 100 pf ± 5%, 500 vdcw	76433	0140-0041	2	1		
C17	Capacitor: fixed, mica, 390 pf ±5%, 500 vdcw	76433	0140-0037	1	1		
C18	Capacitor: fixed, mica, 39 pf ±5%, 500 vdcw	76433	0140-0035	1	1		
C19	Capacitor: fixed, mica, 4700 pf ±10%, 500 vdcw	76433	0140-0017	1	1		
C20	Capacitor: fixed, mica, 5 pf ±20%, 500 vdcw	76433	0140-0033	1	1		
C21	Capacitor: fixed, mica, 68 pf ±10%, 500 vdcw	76433	0140-0025	1	1		
C22	Capacitor: fixed, mica, 27 pf ±10%, 500 vdcw	76433	0140-0005	2	1		
C23	Same as C15						
C24	Same as C4						

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 3 of 12)

Ckt Ref.	Description	Mfr *	℗ Stock No.	TQ*	RS*		
C25	Same as C22						
C26	Capacitor: fixed, mica, 47 pf ±10%, 500 vdcw	76433	0140-0032	4	1		
C27 thru C30	Not assigned						
C31	Capacitor: fixed, mica, 470 pf ±10%, 500 vdcw	76433	0140-0027	5	2		
C32	Capacitor: fixed, paper, 1.0 μf ±20%, 400 vdcw	56289	0160-0064	1	1		
C33	Capacitor: fixed, mica, 1000 pf ± 5%, 500 vdcw	76433	0140-0018	1	1		
C34, 35	Capacitor: fixed, mica, 820 pf ±10%, 500 vdcw	76433	0140-0010	2	1		
C36	Capacitor: fixed, mylar, 0.047 μf ±10%, 400 vdcw	84411	0170-0060	2	1		
C37, 38	Same as C31						
C39	Capacitor: fixed, paper, 2200 pf ±10%, 600 vdcw	56289	0160-0007	1	1		
C40	Same as C31						
C41, 42	Same as C15						
C43	Same as C31						
C44	Same as C26						
C45	Capacitor: fixed, mica, 75 pf ±5%, 500 vdcw	00853	0140-0040	2	1		
C46, 47	Capacitor: fixed, mica, 150 pf ±10%, 500 vdcw	76433	0140-0055	2	1		
C48	Same as C45						
C49, 50	Same as C26						
C51	Capacitor: fixed, paper, 1500 pf ±10%, 600 vdcw	56289	0160-0012	1	1		
C52	Capacitor: fixed, paper, 0.001 μf ±10%, 600 vdcw	56289	0160-0006	1	1		
C53	Same as C12						
C54	Capacitor: fixed, paper, 3300 pf ±10%, 600 vdcw	56289	0160-0008	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 4 of 12)

Ckt Ref.	Description	Mfr *	℗ Stock No.	TQ*	RS*		
C55	Same as C36						
C56, 57	Same as C3						
C58	Capacitor: fixed, electrolytic, 4 sections, 20 μf/sect., 450 vdcw	56289	0180-0025	1	1		
C59	Capacitor: fixed, paper, 0.047 μf, ±10%, 600 vdcw	56289	0160-0005	2	2		
C60	Same as C3						
C61	Same as C59						
C62, 63	Not assigned						
C64, 65	Capacitor: fixed, electrolytic, 20 μf, 450 vdcw	56289	0180-0011	2	1		
C66	Capacitor: fixed, electrolytic, 8 μf, 350 vdcw	56289	0180-0038	1	1		
C67	Capacitor: fixed, paper, 0.1 μf ±10%, 400 vdcw	56289	0160-0013	1	1		
C68	Same as C14						
C69	Same as C16						
C70	Capacitor: fixed, ceramic, 0.005 μf, 500 vdcw	96095	0150-0014	1	1		
C71	Capacitor: fixed, ceramic, 0.001 μf, GMV, 600 vdcw	000RR	0150-0050	1	1		
CR1	Internal secondary voltage standard	28480	405A-95D	1	1		
CR2	Diode, breakdown	28480	G-31A-18A	1	1		
CR3, 4	Diode, silicon	28480	1901-0025	4	4		
CR5 thru CR8	Diode, silicon	000CC	1901-0023	4	4		
CR9	Same as CR3						
CR10	Not assigned						
CR11	Same as CR3						
CR12	Diode, silicon: 500 ma, 600 PIV	28480	1901-0028	5	5		
CR13, 14	Diode, germanium : 1N90	73293	1910-0004	2	2		
CR15	Same as CR12						
CR16	Not assigned						
CR17	Same as CR12						
CR18, 19	Not assigned						
CR20, 21	Diode, silicon	28480	1901-0029	8	8		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 5 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
CR22	Same as CR12						
CR23 thru CR26	Same as CR20						
CR27	Diode, metallic: 65 ma, 275V	77638	1880-0012	1	1		
CR28	Diode, breakdown: 150V	28480	405A-75Z	1	1		
CR29, 30	Same as CR20						
CR31	Same as CR12						
DS1 thru DS5	Lamp, miniature: 6.3V , 2 pin base, G.E. #12	24455	2140-0012	5	5		
DS6	Tube, electron: nixie, 13 pin	83594	1970-0001	1	1		
DS7	Lamp, neon: NE2U	24455	2140-0024	1	1		
F1	Fuse, cartridge: 2 amp, slow-blow for 115V operation	71400	2110-0006	1	10		
	Fuse, cartridge: 1 amp, slow blow for 230V operation	71400	2110-0007				
J1	Binding Post Assembly	28480	G-76K	1	1		
J2	Connector, male: 3 pin	02660	1251-0039	1	1		
J3	Not assigned						
J4	Connector, female: BNC, UG-1094/U	91737	1250-0083	1	1		
K1	Switch, stepping	04773	0492-0001	1	1		
K2	Relay, high speed: SPDT	80640	0490-0024	1	1		
K3	Relay: 6PDT	04773	0490-0023	1	1		
K4	Relay, armature: DPDT	77342	0490-0017	1	1		
L1	Coil, oscillator: 25 mh	28480	405A-60A	1	1		
P1	Cable, power	70903	8120-0050	1	1		
R1	Resistor: fixed, deposited carbon, 250,000 ohms ±1%, 1/2 W	19701	0727-0226	1	1		
R2, 3	Resistor: fixed, deposited carbon, 500,000 ohms ±1%, 1/2 W	19701	0727-0244	2	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 6 of 12)

Ckt Ref.	Description	Mfr *	hp Stock No.	TQ*	RS*		
R4 thru R7	Part of Resistor Network A1 in ranges 9 megohms, 900,000 ohms, 90,000 ohms, 10,000 ohms, matched to within .1% of each other in ratio						
R8	Resistor: fixed, composition, 47,000 ohms ±10%, 1/2 W	01121	0687-4731	4	1		
R9	Resistor: fixed, composition, 56,000 ohms ±10%, 1 W	01121	0690-5631	2	1		
R10	Resistor: fixed, deposited carbon, 100,000 ohms ±1%, 1/2 W	19701	0727-0208	5	2		
R11	Resistor: fixed, composition, 470,000 ohms ±10%, 1/2 W	01121	0687-4741	11	3		
R12	Same as R10						
R13	Same as R9						
R14	Resistor: variable, composition, linear taper, 6000 ohms ±20%, .3 W	11237	2100-0136	1	1		
R15	Resistor: fixed, composition, 8200 ohms ±10%, 1/2 W	01121	0687-8221	1	1		
R16	Same as R10						
R17	Resistor: fixed, composition, 180,000 ohms ±10%, 1/2 W	01121	0687-1841	2	1		
R18	Same as R10						
R19, 20	Resistor: fixed, deposited carbon, 1.5 megohms ±1%, 1/2 W	19701	0727-0282	2	1		
R21, 22	Resistor: fixed, composition, 1 megohm ±1%, 1/2 W	19701	0727-0274	2	1		
R23	Same as R8						
R24	Same as R10						
R25	Resistor: fixed, composition, 220,000 ohms ±5%, 1/2 W	01121	0686-2245	1	1		
R26	Resistor: fixed, composition, 200,000 ohms ±5%, 1/2 W	01121	0686-2045	1	1		
R27	Resistor: fixed, composition, 10,000 ohms ±10%, 1/2 W	01121	0687-1031	5	2		
R28 thru R30	Resistor: fixed, composition, 47,000 ohms ±10%, 2 W	01121	0693-4731	3	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 7 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
R31	Resistor: fixed, composition, 3.9 megohms ±10%, 1/2 W Optimum value selected at factory Average value shown	01121	0687-3951	1	1		
R32	Resistor: fixed, composition, 33,000 ohms ±10%, 2 W	01121	0693-3331	3	1		
R33	Same as R11						
R34	Resistor: fixed, composition, 2200 ohms ±10%, 1/2 W	01121	0687-2221	2	1		
R35	Same as R32						
R36	Same as R11						
R37, 38	Resistor: fixed, composition, 220,000 ohms ±10%, 1/2 W	01121	0687-2241	9	2		
R39, 40	Same as R27						
R41, 42	Same as R37						
R43	Resistor: fixed, deposited carbon, 3.16 megohms ±1%, 1 W Optimum value selected at factory Average value shown	19701	0730-0119	1	1		
R44	Resistor: variable, composition, 500,000 ohms ±30%, 1/4 W	11237	2100-0201	1	1		
R45	Same as R8						
R46	Resistor: fixed, composition, 4700 ohms ±10%, 1/2 W	01121	0687-4721	2	1		
R47	Resistor: fixed, composition, 68,000 ohms ±10%, 1/2 W	01121	0687-6831	1	1		
R48	Resistor: fixed, composition, 33,000 ohms ±10%, 1 W	01121	0690-3331	1	1		
R49	Resistor: fixed, composition, 820,000 ohms ±10%, 1/2 W	01121	0687-8241	1	1		
R50	Resistor: fixed, composition, 560,000 ohms ±10%, 1/2 W	01121	0687-5641	1	1		
R51	Resistor: fixed, composition, 5.6 megohms ±10%, 1/2 W Optimum value selected at factory Average value shown	01121	0687-5651	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 8 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
R52	Resistor: fixed, composition, 18,000 ohms ±10%, 2 W	01121	0693-1831	3	1		
R53	Resistor: fixed, composition, 150,000 ohms ±10%, 1/2 W	01121	0687-1541	4	1		
R54	Resistor: fixed, composition, 2700 ohms ±10%, 1/2 W	01121	0687-2721	2	1		
R55	Resistor: fixed, composition, 8.2 megohms ±10%, 1/2 W	01121	0687-8251	1	1		
R56	Resistor: fixed, composition, 12 megohms ±10%, 1/2 W	01121	0687-1261	1	1		
R57	Resistor: fixed, composition, 33 ohms ±10%, 1/2 W	01121	0687-3301	1	1		
R58	Same as R17						
R59	Same as R11						
R60	Resistor: fixed, composition, 100,000 ohms ±10%, 1/2 W Optimum value selected at factory Average value shown	01121	0687-1041	1	1		
R61	Resistor: fixed, composition, 270,000 ohms ±10%, 1/2 W Optimum value selected at factory Average value shown	01121	0687-2741	1	1		
R62	Same as R27						
R63	Same as R11						
R64	Resistor: fixed, composition, 100 ohms ±10%, 1/2 W	01121	0687-1011	1	1		
R65	Resistor: variable, composition, linear taper, 10 megohms ±30% includes S4, SPDT switch	11237	2100-0152	1	1		
R66	Same as R46						
R67	Resistor: fixed, composition, 330,000 ohms ±10%, 1/2 W	01121	0687-3341	3	1		
R68	Resistor: fixed, composition, 9.1 megohms ±5%, 1/2 W Optimum value selected at factory Average value shown	01121	0686-9155	1	1		
R69	Resistor: fixed, composition, 100,000 ohms ±10%, 1/2 W	01121	0687-1041	8	2		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 9 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
R70	Same as R27						
R71	Resistor: fixed, composition, 1.2 megohms ±10%, 1/2 W	01121	0687-1251	1	1		
R72	Same as R8						
R73	Resistor: fixed, composition, 1.5 megohms ±10%, 1/2 W	01121	0687-1551	2	1		
R74	Resistor: fixed, composition, 1 megohm ±10%, 1/2 W Optimum value selected at factory Average value shown	01121	0687-1051	1	1		
R75	Resistor: fixed, composition, 390,000 ohms ±10%, 1/2 W	01121	0687-3941	1	1		
R76	Same as R32						
R77	Same as R34						
R78	Same as R69						
R79	Same as R54						
R80	Same as R53						
R81	Resistor: fixed, composition, 330 ohms ±10%, 1/2 W	01121	0687-3311	1	1		
R82	Same as R67						
R83	Resistor: fixed, composition, 1 megohm ±10%, 1/2 W	01121	0687-1051	10	2		
R84	Same as R69						
R85	Same as R83						
R86	Same as R11						
R87	Same as R37						
R88	Same as R53						
R89	Resistor: fixed, composition, 1 megohm ±5%, 1/2 W	01121	0686-1055	4	1		
R90	Same as R52						
R91	Same as R67						
R92	Resistor: fixed, composition, 1500 ohms ±10%, 1/2 W	01121	0687-1521	2	1		
R93, 94	Same as R89						
R95	Same as R52						

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 10 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
R96	Same as R89						
R97	Same as R53						
R98	Same as R92						
R99	Same as R37						
R100	Same as R11						
R101	Same as R83						
R102	Same as R69						
R103 thru R105	Same as R83						
R106	Resistor: fixed, composition, 2.2 megohms ±10%, 1/2 W	01121	0687-2251	1	1		
R107,108	Same as R69						
R109,110	Same as R37						
R111	Same as R11						
R112	Same as R83						
R113	Resistor: fixed, composition, 2.7 megohms ±10%, 1/2 W	01121	0687-2751	1	1		
R114	Same as R69						
R115	Same as R37						
R116	Resistor: fixed, composition, 680,000 ohms ±5%, 1/2 W	01121	0686-6845	1	1		
R117	Resistor: fixed, composition, 750,000 ohms ±5%, 1/2 W	01121	0686-7545	1	1		
R118 thru R121	Not assigned						
R122	Same as R73						
R123,124	Same as R11						
R125	Resistor: fixed, composition, 39,000 ohms ±10%, 1/2 W	01121	0687-3931	1	1		
R126	Resistor: fixed, wirewound, 2000 ohms ±5%, 10 W Optimum value selected at factory Average value shown	35434	0816-0012	1	1		
R127	Resistor: fixed, wirewound, 4000 ohms ±5%, 10 W	75042	0815-0003	1	1		
R128	Resistor: fixed, composition, 510,000 ohms ±5%, 1/2 W	01121	0686-5145	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 11 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
R129	Resistor: variable, composition, linear taper, 100,000 ohms ±30%, 1/4 W	11237	2100-0195	1	1		
R130	Resistor: fixed, composition, 270,000 ohms ±5%, 1/2 W	01121	0686-2745	1	1		
R131	Resistor: fixed, composition, 10 ohms ±10%, 1/2 W	01121	0687-1001	1	1		
R132	Resistor: fixed, composition, 33 ohms ±10%, 2 W	01121	0693-3301	1	1		
R133,134	Resistor: fixed, composition, 5600 ohms ±10%, 2 W	01121	0693-5621	2	1		
R135,136	Resistor: fixed, composition, 3900 ohms ±10%, 2 W	01121	0693-3921	2	1		
R137	Resistor: fixed, composition, 1000 ohms ±10%, 1 W	01121	0690-1021	1	1		
R138	Same as R11						
R139	Not assigned						
R140	Resistor: fixed, composition, 4700 ohms ±10%, 1 W	01121	0690-4721	1	1		
R141	Resistor: fixed, composition, 82,000 ohms ±10%, 1/2 W	01121	0687-8231	1	1		
R142	Same as R69						
R143,144	Same as R83						
R145	Resistor: fixed, composition, 680,000 ohms ±10%, 1/2 W	01121	0687-6841	1	1		
R146	Resistor: fixed, composition, 47,000 ohms ±10%, 1/2 W	01121	0687-4731	1	1		
R147	Same as R69						
R148	Resistor: fixed, composition, 47 ohms ±10%, 1/2 W	01121	0687-4701	1	1		
S1	Switch, push-button: SPDT	82389	3101-0019	1	1		
S2	Switch, toggle: SPST	04009	3101-0001	1	1		
S3	Switch, toggle: DPDT	88140	3101-0015	1	1		
S4	Part of R65						
T1	Transformer, power	98734	9100-0106	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 12 of 12)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
V1	Tube, electron: 12AU7	80131	1932-0029	1	1		
V2 thru V4	Tube, electron: 12AX7	80131	1932-0030	3	3		
V5	Tube, electron: 12AT7	80131	1932-0027	7	7		
V6	Tube, electron: 6U8	80131	1933-0004	1	1		
V7	Same as V5						
V8	Tube, electron: 2D21	80131	1941-0005	2	2		
V9, 10	Same as V5						
V11	Same as V8						
V12	Tube, electron: 5696	80131	1941-0003	1	1		
V13, 14	Same as V5						
V15	Tube, electron: OA2	80131	1940-0004	1	1		
V16	Tube, electron: 12B4A	80131	1921-0010	1	1		
V17	Tube, electron: 6AU6	80131	1923-0021	1	1		
V18	Same as V5						
V19, 20	Not assigned						
V21	Lamp, neon: NE2	24455	2140-0008	3	3		
V22	Not assigned						
V23	Cell, photoconductive	28480	G-30D	1	1		
V24, 25	Same as V21						
V26, 27	Not assigned						
V28	Lamp, neon: aged and selected green code	28480	G-84D	1	1		
XZ1, 2, 3	Decade Counter	28480	AC-4K	3	1		
	MISCELLANEOUS						
	Fuseholder	75915	1400-0084	1	1		
	Knob	28480	G-74G	1	0		
	Lampholder, for 2 pin base	72765	1450-0022	5	0		
	Lube, oil kit	04773	6040-0019	1	0		
	Oven: for CR1 and CR28	28480	0410-0016	2	1		
	Socket, tube: 9 pin	71785	1200-0019	1	1		
	Socket, tube: 13 pin	71785	1200-0055	1	1		
	Socket, tube: octal	71785	1200-0020	2	1		
	Socket, tube: 12 pin	02660	1200-0038	6	1		
	Socket, tube: 9 pin	71785	1200-0008	11	1		
	Socket, tube: 7 pin	91662	1200-0009	5	1		

* See introduction to this section

Table 5-2. Digital Recorder Adapter 405A-95C

Ckt Ref.	Description	Mfr *	hp Stock No.	TQ*	RS*		
CR1 thru CR300	Not assigned						
CR301	Diode, zener: 18V	28480	G-29A-18	1	1		
J1 thru J300	Not assigned						
J301	Connector, female: 19 pin	71468	1251-0056	1	1		
P1 thru P300	Not assigned						
P301A/B	Connector, male: 50 pin miniature	02660	1251-0099	2	1		
R1 thru R300	Not assigned						
R301	Resistor: fixed, deposited carbon, 1.2 megohms ±1%, 1/2 W	19701	0727-0280	1	1		
R302	Resistor: variable, composition, linear taper, 10,000 ohms ± 20%, 1/4W	11237	2100-0092	2	1		
R303	Resistor: fixed, deposited carbon, 41,700 ohms ± 1%, 1/2 W	19701	0727-0189	1	1		
R304 thru R306	Resistor: fixed, deposited carbon, 6000 ohms ± 1%, 1/2 W	19701	0727-0140	3	1		
R307	Resistor: fixed, deposited carbon, 37.4K ohms ± 1%, 1/2 W	19701	0727-0187	1	1		
R308	Same as R302						
R309	Resistor: fixed, composition, 56,000 ohms ± 10%, 1/2 W Optimum value selected at factory; average value shown	01121	0687-5631	1	1		
R310	Resistor: fixed, deposited carbon, 1 megohm ± 1%, 1/2 W	19701	0727-0276	1	1		
R311 thru R313	Resistor: fixed, deposited carbon, 1.23 megohms ± 1%, 1 W	19701	0730-0108	3	1		
R314	Resistor: fixed, composition, 10,000 ohms ± 10%, 2W	01121	0693-1031	1	1		

* See introduction to this section

APPENDIX
CODE LIST OF MANUFACTURERS (Sheet 1 of 2)

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

CODE NO.	MANUFACTURER	ADDRESS
00136	McCoy Electronics	Mount Holly Springs, Pa.
00334	Humidial Co.	Colton, Calif.
00335	Westrex Corp.	New York, N.Y.
00373	Garlock Packing Co., Electronic Products Div.	Camden, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp, Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.
00866	Goe Engineering Co.	Los Angeles, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.
01295	Texas Instruments, Inc. Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
01561	Chassi-Trak Corp.	Indianapolis, Ind.
01589	Pacific Relays, Inc.	Van Nuys, Calif.
01930	Amerock Corp.	Rockford, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Calif.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	El Monte, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co.	Morristown, N.J.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04062	Elmenco Products Co.	New York, N.Y.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.
04404	Dymec Division of Hewlett-Parkard Co.	Palo Alto, Calif.
04651	Sylvania Electric Prods., Inc. Electronic Tube Div.	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Division	Culver City, Calif.
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire & Cable Company	Redwood City, Calif.
04870	P. M. Motor Co.	Chicago 44, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	San Mateo, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.
05624	Barber Colman Co.	Rockford, Ill.
05729	Metropolitan Telecommunications Corp., Metro Cap. Div.	Brooklyn, N.Y.
05783	Stewart Engineering Co.	Santa Cruz, Calif.
06004	The Bassick Co.	Bridgeport, Conn.
06136	Ward Leonard Electric	Los Angeles, Calif.
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06751	U.S. Semcor Div. of Nuclear Corp. of Am.	Phoenix, Ariz.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.
07126	Digitran Co.	Pasadena, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07261	Avnet Corp.	Los Angeles, Calif.
07263	Fairchild Semiconductor Corp.	Mountain View, Calif.
07700	Technical Wire Products	Springfield, N.J.
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Rheem Semiconductor Corp.	Mountain View, Calif.
07966	Shockley Semi-Conductor Laboratories	Palo Alto, Calif.
07980	Boonton Radio Corp.	Boonton, N.J.
08145	U.S. Engineering Co.	Los Angeles, Calif.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08717	Sloan Company	Burbank, Calif.
08718	Cannon Electric Co. Phoenix Div.	Phoenix, Ariz.
08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.
08994	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays, Inc.	Costa Mesa, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09250	Electro Assemblies, Inc.	Chicago, Ill.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
10214	General Transistor Western Corp.	Los Angeles, Calif.
10411	Ti-Tal, Inc.	Berkeley, Calif.
10646	Carborundum Co.	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11312	Microwave Electronics Corp.	Palo Alto, Calif.
11534	Duncan Electronics, Inc.	Santa Ana, Calif.
11711	General Instrument Corporation Semiconductor Division	Newark, N.J.
11717	Imperial Electronics, Inc.	Buena Park, Calif.
11870	Melabs, Inc.	Palo Alto, Calif.
12697	Clarostat Mfg. Co.	Dover, N.H.
12859	Nippon Electric Co., Ltd.	Tokyo, Japan
14298	American Components, Inc.	Conshocken, Pa.
14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.
15909	The Daven Co.	Livingston, N.J.
16688	De Jur-Amsco Corporation	Long Island City 1, N.Y.
16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.
18873	E. I. DuPont and Co., Inc.	Wilmington, Del.
19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.
19701	Electra Manufacturing Co.	Kansas City, Mo.
20183	Electronic Tube Corp.	Philadelphia, Pa.
21226	Executive, Inc.	New York, N.Y.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
21335	The Fafnir Bearing Co.	New Britain, Conn.
21964	Fed. Telephone and Radio Corp.	Clifton, N.J.
24446	General Electric Co.	Schenectady, N.Y.
24455	G.E., Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm inc.	Chicago, Ill.
37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
43990	C. A. Norgren Co.	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
49956	Raytheon Company	Lexington, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
59446	Telex, Inc.	St. Paul, Minn.
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Swissvale, Pa.
62119	Universal Electric Co.	Owosso, Mich.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
66295	Wittek Manufacturing Co.	Chicago 23, Ill.
66346	Wollensak Optical Co.	Rochester, N.Y.
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control Co., Inc.	New York, N.Y.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	New York, N.Y.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
71218	Bud Radio Inc.	Cleveland, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
71450	CTS Corp.	Elkhart, Ind.
71468	Cannon Electric Co.	Los Angeles, Calif.
71471	Cinema Engineering Co.	Burbank, Calif.
71482	C. P. Clare & Co.	Chicago, Ill.
71528	Standard-Thomson Corp., Clifford Mfg. Co. Div.	Waltham, Mass.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71700	The Cornish Wire Co.	New York, N.Y.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A. O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Corp.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
71707	Coto Coil Co., Inc.	Providence, R.I.
72354	John E. Fast & Co.	Chicago, Ill.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	General Ceramics Corp.	Keasbey, N.J.
72758	Girard-Hopkins	Oakland, Calif.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72964	Robert M. Hadley Co.	Los Angeles, Calif.
72982	Erie Resistor Corp.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	Hamden, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73682	George K. Garrett Co., Inc.	Philadelphia, Pa.

From: F.S.C. Handbook Supplements
H4-1 DATED: February 1963
H4-2 DATED: April 1962

00015-30
Revised: March 1963

APPENDIX
CODE LIST OF MANUFACTURERS (Sheet 2 of 2)

CODE NO.	MANUFACTURER	ADDRESS
73734	Federal Screw Products Co.	Chicago, Ill.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	The General Industries Co.	Elyria, Ohio
73905	Jennings Radio Mfg. Co.	San Jose, Calif.
74455	J. H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75173	Jones, Howard B., Division of Cinch Mfg. Corp.	Chicago, Ill.
75378	James Knights Co.	Sandwich, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littelfuse Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C. W. Marwedel	San Francisco, Calif.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76493	J. W. Miller Co.	Los Angeles, Calif.
76530	Monadnock Mills	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Pacific Division of Bendix Corp.	No. Hollywood, Calif.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	Potter and Brumfield, Div. of American Machine and Foundry	Princeton, Ind.
77630	Radio Condenser Co.	Camden, N.J.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
78283	Signal Indicator Corp.	New York, N.Y.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	Pasadena, Calif.
78947	Ucinite Co.	Newtonville, Mass.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80120	Schnitzer Alloy Products	Elizabeth, N.J.
80130	Times Facsimile Corp.	New York, N.Y.
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.
80207	Unimax Switch, Div. of W. L. Maxson Corp.	Wallingford, Conn.
80248	Oxford Electric Corp.	Chicago, Ill.
80294	Bourns Laboratories, Inc.	Riverside, Calif.
80411	Acro Div. of Robertshaw Fulton Controls Co.	Columbus 16, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80583	Hammerlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments, Inc.	New Haven, Conn.
81073	Grayhill Co.	LaGrange, Ill.
81312	Winchester Electronics Co., Inc.	Norwalk, Conn.
81415	Wilkor Products, Inc.	Cleveland, Ohio
81453	Raytheon Mfg. Co., Industrial Components Div., Industr. Tube Operations	Newton, Mass.
81483	International Rectifier Corp.	El Segundo, Calif.
81860	Barry Controls, Inc.	Watertown, Mass.
82042	Carter Parts Co.	Skokie, Ill.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.
82376	Astron Co.	East Newark, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals and Controls, Inc., Div. of Texas Instruments, Inc., Spencer Prods.	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Manufacturing Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83053	Western Washer Mfr. Co.	Los Angeles, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.
83125	Pyramid Electric Co.	Darlington, S.C.
83148	Electro Cords Co.	Los Angeles, Calif.
83186	Victory Engineering Corp.	Union, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
84171	Arco Electronics, Inc.	New York, N.Y.
84396	A. J. Glesener Co., Inc.	San Francisco, Calif.
84411	Good All Electric Mfg. Co.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.
85471	A. B. Boyd Co.	San Francisco, Calif.
85474	R. M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	New Haven, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86197	Clifton Precision Products	Clifton Heights, Pa.
86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.
87216	Philco Corp. (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.
89665	United Transformer Co.	Chicago, Ill.
90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91260	Connor Spring Mfg. Co.	San Francisco, Calif.
91345	Miller Dial & Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Brothers,'Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Philadelphia, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Calif.
91921	Minneapolis-Honeywell Regulator Co., Micro-Switch Division	Freeport, Ill.
92196	Universal Metal Products, Inc.	Bassett Puente, Calif.
93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.
93369	Robbins and Myers, Inc.	New York, N.Y.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N.H.
94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.
94145	Raytheon Mfg. Co., Semiconductor Div., California Street Plant	Newton, Mass.
94148	Scientific Radio Products, Inc.	Loveland, Colo.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp., Electronics Div.	East Paterson, N.J.
94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
94928	Telefunken	Berlin, W. Germany
95236	Allies Products Corp.	Miami, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	New York, N.Y.
95264	Lerco Electronics, Inc.	Burbank, Calif.
95265	National Coil Co.	Sheridan, Wyo.
95275	Vitramon, Inc.	Bridgeport, Conn.
95354	Methode Mfg. Co.	Chicago, Ill.
95987	Weckesser Co.	Chicago, Ill.
96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Division of Aerovox	Olean, N.Y.
96256	Thordarson-Meissner Div. of Maguire Industries, Inc.	Mt. Carmel, Ill.
96296	Solar Manufacturing Co.	Los Angeles, Calif.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Calif.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
97979	Reon Resistor Corp.	Yonkers, N.Y.
98141	Axel Brothers Inc.	Jamaica, N.Y.
98220	Francis L. Mosley	Pasadena, Calif.
98278	Microdot, Inc.	So. Pasadena, Calif.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98405	Carad Corp.	Redwood City, Calif.
98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
98821	North Hills Electric Co.	Mineola, N.Y.
98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
98978	International Electronic Research Corp.	Burbank, Calif.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Calif.
99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp.	Evanston, Ill.
99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.

THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

0000F	Malco Tool and Die	Los Angeles, Calif.
00001	Telefunken (c/o American Elite)	New York, N.Y.
0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
0000T	Texas Instruments, Inc. Metals and Controls Div.	Versailles, Ky.
0000U	Tower Mfg. Corp.	Providence, R.I.
0000W	Webster Electronics Co. Inc.	New York, N.Y.
0000X	Spruce Pine Mica Co.	Spruce Pine, N.C.
0000Y	Midland Mfg. Co. Inc.	Kansas City, Kans.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AA	British Radio Electronics Ltd.	Washington, D.C.
000AB	ETA	England
000BB	Precision Instrument Components Co.	Van Nuys, Calif.
000CC	Computer Diode Corp.	Lodi, N.J.
000EE	A. Williams Manufacturing Co.	San Jose, Calif.
000GG	Goshen Die Cutting Service	Goshen, Ind.
000HH	Rubbercraft Corp.	Torrance, Calif.
00011	Birtcher Corporation, Industrial Division	Monterey Park, Calif.
000KK	Amatom	New Rochelle, N.Y.
000LL	Avery Label	Monrovia, Calif.
000MM	Rubber Eng. & Development	Hayward, Calif.
000NNA	"N" D Manufacturing Co.	San Jose 27, Calif.
000PP	Atohm Electronics,	Sun Valley, Calif.
000QQ	Cooltron	Oakland, Calif.
000RR	Radio Industries	Des Plaines, Ill.
000SS	Control of Elgin Watch Co.	Burbank, Calif.
000TT	Thomas & Betts Co., The	Elizabeth 1, N.J.
000WW	California Eastern Lab.	Burlingame, Calif.
000XX	Methode Electronics, Inc.	Chicago 31, Ill.
000YY	S. K. Smith Co.	Los Angeles 45,Calif.

From: F.S.C. Handbook Supplements
H4-1 DATED: February 1963
H4-2 DATED: April 1962

00015-30
Revised: March 1963

MANUAL CHANGES

MODEL 405C

AUTOMATIC DC DIGITAL VOLTMETER

Manual Serial Prefixed: 243-
Manual Printed: JUNE 1963

MAKE ALL CORRECTIONS IN THIS MANUAL ACCORDING TO ERRATA BELOW, THEN CHECK THE FOLLOWING TABLE FOR YOUR INSTRUMENT SERIAL PREFIX (3 DIGITS) OR SERIAL NUMBER (8 DIGITS) AND MAKE ANY LISTED CHANGE(S) IN THE MANUAL.

► NEW ITEM.

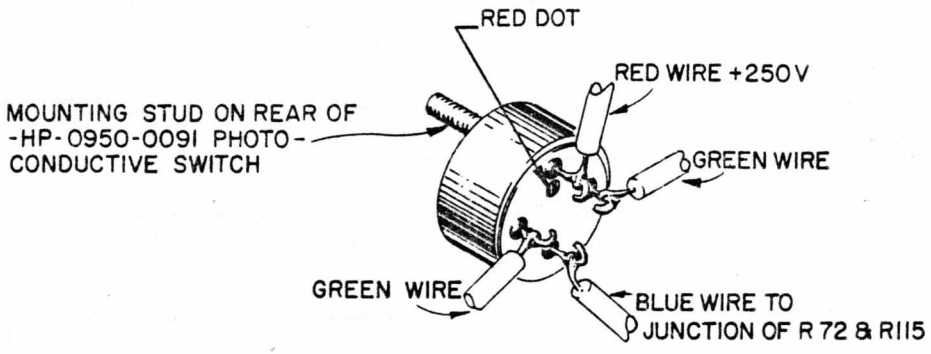
SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES	SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES
402-	1		

ERRATA

Figure 4-8, Power Supply,
R126: Change value to 1500 ohms,
Figure 4-9, Amplifier/Oscillator,
R34: Add resistor R34 (2200 ohms) in series between input terminals J1 (high side) and CALIBRATE switch S1. Add resistor between J1 terminal and junction of wire from J2 pin A.
Figure 4-10, Control/Counter Section,
Change diagram to show pin 11 of sockets XZ2B, and XZ1B going to pin 13 of J3A instead of pin 13 of J3B.
Table 5-1, Replaceable Parts,
C4, 24: Change hp Stock No. to 0160-0314.
C20: Change hp Stock No. to 0140-0001.
CR2: Change hp Stock No. to 1902-0172.
CR5 thru CR8: Change to Diode, silicon; hp Stock No. 1901-0156; Mfr. 28480.
CR13, CR14: Change hp Stock No. to 1910-0016; Mfr. 28480.
DS2 thru DS5: Change to Lamp, miniature, 6.3V, 2 pin base, GE#12, painted, Mfr. 28480, hp Stock No. 405A-33C.
R116 and R117: Transpose descriptions.
R126: Change to resistor, fixed, wirewound, 1500 ohms 5%, 20W; hp Stock No. 0819-0016.
R142: Change to resistor, fixed, composition, 100,000 ohms ±10%, 2W, Mfr. 01121, hp Stock No. 0693-1041.
V8: Change to tube, electron: 2D21; Mfr. 86684; hp Stock No. 1941-0007; TQ 2; RS 2.
► V28: Change to hp Stock No. 2140-0084.
Z1, Z2, Z3: Change hp Stock No. to 5080-0014 (formerly AC-4K).
Under MISCELLANEOUS,
Change hp Stock No. G-74G to 0370-0029.
Table 5-2, Digital Recorder Adapter 405A-95C,
CR301: Change hp Stock No. to 1902-0054.

CHANGE 1

Table 5-1, Replaceable Parts,
DS7: Change to Lamp, neon; part of V23, not separately replaceable.
V23: Change to Lamp and Photoconductive Cell Assembly,
Stock No. 0950-0091.



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Bombay 400 025
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P.O.Box 25016
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4-20, Nishinakajima 5-chome
Yodogawa-ku, Osaka-shi
Osaka,532
Tel: 06-304-6021
Telex: 523-3624

Yokogawa-Hewlett-Packard Ltd.
29-21, Takaido-Higashi 3-chome
Suginami-ku, **Tokyo** 168
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24 Kami Sasajima-cho
Nakamura-ku, Nagoya, 450
Tel: 052 571-5171

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Tamigawa Building
2-24-1 Tsuruya-cho
Kanagawa-ku
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Mito Mitsui Building
105, 1-chome, San-no-maru
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Tel: 0292-25-7470

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Atsugi, Kanagawa 243
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Lagos
Cable: THETEIL Lagos

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Howard Place, Cape Province, 7450
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Tel: 53-7955 thu 9
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TAIWAN
Hewlett-Packard Far East Ltd.
Taiwan Branch
39 Chung Hsiao West Road
Section 1, 7th Floor
Taipei
Tel: 3819160-4,3141010,3715121 Ext. 270-279
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Carrera 7 No. 48-75
Apartado Aereo 6287
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Instrumentacion
H.A. Langebaek & Kier S.A.
Apartado Aereo 54098
Medellin
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COSTA RICA
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Avenida 2, Calle 5
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Apartado Postal 689
Edificio Terán
Managua
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Palo Alto, California 94304
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TWX: 910-373-1260
Cable: HEWPACK Palo Alto
Telex: 034-8300, 034-8493

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Hewlett-Packard Ges.m.b.H.
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Nicosia
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Cable: Kypronics Pandehis
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CSSR-25097 **Bechovice u Prahy**
Tel: 89 93 41
Telex: 121333

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Vyskumny Ustav Lekarskej Bioniky
Jedlova 6
CS-88346
Bratislava-Kramare
Tel: 4251
Telex: 93229

DDR
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Waidheim/Meinsberg
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1040 **Berlin**
Tel: 42-74-12
Telex: 111889

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Datavej 52
DK-3460 **Birkerod**
Tel: (02) 81 66 40
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Hewlett-Packard A/S
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DK-8600 **Silkeborg**
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Telex: 37409 hpas dk
Cable: HEWPACK AS

EGYPT
I.E.A.
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Berner Strasse 117
Postfach 560 140
D-6000 **Frankfurt** 56
Tel: (0611) 50-04-1
Cable: HEWPACKSA Frankfurt
Telex: 04 13249 hpftm d

Hewlett-Packard GmbH
Technisches Büro Böblingen
Herrenberger Strasse 110
D-7030 **Böblingen**, Württemberg
Tel: (0703) 667-1
Cable: HEWPACK Böblingen
Telex: 07265739 bbn

Hewlett-Packard GmbH
Technisches Büro Düsseldorf
Emanuel-Leutze-Str.1(Seestern)
D-4000 **Düsseldorf**
Tel: (0211) 59711
Telex: 085/86 533 hpdd d

Hewlett-Packard GmbH
Technisches Büro Hamburg
Wendenstrasse 23
D-2000 **Hamburg** 1
Tel: (040) 24 13 93
Cable: HEWPACKSA Hamburg
Telex: 21 63 032 hphh d

Hewlett-Packard GmbH
Technisches Büro Hannover
Am Grossmarkt 6
D-3000 **Hannover 91**
Tel: (0511) 46 60 01
Telex: 092 3259

Hewlett-Packard GmbH
Technisches Büro Nürnberg
Neumeyerstrasse 90
D-8500**Nürnberg**
Tel: (0911) 56 30 83
Telex: 0623 860

Hewlett-Packard GmbH
Technisches Büro München
Eschenstrasse 5
D-8021 **Taufkirchen**
Tel: (089) 6117-1

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Technisches Büro Berlin
Kaithstrasse 2-4
D-1000 **Berlin** 30
Tel: (030) 24 90 86
Telex:018 3405 hpbln d

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Kostas Karayannis
8 Omirou Street
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Tel: 32 30 303/32/37 731
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