COPY

INSTRUCTION MANUAL

FOR

MODEL 521A

INDUSTRIAL ELECTRONIC

COUNTER

Serial 397 and Above

HEWLETT-PACKARD COMPANY
275 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

INSTRUCTION MANUAL

FOR

MODEL 521A

INDUSTRIAL ELECTRONIC

COUNTER

ERRATA

Add to parts list:

J 201: input connector, (cabinet mount), -hp- Stock No. 125-UG-1094/U, Mfr. -hp-

J 201: input connector, (rack mount), -hp- Stock No. 125-9, Mfr. LL, No. 5126.

PRODUCTION CHANGES

Add to Serial 397 and above

Serial 643 and above:

Change R114 from 23-2.7M to: resistor, fixed, composition, 2.4 megohms, ±5%, 1/2 W., -hp- Stock No. 23-2.4M-5, Mfr. B, EB 2455.

Serial 605 and above:

Change C9 from 820 μμf, to: capacitor, fixed, mylar dielectric, 4700 μμf, ±10%, 400 vdcw, -hp Stock No. 16-105, Mfr. Goodall, Type 620M47294.

Change R12 & R22 from 3900 ohms to: resistor, fixed, composition, 3300 ohms, ±10%, 1/2 W., -hp- Stock No. 23-3300, Mfr. B, EB 3321.

Change R17, R27, & R36 from 18K ohms to: resistor, fixed, composition, 390,000 ohms, ±10%, 1/2 W., -hp- Stock No. 23-390K, Mfr. B, EB 3941.

Change R18 & R28 from 220K ohms to: resistor, fixed, composition, 270,000 ohms, ±10%, 1/2 W., -hp- Stock No. 23-270K, Mfr. B, EB 2741.

Change R19 & R29 from 1.8M ohms to: resistor, fixed, composition, 2.7 megohms, ±10%, 1/2 W., -hp- Stock No. 23-2.7M, Mfr. B, EB 2751.

Change R33 from 15M ohms to: resistor, fixed, composition, 2.7 megohms, ±10%, 1/2 W., -hp- Stock No. 23-2.7M, Mfr. B, EB 2751.

Change R13 & R 23 from 560 ohms to: resistor, fixed, composition, 680 ohms, ±10%, 1/2 W., -hp- Stock No. 23-680, Mfr. B, EB 6811.

Change R16, R26, & R35 from 120K ohms to: resistor, fixed, composition, 150,000 ohms, ±10%, 1 W., -hp- Stock No. 24-150K, Mfr. B, GB 1541.

Change R38 from 10K ohms to: resistor, fixed, composition, 12,000 ohms, ±10%, 1/2 W., -hp- Stock No. 23-12K, Mfr. B, EB 1231.

Add R39 & R40: resistor, fixed, composition, 12,000 ohms, ±10%, 1/2 W. -hp- Stock No. 23-12K, Mfr. B, EB 1231.

Add C11 & C12: capacitor, fixed, ceramic disc, .02μf, tol. +100% –0%, 600 vdcw, -hp- Stock No. 15-85, Mfr. DD, 203.

SERVICE NOTES

HEWLETT-PACKARD COMPANY · 1501 PAGE MILL ROAD · PALO ALTO, CALIFORNIA, U.S.A.
CABLE "HEWPACK" TELEPHONE DAVENPORT 6-7000

MODEL 521C ELECTRONIC COUNTER

SERIAL 3631 AND BELOW

PHANTASTRON MODIFICATION KIT 521C-95A

These Service Notes outline a recommended modification procedure that will improve the stability of the phantastron frequency dividers in the time base section of your Model 521C Electronic Counter. This improved stability assures a constant division ratio and thereby eliminates frequent readjustment of the phantastrons.

The necessary parts and instructions to perform this modification are available in a convenient-to-order modification kit (Stock No. 521C-95A). The modification can be installed in either cabinet mount or rack mount instruments.

The modification consists of various resistor and capacitor changes in the .1 SEC, 1 SEC, and 10 SEC phantastron circuits. No special tools or test equipment are required.

A simple adjustment of a variable resistor in each phantastron circuit completes the modification.

PARTS FURNISHED IN MODIFICATION KIT 521C-95A

QUANTITY	DESCRIPTION	STOCK NO.
2	Capacitor: fixed, mica, 270 pf, 500 vdcw for C106 and C118	0140-0015
1	Capacitor: fixed, polystyrene, .039 μf, ±2%, 400 vdcw, for C105	0170-0032
2	Capacitor: fixed, polystyrene, .39 μf, ±2%, 400 vdcw, for C109 and C119	0170-0031
1	Resistor: fixed, composition, 620 ohms, ±5%, 1/2 W for R281	0686-6215
3	Resistor: fixed, composition, 1000 ohms, ±10%, 1/2 W for R114B, R122B, and R160B	0687-1021
1	Resistor: fixed, composition, 2700 ohms, ±5%, 1/2 W for R280	0686-2725
2	Resistor: fixed, composition, 3300 ohms, ±5%, 1/2 W for R113 and R121	0686-3325
3	Resistor: fixed, composition, 22,000 ohms, ±5%, 1/2 W for R117, R125, and R164	0686-2235
3	Resistor: variable, 50,000 ohms, ±10%, 1/2 W for R115, R123, and R161	2100-0028
3	Resistor: fixed, composition, 82,000 ohms, ±5%, 1/2 W for R116, R124, and R163	0686-8235
2	Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 W for R118 and R156	0687-1041
3	Resistor: fixed, composition, 110,000 ohms, ±5%, 1 W for R112, R120, and R159	0689-1145
3	Resistor: fixed, composition, 120,000 ohms, ±10%, 1/2 W for R154, R155, and R162	0687-1241
1	Resistor: fixed, composition, 470,000 ohms, ±10%, 1/2 W for R110	0687-4741
2	Resistor: fixed, composition, 1.8 megohms, ±10%, 1/2 W for R142 and R157	0687-1851

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01121-1

PARTS FURNISHED IN MODIFICATION KIT 521C-95A (Cont'd)

QUANTITY	DESCRIPTION	℗ STOCK NO.
1	Machine screw 6-32 x 2 inch	2360-0020
1	Resistor: fixed, deposited carbon, 24.9 megohms, ±1%, 1 W, for R160A	0730-0148
2	Resistor: fixed, deposited carbon, 2.163 megohms, ±1%, 1 W, for R114A and R122A	0730-0113
1	Resistor: fixed, composition, 8.2 megohms, ±10%, 1/2 W for R140	0687-8251
2	Washers, #6 flat	3050-0100
1	Cable clamp, 1/2 inch for mounting C105	1400-0025
5	Hex nut, w/lockwasher	2420-0001
1	Capacitor mounting assembly	521A-95C-1
2	Spacers, 1/4 in. O. D. x 1/8 in. long	0380-0003
3	Machine screws, binding head, 6-32 x 1/2 in. with lockwasher	2390-0001
1	Spade lug, 6-32 x 1 in.	0560-0006
1	Blue wire, #22 stranded, 4-1/2 in.	8150-0014
1	Blue wire, #22 stranded, 8 in.	8150-0014
1	Green wire, #22 stranded, 4-1/2 in.	8150-0011
1	Green wire, #22 stranded, 5-1/2 in.	8150-0011
1	Green wire, #22 stranded, 12 in.	8150-0011
1	Orange wire, #22 stranded, 2-1/2 in.	8150-0017
1	Orange wire, #22 stranded, 4 in.	8150-0017
1	Orange wire, #22 stranded, 4-1/2 in.	8150-0017
1	Red wire, #22 stranded, 4-1/2 in.	8150-0022
1	Service Notes	521C-2

INSTALLATION PROCEDURE

Note: In the following procedure note the new positions for C105, C109, and C119. Figure 1 shows new locations.

1) Disconnect power.

2) Remove two screws at rear of instrument. Remove cabinet by sliding instrument forward.

3) Remove and discard C119 (.5 μf) and pads if present, behind turret socket for V17. Remove and discard tie point. Leave the blue wire for connecting a new capacitor.

4) Remove rivet nuts from capacitor mounting bracket. Use a 6-32 x 2 inch machine screw as a knock-out tool.

Position capacitor mounting bracket 1/4 inch above chassis as in figure 1. Mark and drill #22 holes. Be careful not to damage wiring or components while drilling.

5) Loosen terminal board on rear vertical chassis and install capacitor mounting bracket. Use 1/2 inch screws and 1/8 inch spacers. Install .39 mf ±2%, 400 vdcw, capacitors for C109 and C119.

6) At pin 7 of tube sockets for V3, V4, and V16, replace the 12,000-ohm resistors R117, R125, and R164 with 22,000 ohms ±5%, 1/2 watt resistors.

7) At sockets for V3 and V4, remove 3900-ohm resistors for R113 and R121 from pin 2. Replace with 3300-ohm ±5%, 1/2 watt resistors.

Note: If your counter has a printer kit installed, the 3900-ohm resistor for R121 should be replaced by 2700-ohm (R280) in series with 620-ohm (R281). These resistors are included in both the Phantastron Modification Kit and in the Digital Recorder Adapter Kit.

8) Remove and discard 3.9-megohm resistors R140, R142, and R157 at socket for V2. Install an 8.2-megohm ±10%, 1/2 watt resistors from pin 1 to ground for R140. R142 and R147 are no longer used.

9) Remove the original capacitor for C119 (.22 μf) and cable clamp assembly from pin 5 of V4 to R112A. Remove 5.6-megohm resistor R122A and wire connecting to pin 1 of V4. Install a 1000-ohm ±10% 1/2 watt resistor in place of the wire jumper for R122B. Use a 1-inch length of tubular insulation over the end connecting to the terminal board.

Install a 2.163 megohm ±1%, 1 watt resistor for R122A.

10) On the upper terminal board remove 150K resistors R116, R124, and R163. Remove 390,000-ohm resistors R110 and R156, and capacitor C118 (100 pf). Remove the two red jumpers and the shorting bar shown in figure 1.

In rack mount instruments remove red jumper connecting outer end of R124 to R246 (100,000 ohms) near DISPLAY TIME control. Connect a 4-1/2 inch red wire between outer end of R110 and R246.

11) Connect the orange jumpers as follows:

Outside terminal of R163 to inside terminal of R158 (4-1/2 in.).
Outside terminal of R116 to inside terminal of R111 (2-1/2 in.).
Outside terminal of R124 to inside terminal of R119 (4 in.) on lower terminal board.

12) Connect a 12 in. green jumper from the inside terminal of R122A to one side of C109. Connect the other side of C109 to pin 6 of V2 with an 8 in. blue jumper.

13) On the upper terminal board replace the components removed in step 10 with the values indicated: (see figure 1)

R110	470,000 ohms ±10%, 1/2 W
R156	100,000 ohms ±10%, 1/2 W
R116, 124, 163	82,000 ohms ±5%, 1/2 W
C118	270 pf 500 vdcw w/parallel 1.8 megohm ±10%, 1/2 W resistor for R157

14) Refer to figure 2. On the lower terminal board remove the original capacitor for C105 (.047 mf). Replace the following components with the values indicated:

Change	From	To
R112, 120, 159:	100,000	110,000 ohms ±5%, 1 W
R118	390,000	100,000 ohms ±10%, 1/2 W
C106	100 pf	270 pf 500 vdcw w/parallel 1.8 megohm ±10%, 1/2 W resistor for R142

Remove 2.7 megohm resistor for R114A and the green wire connecting to pin 1 of V3. Replace the wire jumper with a 1000-ohm ±10%, 1/2 watt resistor for R114B. Replace R114A with a 2.163 megohm ±1%, 1 watt resistor.

15) Install a .039 mf ±2%, 400 vdcw capacitor for C105, in original mounting hole for C109. Use 6-32 x 1 inch spade lug and 1/2 inch plastic clamp, flat washers, 6-32 screw, and nuts. Refer to figure 1.

Connect one terminal of C109 to outer terminal of R114A with a 4-1/2 inch green wire. Connect the other terminal to pin 5 of V3, using a 4-1/2 inch blue wire.

16) Remove resistor R160B (22 megohms) and white jumper to end terminal of turret socket for V17. Replace the resistor with 1000-ohm ±10%, 1/2 watt resistor for R160B. Replace the white jumper with a 24.9 megohm ±1%, 1 watt resistor for R160A.

17) Connect the existing blue wire from pin 8 of V2 to one side of C119. Connect a 5-1/2 inch green wire from the other side of C119 to the outer terminal of R160B at the rear of the lower terminal board (see figure 2).

18) Remove the three variable resistors and series fixed resistors at the rear of the chassis as shown in figure 3. Slot the holes with a round file for the slightly larger replacement variable resistors. Make sure controls do not short against contacts of J202 PHOTO input jack. If necessary, the hole for J202 may be moved slightly.

19) Install the replacement variable resistors R115, R123, and R161, 50,000 ohms ±10%. Connect to agree with figure 3. Use 120,000 ohm ±10%, 1/2 watt resistors for R154, R155, and R162.

ADJUSTMENTS

20) If crystal time base plug-in unit is installed set TIME BASE switch to LINE-EXT.

21) Turn instrument on and allow five-minute warmup.

22) Set:

INPUT SENSITIVITY . . . . . CHECK
DISPLAY TIME . . . . . minimum (ccw)

23) Set GATE SELECTOR to 1/10 SEC and adjust .1 SEC potentiometer to give readout of 00006 (see note below).

24) Set GATE SELECTOR to 1 SEC and adjust 1 SEC potentiometer to give readout of 00060 (see note below).

25) Set GATE SELECTOR to 10 SEC and set 10 SEC potentiometer to give readout of 00600 (see note below).

26) Return TIME BASE switch to its original setting.

27) Repeat step 23, adjusting for a readout of 1000.

Note

When adjusting phantastrons, turn potentiometers clockwise until counter miscounts. Continue slightly past this point and then turn potentiometer counterclockwise until counter just begins to give correct count. Note shaft position; this is the clockwise limit. Repeat procedure in counterclockwise direction and note shaft position. This is the counterclockwise limit. Set potentiometer midway between these limits. Check phantastrons for correct count with line voltage set at 103 and 127 volts. Allow counter to operate at each extreme voltage for at least one minute. Improper operation may indicate incorrect control setting, a weak tube, or poor power supply regulation.

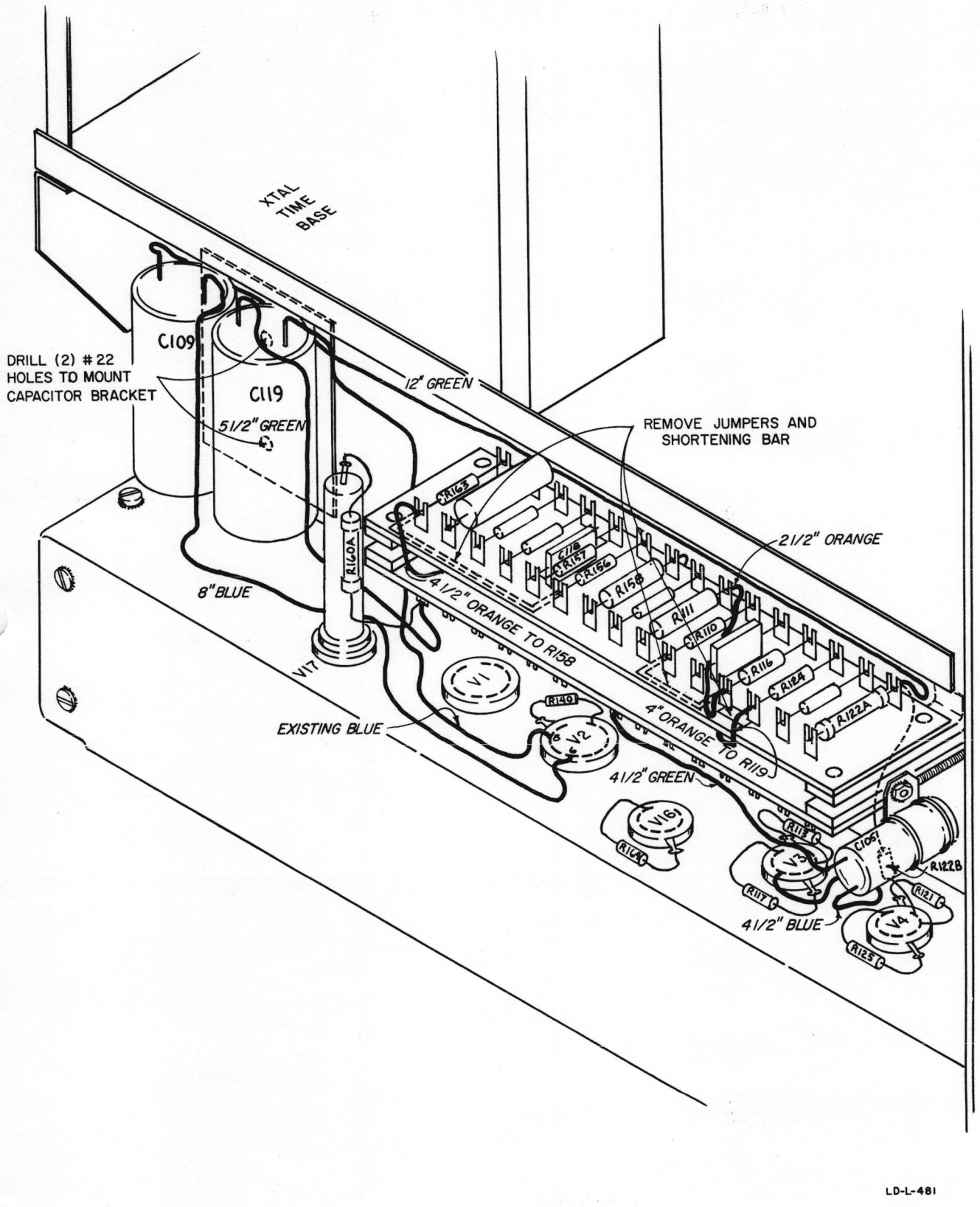


Figure 1. After Modification

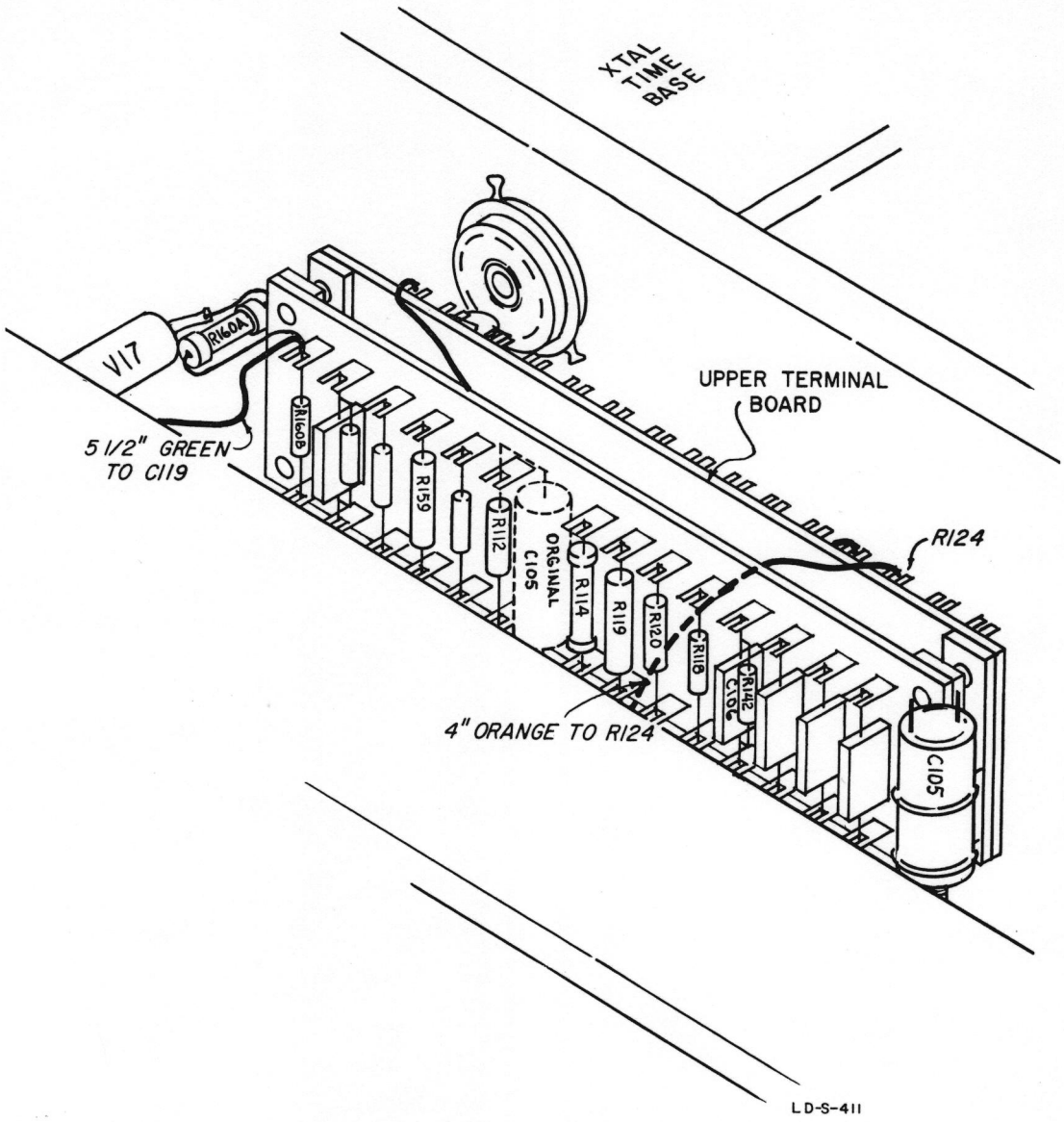


Figure 2. Lower Terminal Board

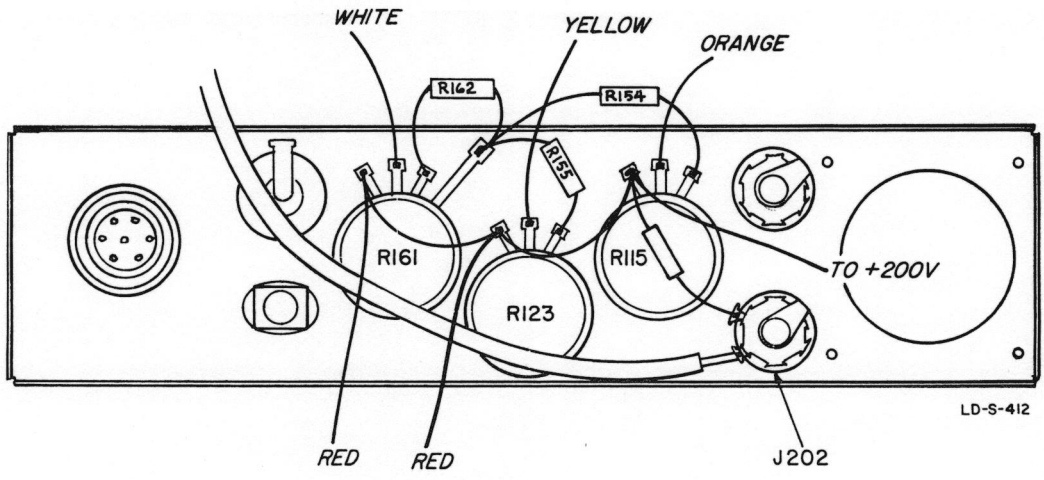


Figure 3. Phantastron Control Wiring

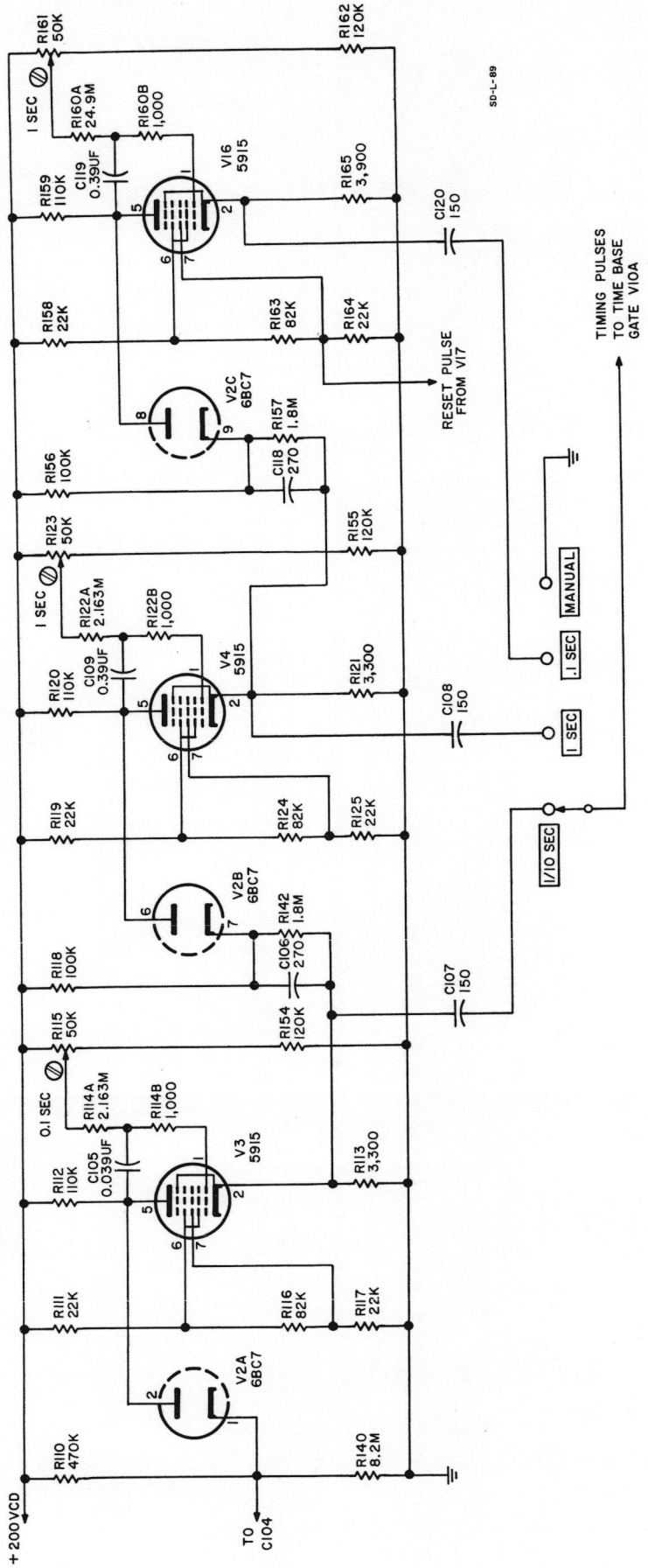


Figure 4. Model 521C Modified Time Base. (Partial Schematic Diagram.)

DICK LEWIS

SPECIFICATIONS

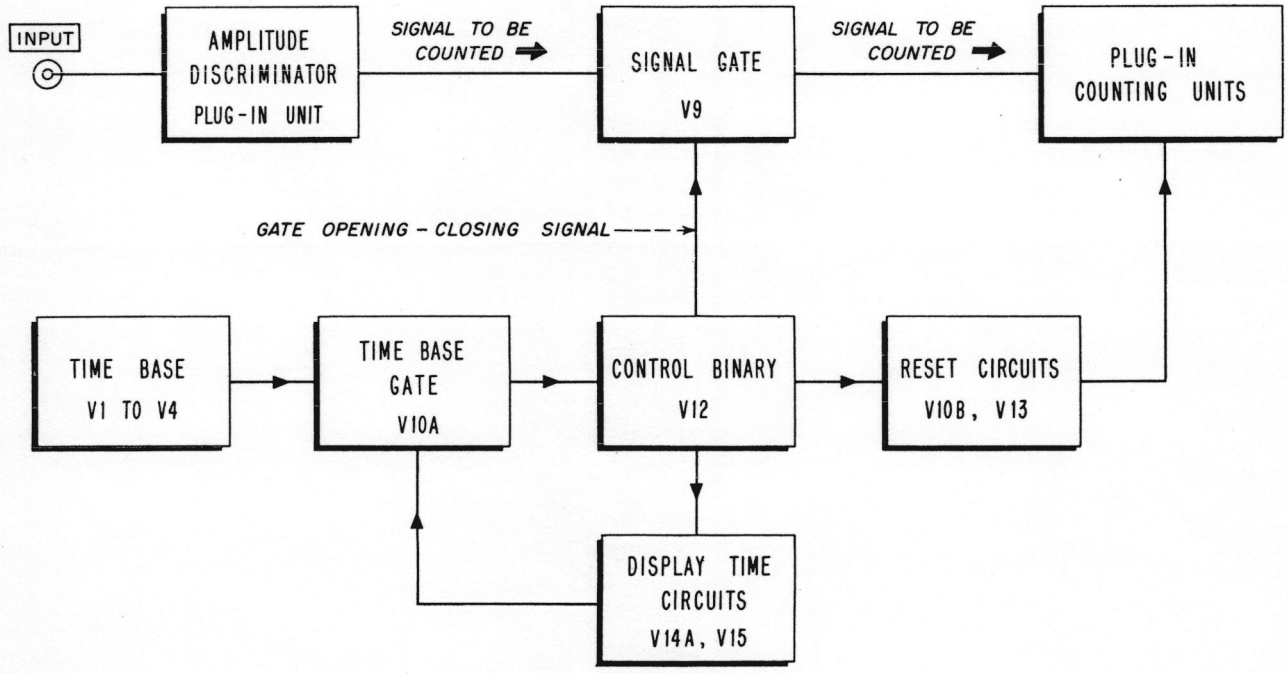
MODEL 521A

RANGE:	1 cps to 120 kc, or 1 cps to 220 kc at slight extra cost.
ACCURACY:	±1 count ± accuracy of timing frequency. (Approximately ±0.1% when power line used, ±0.01% with crystal time base installed.)
REGISTRATION:	4 places. Total count capacity, 9,999.
INPUT REQUIREMENTS:	0.2v rms minimum or output from 1P41 Phototube (or equal). Phototube bias provided at "PHOTOTUBE" jack. 1/2 rms required at frequencies above 120 kc with 220 kc option. Attenuator reduces sensitivity to 100v rms to overcome noise.
INPUT IMPEDANCE:	Approximately 1 megohm 50 μμf shunt (500K ohms on "PHOTOTUBE" jack).
GATE TIME:	1/10 and 1 second. Panel neon lamp indicates that gate is open.
MANUAL GATE:	Controlled by "Open-Closed" switch or external contacts.
DISPLAY TIME:	Variable from 1/10 to 15 seconds; or display can be held indefinitely.
RESET TO ZERO:	Automatic or manual.
READS IN:	Cps or rps directly or in rps or rpm with hp 506A or 508A Tachometer Accessories.
SELF-CHECK:	Counts 50/60 cps line frequency for any selected gate time.
EXTERNAL STANDARD:	Can be operated from any multiple of 10 cps, 10 cps to 100 cps.
PHOTOTUBE INPUT:	Supply voltage for 1P41 (or equal) phototube provided at phone jack on rear.
ACCESSORY SOCKET:	Cannon type AN 3102-A-16S-1S, supplies 6.3vac, 0.6a; + 300vdc, 10 ma -150vdc, 5 ma.
CONNECTORS:	BNC and standard phone jacks.
POWER SUPPLY:	115/230v ±10%, 50/60 cps, 185 watts.
SIZE:	Cabinet Mount: 9-3/4" wide, 15-1/4" high, 14-1/2" deep. Rack Mount: 19" wide, 8-3/4" high, 14-1/2" deep.
WEIGHT:	Cabinet Mount: Net 28 lbs., Shipping 41 lbs. Rack Mount: Net 28 lbs., Shipping 35 lbs.
ACCESSORIES PROVIDED:	hp AC-16D Cable Assembly, 44" RG-58/U cable terminated one end with UG-88/U Type BNC connector.
ACCESSORIES AVAILABLE:	hp Model 506A Optical Tachometer Pickup. hp Model 508 Tachometer Generator. hp Model AC-4B Decade Counter for 220 kc operation. hp Model 521A-59B Crystal Time Base for field installation. hp 521A-95A, hp 560A Digital Recorder Adapter Kit.

SPECIFICATIONS

hp MODEL 521C

RANGE:	1 cps to 120 kc, or 1 cps to 220 kc at slight extra cost.
ACCURACY:	±1 count ±0.01%.
REGISTRATION:	5 places. Total display capacity 99,999.
INPUT REQUIREMENTS:	0.2v rms minimum or output from 1P41 Phototube (or equal). 1/2v rms required at frequencies above 120 kc with 220 kc option. Attenuator can be used to reduce sensitivity to 100v rms to overcome noise.
INPUT IMPEDANCE:	Approximately 1 megohm 50μμf shunt (500K ohms on "PHOTOTUBE" jack).
GATE TIME:	1/10, 1, and 10 seconds. Panel lamp indicates open gate.
MANUAL GATE:	Controlled by "Count" switch or external contacts.
DISPLAY TIME:	Variable from 1/10 to 15 seconds; or display can be held indefinitely.
RESET TO ZERO:	Automatic or manual.
READS IN:	Cps or directly in rps or rpm with hp 506A or 508A Tachometer Accessories.
SELF-CHECK:	Counts 10 kc time base frequency for selected gate time.
EXTERNAL STANDARD:	Can be operated from any multiple of 10 cps, 10 cps to 100 cps.
PHOTOTUBE INPUT:	Provides voltage for and receives signal from 1P41 (or equal) phototube.
ACCESSORY SOCKET:	Cannon type AN 3102-A-16S-1S, supplies 6.3vac, 0.6a; +300vdc, 10 ma; -150vdc, 5 ma.
CONNECTORS:	BNC and standard phone jacks.

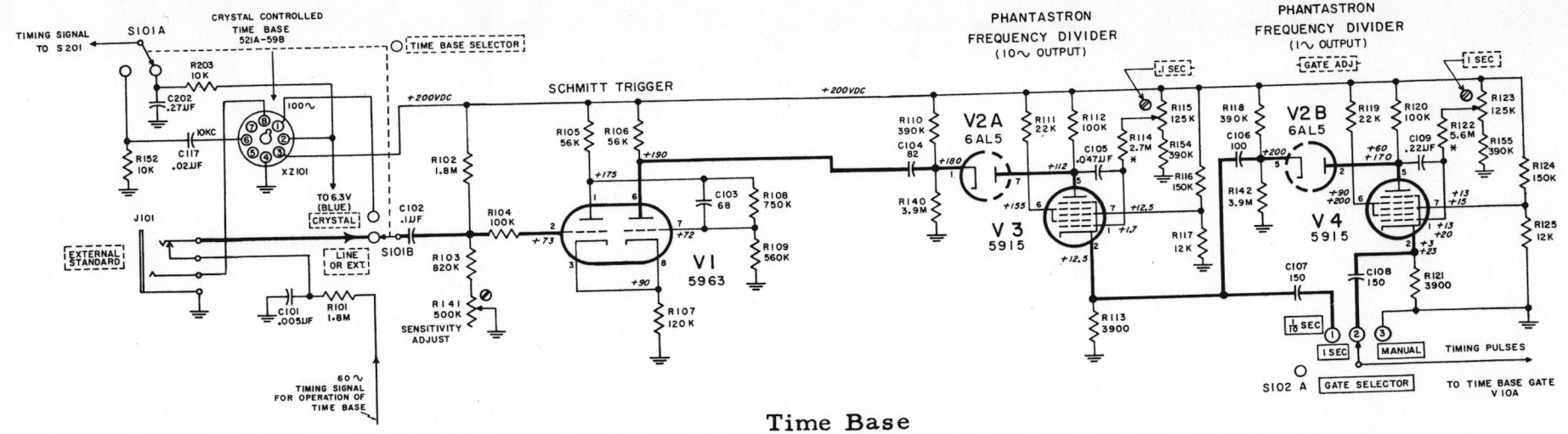


Simplified Block Diagram of the 521

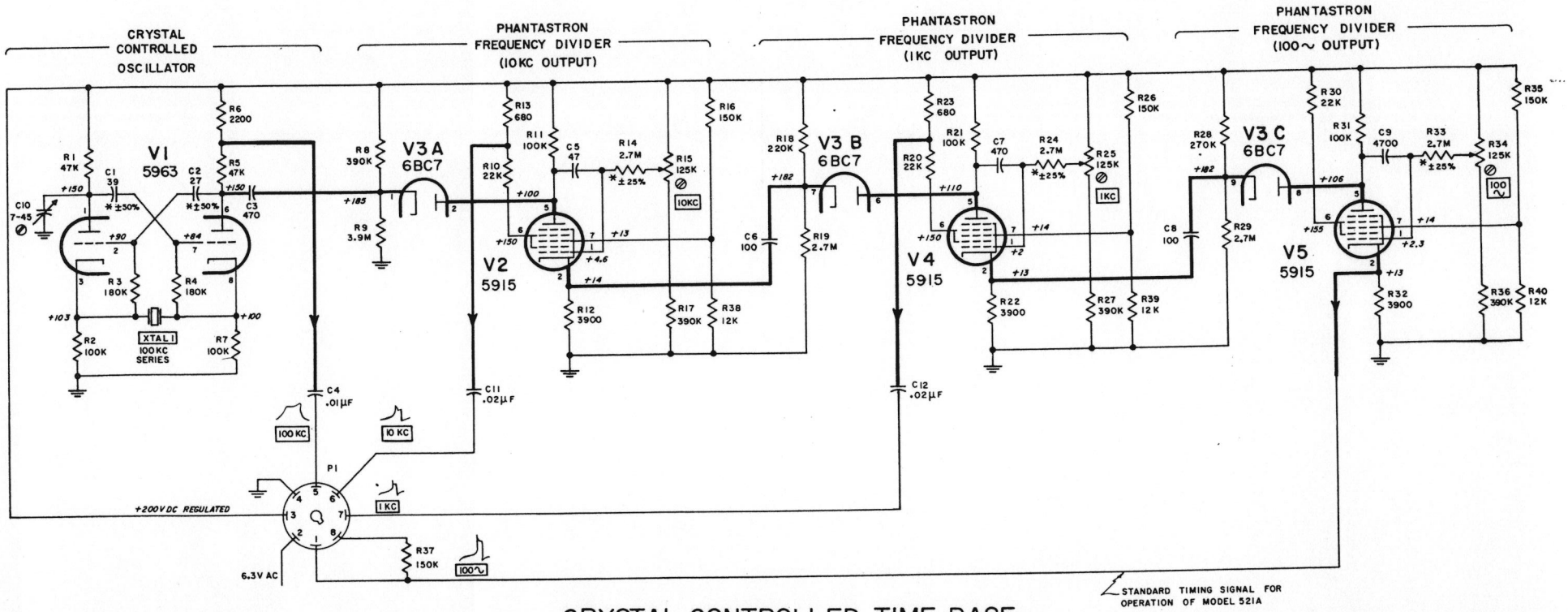
MODEL 521A/C

CONDENSED TEST AND ADJUSTMENT PROCEDURE

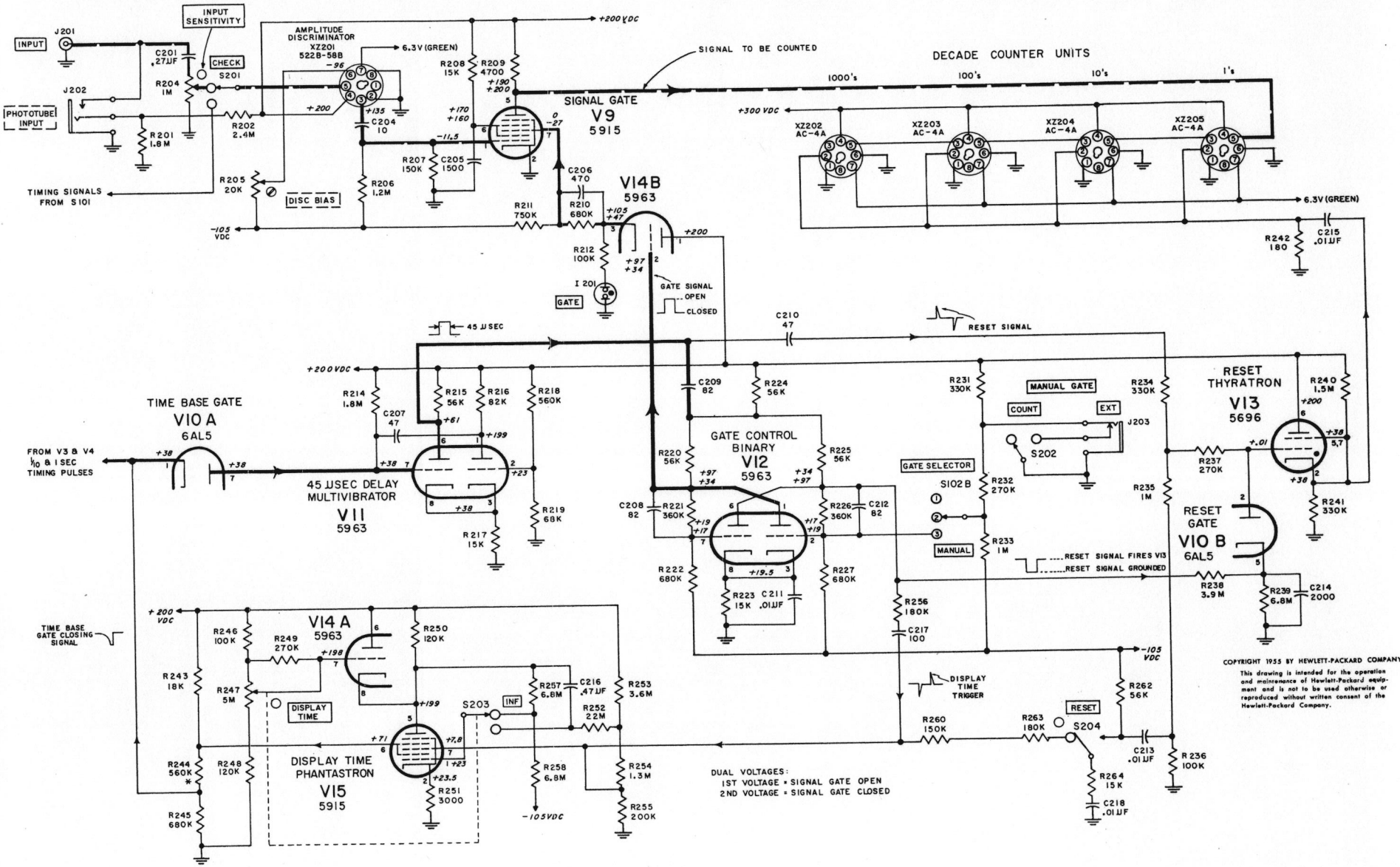
TEST	EXTERNAL EQUIPMENT REQUIRED	PROCEDURE	ADJUST	NOTES
1. Power Supply	DC VTVM	Measured power supply output should be: +200V ±8 volts	Do Not adjust R134 (+200V Adjust) if voltage is within limits.	
2. Phantastron	None	Set INPUT SENSITIVITY to CHECK: GATE SELECTOR to 1/10 SEC. Set TIME BASE switch to LINE.	Adjust 1/10 Sec. Gate (R115) for a count of 6.	Ideal setting is center of range giving correct count.
		Set GATE SELECTOR to 1 SEC.	Adjust 1 Sec. Gate (R123) for a count of 60.	
		521C Only Set GATE SELECTOR to 10 SEC.	Adjust 10 Sec. Gate (R161) for a count of 600.	
3. Crystal Control Plug-in.	None	Set TIME BASE switch to LINE; INPUT SENSITIVITY full cw; GATE SELECTOR to 1/10 SEC. Connect jumper between Time Base socket (XZ101) pin 6 and INPUT.	Set 10 kc Adjust (R15) for a count of 1000.	
		Move jumper to pin 7.	Set 1 kc Adjust (R25) for a count of 100.	
		Move jumper to pin 8. Set GATE SELECTOR to 1 SEC.	Set 100 cps Adjust (R34) for a count of 100.	
		Set TIME BASE switch to CRYSTAL; INPUT SENSITIVITY control to CHECK: GATE SELECTOR to 1/10 SEC.	Adjust R115 for a count of 1000.	Ideal setting is center of range giving correct count.
4. Frequency Sensitivity	1 KC (Approx) Sine Wave Source, AC VTVM.	Set GATE SELECTOR to 1 SEC; INPUT SENSITIVITY full cw. Connect 3V rms 1 KC Sine Wave to INPUT.	Set Disc. Bias Adjust (R205) full ccw. Adjust R2 for stable count while reducing input signal to 1 volt (Approx.)	
			Decrease input signal to 0.6V rms and rotate R205 cw until counter just begins to count.	R2 located on top of Disc. Plug-in.
			Set R2 to center of range that gives a stable count.	
		Reduce input signal to 0.1 volt.	Adjust R205 until counter just begins to count.	
5. Time Base Sensitivity	100 (Approx) cps Sine Wave Source; AC VTVM.	Set GATE SELECTOR to 1/10 SEC; TIME BASE switch to LINE. Connect 5V rms 100 cps sine wave to EXTERNAL STANDARD jack.	While reducing input signal, set Sensitivity Adjust (R141) for consistent off/on operation of neon GATE lamp.	



Time Base



CRYSTAL CONTROLLED TIME BASE



MODEL 521A
COUNTER SECTION

SPECIFICATIONS FOR MODEL 521A ELECTRONIC COUNTER

*COUNTING RATE:	1 to 120,000 events per second.
REGISTRATION:	4 places. Total count capacity 9,999 - resets to 0000 on the 10,000th count. Reads directly in cps or cycles per 1/10 second.
RESOLUTION:	8.3 μsec.
*ACCURACY:	±1 count, ± accuracy of timing frequency signal. (Approximately ±0.1% when power line is used.)
*INPUT VOLTAGE:	0.2 V RMS minimum to 200 V RMS maximum.
INPUT WAVEFORM:	Must have rise time of 0.2 volts per second or faster.
INPUT IMPEDANCE:	1 megohm shunted by 50 μμf. 0.5 meg. at phototube jack.
GATE TIMES:	1/10 and 1 second. (10 second standard gate time available on special order.) Neon panel lamp indicates when gate is open.
DISPLAY TIME:	Continuously adjustable from 1/10 second to 15 seconds or can be held indefinitely.
POWER REQUIREMENTS:	115/230 volts, 50 or 60 cycles, ac. 185 watts.
SIZE:	Cabinet Mount: 9-3/4" wide, 15-1/4" high, 14-1/2" deep. Rack Mount: 19" wide, 8-3/4" high, 14-1/2" deep.
WEIGHT:	Cabinet Mount: 28 lbs net, shipping weight 71 lbs. Rack Mount: 28 lbs net, shipping weight 68 lbs.
MEASUREMENT RANGES:	Frequency: 1 cps to 120 kc. Time Interval: Depends upon standard frequency that is counted: 1/60 second to 167 seconds using 60 cps, 1/10,000 sec. to 1 sec. using 10 kc timing signal. Total Events: Up to 10,000 electrical events.

FEATURES

INPUT ATTENUATOR:	Adjusts SENSITIVITY from 0.2 volt to 100 volt rms to overcome noise effects.
SELF CHECK:	Internal counting of Time Base frequency provides check of proper operation of the unit.
ACCESSORY CRYSTAL CONTROLLED TIME BASE PLUG-IN:	Optional and available at extra cost, the -hp- Model 521A-59B Plug-In Crystal Controlled Electronic Time Base can be ordered with the instrument or procured later and installed in the instrument. The unit permits error to be reduced to less than 0.01% ±1 count and can drive several 521A's.
EXTERNAL TIME STANDARD:	Any multiple of 10 cps between 10 cps and 100 cps may be employed. If sine wave driving voltage is used, its amplitude must be between 5 volts RMS minimum and 50 volts RMS maximum.
ACCESSORY SOCKET:	Cannon connector on rear chassis supplies 6.3 V ac at 0.6a, +300 V dc at 10 ma, and -150 V dc at 5 ma.
PHOTOTUBE INPUT:	Standard phone jack on rear chassis supplies bias voltage for type 1P41 (or equal) phototube and is signal input connector for phototube.

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ELECTRONIC COUNTER

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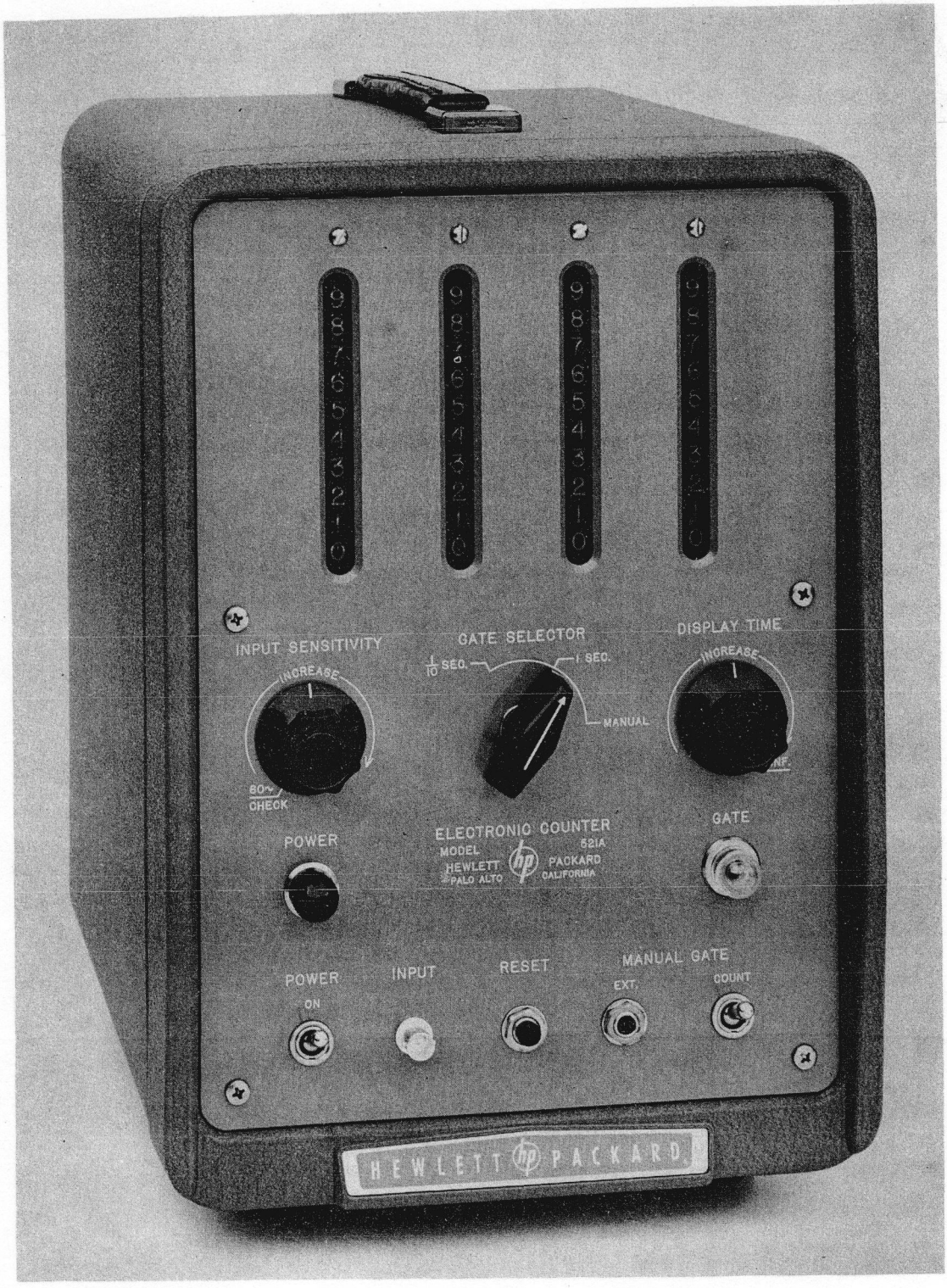


Fig. 1. The Hewlett-Packard Model 521A Electronic Counter

SECTION I

GENERAL INFORMATION

1-1 GENERAL

The Model 521A is a portable, direct-reading instrument that counts periodic and random events and automatically displays the answer in digital form. When coupled to the proper transducers this instrument may be used for a wide range of measurements formerly possible only with much more elaborate equipment. In addition to straightforward frequency and time measurements it measures speed, RPM, RPS, weight, pressure, temperature, acceleration, or any quantity that can be converted into electrical impulses by means of appropriate mechanical and photo-electric transducers. The 521A counts total random events within a selected time interval or it may be used to measure the time between two events from a fraction of a second to over one hundred seconds. An internal self-checking feature is provided to confirm the accuracy of operation.

1-2 ACCURACY

The accuracy of the displayed answer on the 521A, when using the power line frequency as a standard timing signal (normal operating condition) is nominally ±0.1%, the accuracy of the line frequency, plus, the possible ±1 count variation inherent with a digital counting system. The ±1 count variation is in general, significant only at frequencies below 500 cycles, for example: at 50 cycles the percent error is ±2% using the 1 SEC. automatic gate time. If greater accuracy is required for measurement of frequencies above 500 cps, an externally generated signal of 10 cycles, or any multiple thereof up to 100 cycles, may be used instead of the power line frequency. The 521A then assumes the accuracy of the applied signal unless the ±1 count is of greater significance. An accessory plug-in unit, the hp Model 521A-59B Crystal Controlled Time Base, is available which can be quickly installed in any 521A Electronic Counter to increase the accuracy of measurement to better than 0.01%. Installation is fully described in Section II.

1-3 PHYSICAL CHARACTERISTICS

The 521A is a very compact counter, weighing only 28 lbs. It can be obtained either for rack mounting in a standard 19 inch wide relay rack, or in the cabinet model. The cabinet model is designed for table top use and with its convenient carrying handle

and rigid construction is very suitable for field use. Both models are ventilated by a fan and air filter located in the bottom of the instrument, and louver in the sides and top. Do not obstruct the ventilating louvers.

1-4 HOW THE 521A WORKS

For frequency measurement, the unknown signal applied to the INPUT jack is fed through a Signal Gate to four Counter Units. The Signal Gate is opened and closed by the Time Base for an accurately controlled period of time, such as 1 second. The Counter Units count and display the number of events which occurred during the one second period and the answer is read across the front panel directly in cycles per second. When the 1/10 second gate time is used, the answer is read directly in cycles per 1/10 second.

For time interval measurement, either the power line frequency or 10 KC supplied by the accessory Crystal Controlled Time Base when this unit is installed, is applied through the Signal Gate to the Counter Units. The electrical or mechanical events that mark the beginning and ending of the time interval to be measured are then applied to the 521A to open and close the Signal Gate. The Counter Units count and display the number of cycles that occurred while the gate was open. To convert the displayed number to seconds, multiply the displayed number by 1/60 for a 60 cycle line, 1/50 for a 50 cycle line, etc.

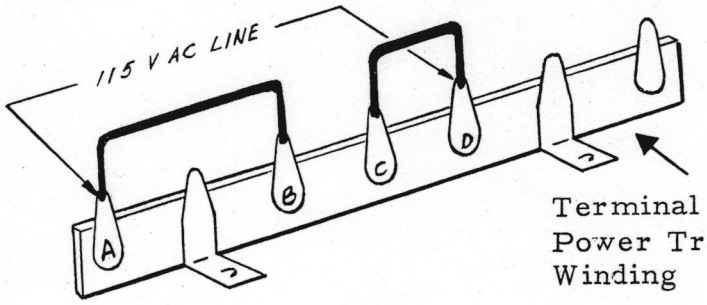
1-5 POWER LINE VOLTAGE

Unless specially ordered from hp for 230 volt service, the 521A Electronic Counter is wired for 115 volt operation. Conversion to 230 volt service is simple and involves only changing wire jumpers on the power transformer primary winding terminal strip.

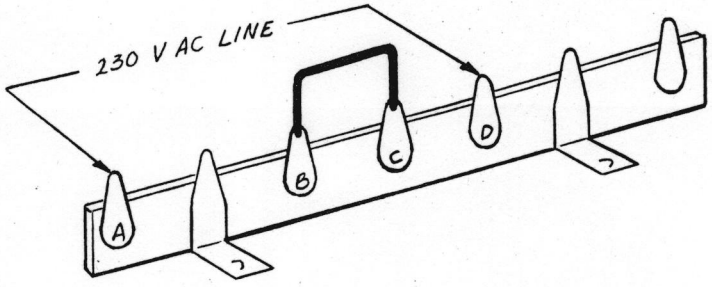
To connect the instrument for 230 volt service, remove any jumpers between AB and between CD as in Figure 2. Install a jumper between BC. To convert to 115 volt operation, remove any jumpers between BC and connect two jumpers - one between AB and one between CD.

1-6 SHIPPING DAMAGE

After unpacking the instrument, turn it on and self-check it as described in the operating instructions. Should any shipping damage be discovered, follow the procedure described in the "Claim for Damage" section on the last page of this manual.

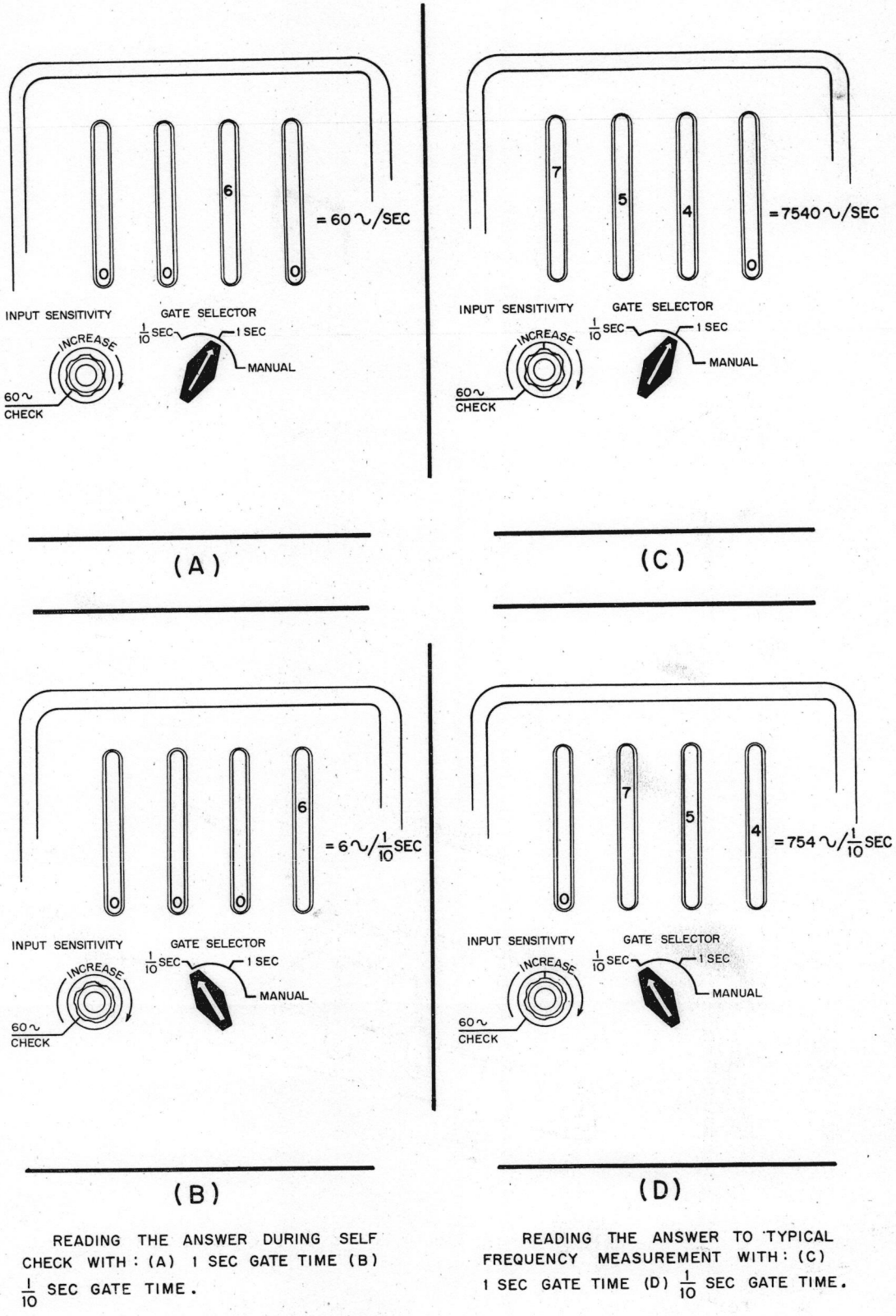


A. Connections for 115 V Operation



B. Connections for 230 V Operation

Fig. 2. Connecting the 521A for use on 115 volt or 230 volt a-c power lines.



READING THE ANSWER DURING SELF CHECK WITH: (A) 1 SEC GATE TIME (B) $\frac{1}{10}$ SEC GATE TIME.

READING THE ANSWER TO TYPICAL FREQUENCY MEASUREMENT WITH: (C) 1 SEC GATE TIME (D) $\frac{1}{10}$ SEC GATE TIME.

Fig. 3. Reading the Displayed Answer from the Model 521A Electronic Counter

SECTION II

OPERATING INSTRUCTIONS

2-1 INTRODUCTION

This section gives instructions for reading the answer from the front panel and for making three basic types of measurements and describes the functions of the various front panel controls and terminals on the 521A Electronic Counter.

2-2 READING THE ANSWER FROM THE FRONT PANEL OF THE 521A

The answer to a measurement made with the 521A is automatically displayed in a number across the front panel by a lighted figure in each of the number columns (see Figure 3). The units' digit appears at the observer's right, the thousandths digit at the extreme left. The number displayed on the panel is the total number of events sensed by the instrument during the time the measurement was made.

When the GATE SELECTOR switch is in the 1 SEC position, the 521A counts the number of electrical events occurring during an accurate 1 second interval and all answers are displayed directly in cycles per second, revolutions per second, etc. When the GATE SELECTOR switch is in the 0.1 SEC position, the 521A counts the number of electrical events occurring during an accurate 0.1 second interval and all answers are indicated directly in cycles per .1 second. In both cases the answer will have four significant figures, however, if the total numberical count is greater than a four figure number, only the last four numbers of the figure will be shown in the displayed answer, for example; if counting a frequency of 14500 only the 4500 will be displayed.

Frequencies up to 9,999 cps are read directly from the displayed answer across the front panel to an accuracy of ±1 cycle with the GATE SELECTOR switch in the 1 SEC position. With the GATE SELECTOR switch in the 0.1 SEC position frequencies up to 99,999 cps are read directly to an accuracy of ±11 cycles, however, the units digit of the number is not included and must be assumed to be zero. Frequencies up to 99,999 cps can be read directly to five significant figures by first using the GATE SELECTOR switch on the 0.1 SEC GATE to read the first four significant figures of the number then switch to the 1 SEC position and read only the Units and Tens Digits. Replace the Units Digit in the 0.1 SEC answer with the Units and Tens Digits from the 1 SEC answer.

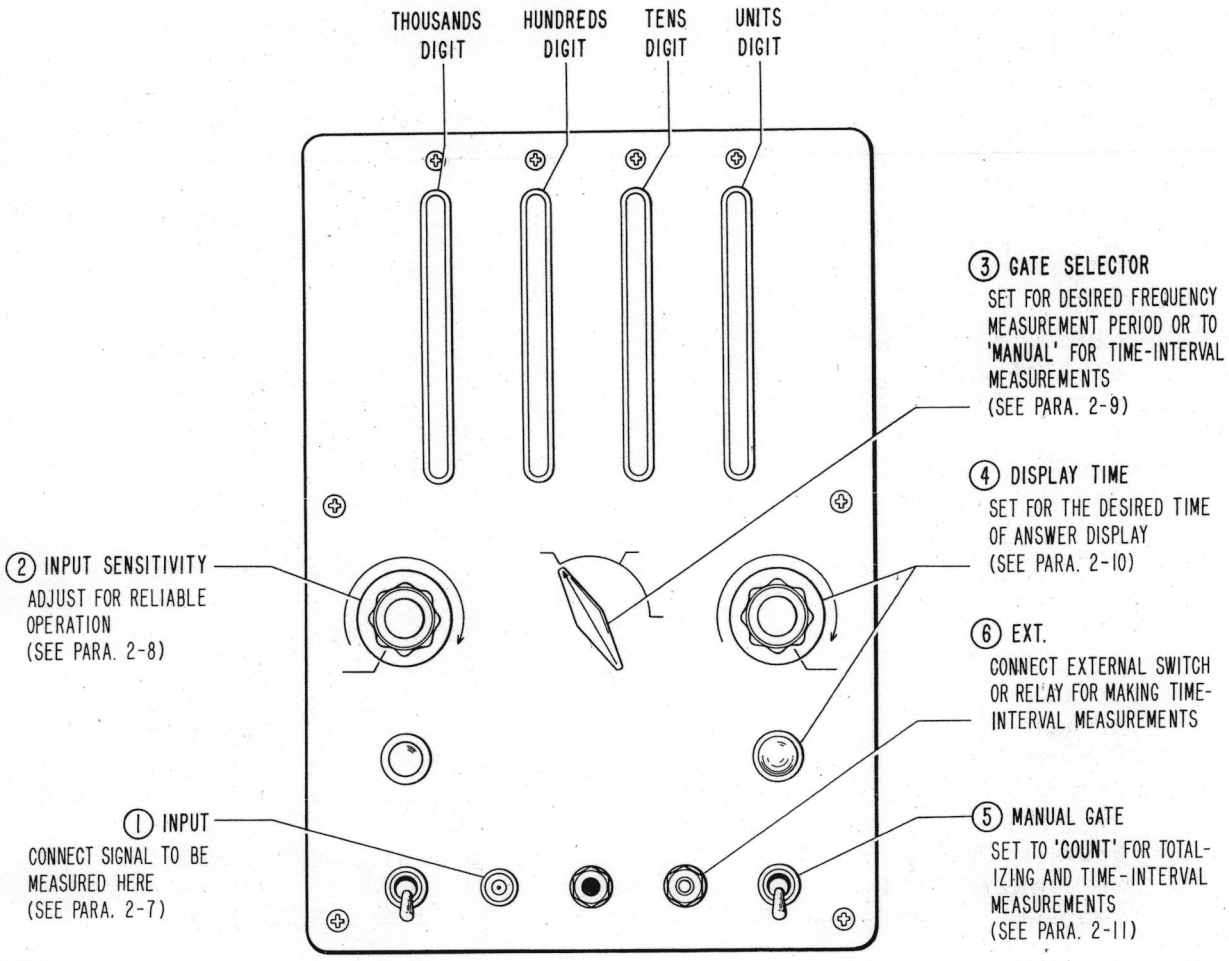


Fig. 4. Controls and Terminals

2-3 HOW TO SELF-CHECK THE MODEL 521A

The operator can, in one simple procedure, check the overall operation of the 521A Electronic Counter as follows:

a. Turn on the 521A and allow to warm up.

b. Set the INPUT SENSITIVITY control to CHECK, set the GATE SELECTOR switch to 1/10 SEC. and adjust the DISPLAY TIME control as desired.

c. The 521A should count and display the number 0006 for a 60∿ power line frequency.

d. Set the GATE SELECTOR switch to 1 SEC. The 521A should count and display 0060. For 50∿ power line frequency the displayed numbers will be 0005 and 0050 in steps d and e.

e. If the accessory Crystal Controlled Time Base plug-in unit is installed and the TIME BASE toggle switch is set to CRYSTAL, the displayed answer will be 1000 for the 1/10 SEC. gate and 0000 for the 1 SEC. gate times.

2-4 HOW TO MEASURE FREQUENCY

The 521A measures frequency by counting the number of cycles which occur within an accurately known period of time, .1 or 1 second, as determined by the GATE SELECTOR switch. When the period is over, the total is displayed in terms of cycles per 0.1 second or cycles per 1.0 second. To measure frequency proceed as follows:

a. Connect the frequency to be measured to the INPUT jack.

b. Turn the INPUT SENSITIVITY control completely clockwise.

c. Set the GATE SELECTOR switch for the desired counting interval (preferably the 1 SEC. position).

d. Adjust the DISPLAY TIME control for the length of answer display time desired.

e. Adjust the INPUT SENSITIVITY control to the lowest level that gives consistent counting (see paragraph 2-8).

f. The 521A will now count the input signal and display the frequencies in cycles per second or cycles per 1/10 second, depending on the GATE SELECTOR switch.

2-5 HOW TO MEASURE TIME INTERVAL

The 521A measures time interval by counting the number of cycles of an accurately known frequency that occur during a time interval determined by the operator or by external equipment. The time interval may be started and stopped either by means of the MANUAL GATE toggle switch on the front panel or by a remote switching device connected to the EXT. jack. The frequency which is counted during this time interval is either the power line frequency, 10 kilocycles supplied by the accessory Crystal Controlled Time Base when this unit is installed, or any externally generated frequency applied to the INPUT jack.

Externally generated frequencies may be used instead of the line frequency for time interval measurements if desired. Higher frequencies provide greater resolution and may sometimes be known to a greater degree of accuracy. An external timing frequency is applied to the INPUT jack and the INPUT SENSITIVITY control turned up as in frequency measurement.

Mechanical switching devices connected to the EXT. jack to start and stop a time interval measurement should have a low resistance such as a relay. The operating time of such a device determines the shortest time interval that can be measured accurately. If the operating time of the mechanical device varies, the accuracy of the short time interval measurements will be affected adversely. If the operating time for starting and stopping are exactly the same, the accuracy of short time interval measurements will be improved. To measure time interval, proceed as follows:

a. If the line frequency is to be used for counting, or if the 10 kc output from the accessory Crystal Controlled Time Base plug-in unit is used, turn the INPUT SENSITIVITY control to the CHECK position.

b. If an externally generated signal is to be used for counting connect this signal to the INPUT jack and turn the INPUT SENSITIVITY control to maximum. Read this frequency exactly.

c. Turn the GATE SELECTOR switch to MANUAL.

d. Set the MANUAL GATE toggle switch to the down position.

e. The 521A is now ready to measure a time interval. Counting will begin when the external switching device closes the circuit or when the MANUAL GATE toggle switch is set to the COUNT position. Counting will stop when the external device opens the circuit, or when the MANUAL GATE toggle switch is returned to the down position. The displayed answer is the number of cycles of the line or 10 KC (or externally applied signal) frequency that was counted during the time interval.

f. To convert the displayed answer to seconds, multiply the displayed number by the period (1/f) of the frequency counted.

2-6 HOW TO MEASURE TOTAL NUMBER OF EVENTS

The 521A can be used to totalize any periodic or random electrical events that fall within the input signal specifications given in paragraph 2-7. To totalize electrical events proceed as follows:

a. Connect the signal to be totalized to the INPUT jack.

b. Adjust the INPUT SENSITIVITY control as described in paragraph 2-8.

c. Set the GATE SELECTOR switch to MANUAL.

d. Start the count by setting the MANUAL GATE switch in the COUNT position. End the count by returning the MANUAL GATE switch to the down position.

e. The displayed answer is the total number of events sensed by the 521A during the time the MANUAL GATE switch was in the COUNT position.

2-7 INPUT SIGNAL REQUIREMENTS

The INPUT connector on the front panel of the Model 521A receives the signal to be counted. This signal must be at least 0.2 volt rms in amplitude and not greater than 200 volts rms. The input wave should have a rise time of .2 volt per second or faster and should have a repetition rate not greater than 120,000 cycles per second. Two pulses separated by less than 8.3 microseconds will be recorded as a single pulse. To prevent counting unwanted signals, the input signal should have a good signal to noise ratio.

2-8 SENSITIVITY CONTROL

The INPUT SENSITIVITY control permits the amplitude of the signal received at the INPUT or PHOTOTUBE INPUT jacks to be adjusted to an optimum operating level for the 521A. The optimum signal voltage for any given application is a little higher than the lowest voltage that will produce a satisfactory count. If the signal level is increased much beyond this point, there is the possibility of erroneous counts if there is random noise in the input signal. If the signal voltage is free of noise, the sensitivity may be increased with safety. To make this adjustment, set the INPUT SENSITIVITY control counterclockwise until the 521A will no longer count the input signal. Increase the INPUT SENSITIVITY control until counting starts. Set the control slightly beyond this point.

If difficulty is encountered with noise (erratic counting), the input signal voltage should be examined with an oscilloscope to disclose the nature of unwanted signals that are large enough to operate the 521A. Signals generated by electro-mechanical devices in particular should be examined for effects of contact bounce or vibration.

The extreme counterclockwise position of the INPUT SENSITIVITY control (CHECK) is used to self-check the 521A and for measuring time intervals. These two functions are described under paragraphs 2-3 and 2-5. No sensitivity adjustment is required for these operations.

2-9 GATE SELECTOR SWITCH

This switch selects one of two time periods for counting the input signal frequency. In the 1/10 SEC. and 1 SEC. positions of the GATE SELECTOR the time is determined in the instrument to be either 0.1 second or one second, as selected. When the GATE SELECTOR switch is in the MANUAL position, the gate is opened and closed by either the MANUAL GATE switch or by a switch connected to the MANUAL GATE-EXT. jack.

For all types of operation the GATE indicator lamp on the front panel always lights, i.e., as long as the 521A is counting.

2-10 DISPLAY TIME CONTROL

This control determines the length of time an answer is displayed. When the GATE SELECTOR is set 1/10 SEC. the display interval is adjustable from 1/10 second to 15 seconds by means of the

DISPLAY TIME control. When the GATE SELECTOR is set to the 1 SEC. position, the display is variable from 1 to 15 seconds. If longer than 15 seconds display is required, set the DISPLAY TIME control to INF and the display will remain until the RESET button is pressed. Pressing the RESET button will return the counters to zero and releasing the RESET button will start a new count of the input signal. The DISPLAY TIME control is disconnected when the GATE SELECTOR switch is set to MANUAL.

2-11 MANUAL GATE

When the GATE SELECTOR is set to MANUAL, a count is started and stopped either by the MANUAL GATE switch or by an external switching device plugged into the EXT. jack. When the MANUAL GATE switch is in the COUNT position, the 521A will count an input signal continuously. When the switch is turned to the down position counting is stopped and the total count will be displayed. When an external switching device is plugged into the EXT. jack, the MANUAL GATE switch is made inoperative and the external switch will start and stop the count. The remote switching device may be any on-off switch connected to open and short the terminals of the phone jack; counting will occur only while the terminals are shorted.

2-12 TIME BASE SELECTOR

A TIME BASE SELECTOR switch, located behind the front panel on the chassis, selects either the line frequency or external time base, or the crystal controlled time base when this accessory plug-in unit is used. When the TIME BASE SELECTOR switch is in the LINE or EXT. position, connecting an external time base to the EXTERNAL STANDARD input jack on the rear of the Model 521A automatically disconnects the power line frequency as a timing signal and uses the external signal applied.

2-13 EXTERNAL TIME BASE

The Model 521A normally employs the power line frequency as a time standard (nominal frequency error of approximately ±0.1%). When greater accuracy is required an externally generated standard frequency of 10, 20, 30, 40, 50, 60, 70, 80, 90 or 100 cps and between 5 and 50 volts rms, may be applied to the EXTERNAL STANDARD jack on the rear of the instrument chassis. The accuracy of this signal then determines the accuracy of the Time Base in the 521A.

521A003-2 4/18/56 Serial 379 ↑ above

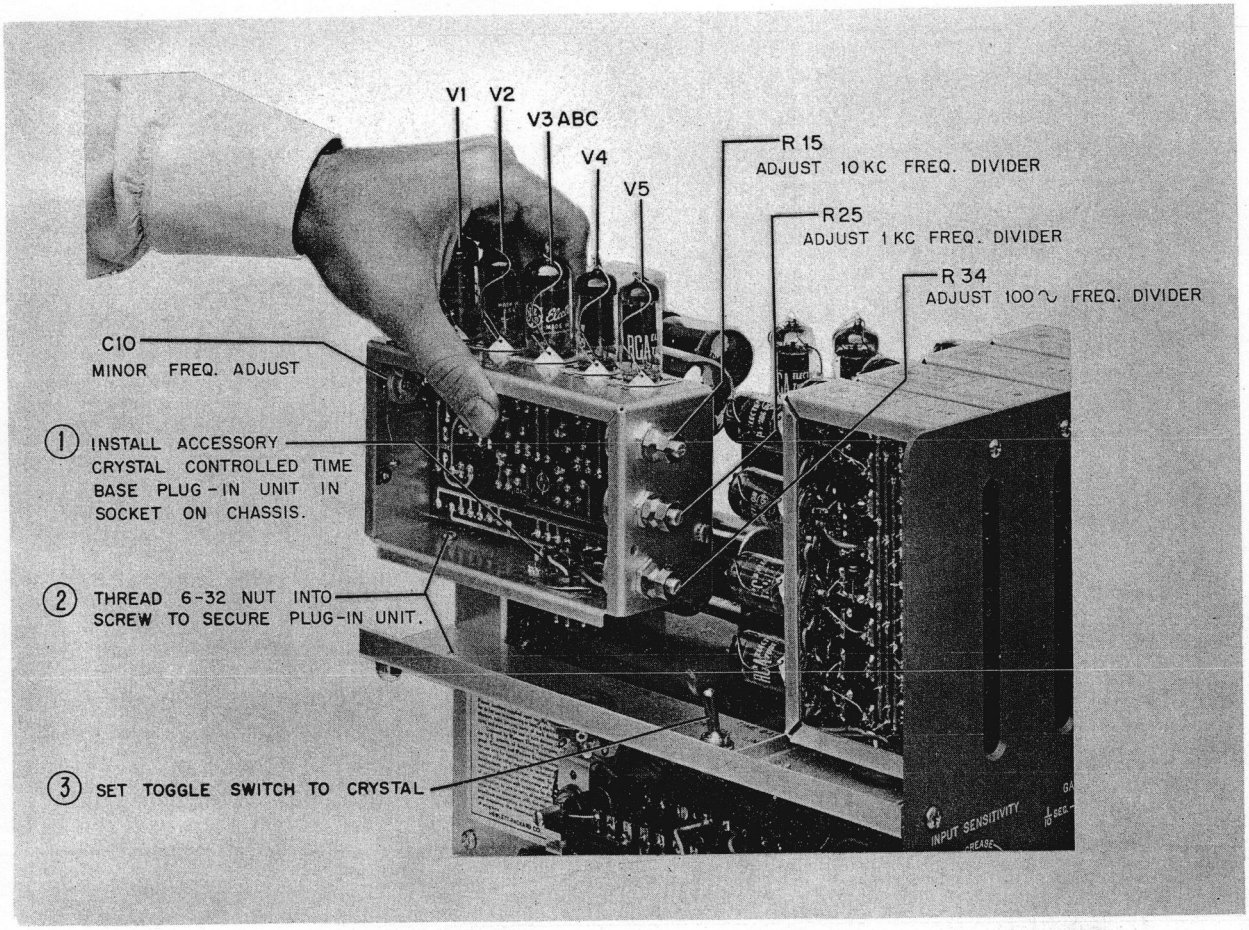


Fig. 5. Installing the accessory Crystal Controlled Time Base plug-in unit

The EXTERNAL STANDARD jack is a three circuit type. The external timing signal is introduced between the tip and body of the plug. The "ring" connection on the plug is a standard frequency output terminal which provides a very accurate 100 cycle signal when the accessory Crystal Controlled Time Base plug-in unit is installed. When the Crystal Controlled Time Base is installed in the 521A measurement accuracy of better than ±0.01% is possible. The "ring" connection on the EXTERNAL STANDARD jack may be used as the standard signal source to drive a number of other 521A Electronic counters that may be used near by.

2-14 PHOTOCELL INPUT

The PHOTOTUBE INPUT on the rear of the instrument is a three circuit phone jack designed to simultaneously supply bias to and to receive a signal from a phototube such as the 1P41. The PHOTOTUBE INPUT jack is connected in parallel with and has the same input signal requirements as the INPUT jack. To adjust the phototube system for optimum performance, connect a vacuum tube voltmeter to the INPUT jack and adjust the optical system for the highest signal reading on the voltmeter.

2-15 CRYSTAL CONTROLLED TIME BASE ACCESSORY PLUG-IN UNIT

The Crystal Controlled Time Base plug-in unit is an accessory which can be conveniently plugged into a socket inside the 521A Electronic Counter to increase the accuracy of frequency measurement to better than 0.01%. The use of the Crystal Controlled Time Base is desirable in areas where the power line frequency is not closely regulated, or whenever an assurance of higher accuracy is required.

The Crystal Controlled Time Base is installed by removing the 521A cabinet and plugging the unit into the socket as shown in Figure 5. Secure the retaining nut and set the toggle switch on the Time Base Section to CRYSTAL. All connections are automatically made and the unit is ready for operation. The adjustments on the Crystal Controlled Time Base have been set at the factory and require no further adjustment upon installation. Instructions for making the adjustments when servicing on the plug-in unit are given in Section V.

SECTION III

APPLICATIONS AND ACCESSORY-TRANSDUCERS

3-1 GENERAL

The Model 521A has a wide range of applications and when coupled with proper transducers can perform many specific industrial measurements heretofore possible only with much more elaborate equipment. A single Model 521A may be employed to monitor many transducers of various type which may be remotely located. For example: Shaft speeds at a number of different locations throughout a plant or system may be accurately measured from one central point employing one 521A Counter. The installation requires only that the proper transducers be attached to each shaft to be measured and that the transducers be wired to a selector switch connected to a Model 521A. The speed of any shaft in the system may be measured in turn as selected by the switch. About 30 seconds is required to make such a measurement. When making the original hook-up, use cables which do not attenuate the signals below the input requirements of the 521A. Check also for stray electric or magnetic fields that can induce noise in the input cables. Low capacity coaxial cables are recommended. The selector switch should also be shielded to prevent pickup from electric fields.

3-2 RPM MEASUREMENTS WITH TACHOMETER GENERATORS

The Model 521A measures RPM and RPS by counting an electrical frequency that is proportional to the speed of a rotating shaft. Generation of this frequency may be accomplished by several types of transducers which allow considerable latitude in measurement technique.

A simple and direct way to measure RPM is through the use of a tachometer generator that produces a frequency that is proportional to the speed of its own shaft. The (hp) Models 508A and 508B are examples of this type transducer, and are recommended for use with the 521A Electronic Counter. Both are of the variable reluctance type and have no brushes or slip rings to cause noise or random irregularities that result in inaccurate readings. Other types of generators may be used if they have an output frequency proportional to their shaft speeds and are free of electrical noise and transients. To assure accurate counts, the use of an oscilloscope to check the signal from other types of tachometer generators is recommended.

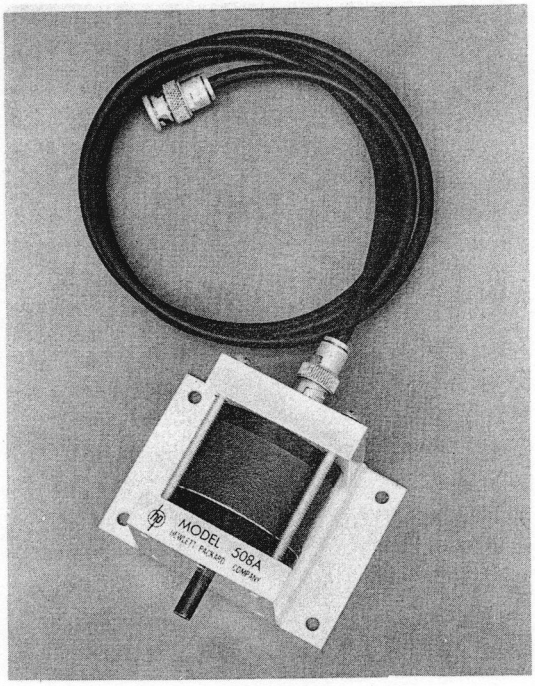


Fig. 6. ⓗp Model 508A, B, C Tachometer Generators

3-3 ACCESSORY TACHOMETER GENERATORS ⓗp MODELS 508A, B, C

The ⓗp Models 508A, 508B and 508C are compact low-torque tachometer generators. The Model 508A produces 60∿ for each revolution of its drive shaft, Model 508B produces 100∿, and the 508C produces 120∿. When using the 508A, the 521A Counter indicated shaft speed directly in RPM. When using the 508B, the displayed answer is divided by 100 to obtain RPS.

The useful shaft speed range for Model 508A Tachometer Generator is from approximately 15 RPM to 40,000 RPM. Consequently, this tachometer generator is entirely suitable for all shaft speeds normally encountered. The output voltage from these transducers increases almost linearly from 15 RPM and 5000 RPM from a minimum of about 0.1 volt RMS to a maximum of almost 10 volts. At shaft speeds above 5000 RPM, the output voltage decreases gradually to a value of about 1 volt at 40,000 RPM. The linear relationship between output voltage and shaft RPM to about 5000 RPM provides a very useful auxiliary function for the tachometer generator. The speed-voltage relationship makes it possible to present on an oscilloscope screen a curve describing the instantaneous rate of rotation of a shaft as a function of time. This allows analysis of the instantaneous effect on rotating equipment from the action of clutches, brakes, or other mechanical components.

For this application, connect the output of the tachometer generator to the vertical deflection plates of an oscilloscope, while the horizontal deflection is controlled by the internal time base in the 521A Counter, or by some other appropriate means. Since the data presented on the oscilloscope screen is usually non-repetitive in nature, a photographic record is normally made. Torsional vibration, harmonic-ringing and the action of intermittent motions are shown as a function of time by variations in the height of the oscilloscope trace.

3-4 RPM MEASUREMENTS USING ACCESSORY PHOTOELECTRIC PICKUPS

Photoelectric tachometry pickups have three particular advantages: they are effective over a wide range of speeds; they are easily adaptable to a wide range of situations; they do not load a system under measurement. The Model 521A is designed for use with photoelectric transducers and a special connector (PHOTOCELL INPUT) located on the rear of the instrument supplies the necessary bias voltage to a photocell of type 1P41 or equal. This jack serves also as the signal input jack for this application.

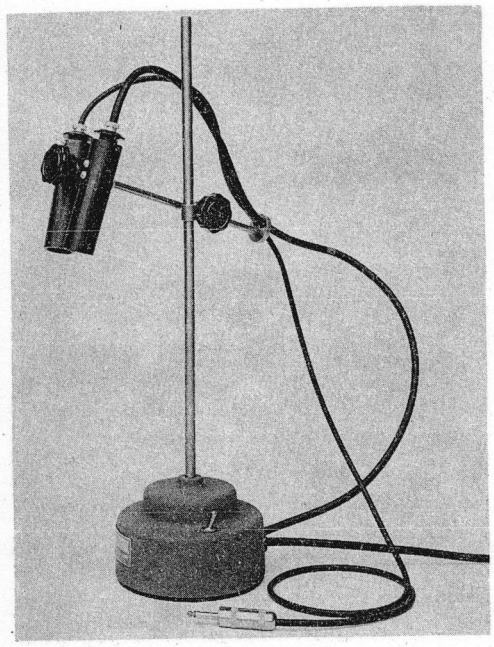


Fig. 7. Model 506A Optical Tachometer Pickup

3-5 PHOTOTUBE OPTICAL TACHOMETER PICKUP -hp- MODEL 506A

The Model 506A Tachometer provides for counting speeds or revolutions over a wide range from about 300 RPM (5 RPS) to 300,000 RPM (5,000 RPS). The light source in the Model 506A Tachometer Pickup illuminates a moving part which is prepared with alternate reflecting and absorbing surfaces. The interrupted reflected light is picked up by the phototube and the electrical impulses generated are transmitted to the 521A Electronic Counter. This system is positive in action and the danger of fractional or multiple errors inherent in other measuring methods is eliminated.

For best results, the size of the reflecting and absorbing surfaces should be approximately 3/4" square. This means that the shaft whose speed is to be measured should have a diameter of at least 1/2". The speeds of smaller diameter shafts may be measured by installing a sleeve of larger diameter, or by providing a rotating, reflecting, and absorbing surface at right angles to the plane of the shaft. Surfaces such as these are also used for increasing resolution in measurement of low RPM where the multiple absorbing and reflecting surfaces provide a large number of impulses per revolution. When this is done, a division factor is applied to the reading obtained on the Model 521A.

The hp Model 506A consists of a pair of shielded tubes, one of which contains an incandescent light source, while the other houses a Type 1P41 Phototube. These are equipped with condensing lenses and are so oriented that proper focus is obtained at a distance between 3 and 6 inches from the reflecting surface. The light source and phototube assembly is mounted on an adjustable stand for optimum positioning of both light source and phototube. The base of this stand contains a transformer which provides the proper voltage for operating the incandescent lamp. The phototube requires a bias voltage from +70 to +90 volts. This voltage is automatically supplied by the PHOTOTUBE INPUT jack on the back of the hp Model 521A.

3-6 RPM MEASUREMENT USING A MAGNETIC PICKUP

Model 521A may be used to count the electrical pulses generated by a magnetic pickup device activated by a gear or keyway or magnetic material (steel) that is affixed to a rotating shaft. Magnetic pickups of this type consist of a permanent magnet core around which is wound a coil of wire. Magnetic material passing near the pickup causes an alternating electrical voltage to be induced in the coil. The frequency of this voltage, which is proportional to the RPM, can be measured by the Model 521A. To obtain R PS, a division factor is applied to the displayed count. Transducers of this type are normally small in dimension and adequately sensitive, especially at high speeds and are useful in circumstances that do not lend themselves to the use of tachometer generators or photo-electric pickups.

3-7 PRESSURE MEASUREMENT

Pressure, or any other variable which can be made to change the tension on a specially mounted wire, can be measured by using Model 521A in conjunction with the Byron Jackson Vibrotron. The Vibrotron is fundamentally a fine wire under tension vibrating at its natural frequency. One end of the wire is attached to a pressure diaphragm. Motion of the diaphragm, caused by a pressure change, changes the natural frequency of the wire to a new value corresponding to the new pressure. The total motion of the diaphragm is limited to a few ten-thousandths of an inch. Small permanent magnets provide a magnetic field in which the wire vibrates, causing an a-c voltage of the wire frequency to be generated across the wire. This voltage is amplified by an amplifier and a portion of the voltage is returned to the wire to maintain continuous vibration. The Vibrotron is manufactured by the Byron Jackson Company, Los Angeles, California.

The output frequency of the Vibrotron, which is proportional to the pressure being measured, can be counted by the Model 521A and the displayed count is adjusted by a suitable calibration factor for the system. Power to drive the Vibrotron circuits can be taken from the accessory socket on the 521A chassis.

3-8 FLOW MEASUREMENTS

Accurate measurement of either total flow or rate of flow of fluids is greatly simplified by the use of an "in the line" transducer that generates an electrical frequency which is proportional to the rate of flow. To measure total flow, the Model 521A is used as a totalizer (see paragraph 2-6) and counts the total number of cycles generated by a suitable transducer. To measure rate of flow, the Model 521A measures the frequency of the altering voltage generated by the transducer. In either case the number displayed on the Model 521A must be modified by a calibration factor suitable for the system. A transducer for flow measurements is manufactured by the Potter Aeronautical Corp. and is available in a number of different sizes and materials. It consists of a housing containing a turbine-type rotor. Within the body of the rotor is a small permanent magnet. Rotation of the magnet sets up an alternating current in a coil of wire mounted on the housing within the field of the magnet. The transducer housing is so designed that it may be inserted directly into the pipe in which flow is to be measured.

3-9 ENGINE EFFICIENCY MEASUREMENT

When coupled with a tachometer pickup and a fuel metering device, the Model 521A measures engine efficiency by determining the number of RPM produced by a known quantity of fuel. In this system, the fuel metering device is connected to operate the external gate of the 521A and holds this gate open during the time that a known amount of fuel is consumed by the engine. While the gate is held open, the Model 521A counts the output of the tachometer generator to determine the number of revolutions produced by the predetermined amount of fuel. The resultant ratio (revolutions per unit fuel) is used in calculating the engine efficiency.

SECTION IV

PRINCIPLES OF OPERATION

4-1 GENERAL

The Model 521A Electronic Counter consists of the basic circuits shown in the block diagram in Figure 8. The block diagram shows the major circuits as they are used for frequency measurement. The purpose of each major circuit is discussed below.

a. The signal applied to the INPUT jack is fed through the INPUT SENSITIVITY control to the Amplitude Discriminator. The essential part of the input signal, the frequency, goes through the amplitude discriminator unchanged; however, the output wave from the discriminator is a constant-amplitude high-speed pulse which is required for accurate, consistent operation of the counters.

b. The signal to be counted passes through a "gate tube", V9, to the counters. The Signal Gate acts as a valve to the input signal; it either passes the input signal on to the counters or it blocks their path completely.

c. The counters consist of four identical plug-in decade counters. The output of each counter is fed to the next counter, the units counter first, tens counter second, etc. Following an applied signal, each counter will display one number in its column, the number of the cycle at which the count was stopped. To return the count to zero, a separate signal is applied to the counter's reset circuit either automatically or by the RESET push button.

d. The Time Base Section generates the accurately controlled signals which open and close the Signal Gate, V9, during frequency measurement. It provides two lengths of signals, 0.1 second and 1.0 second. Both time intervals are obtained either from the power line frequency or by an external signal applied by the operator.

e. The Time Base Gate V10A prevents timing signals from the Time Base from operating the gate control circuits while an answer is being displayed on the counters. When the display time is over, the gate is opened and the timing signals from the Time Base again operate the gate control circuits.

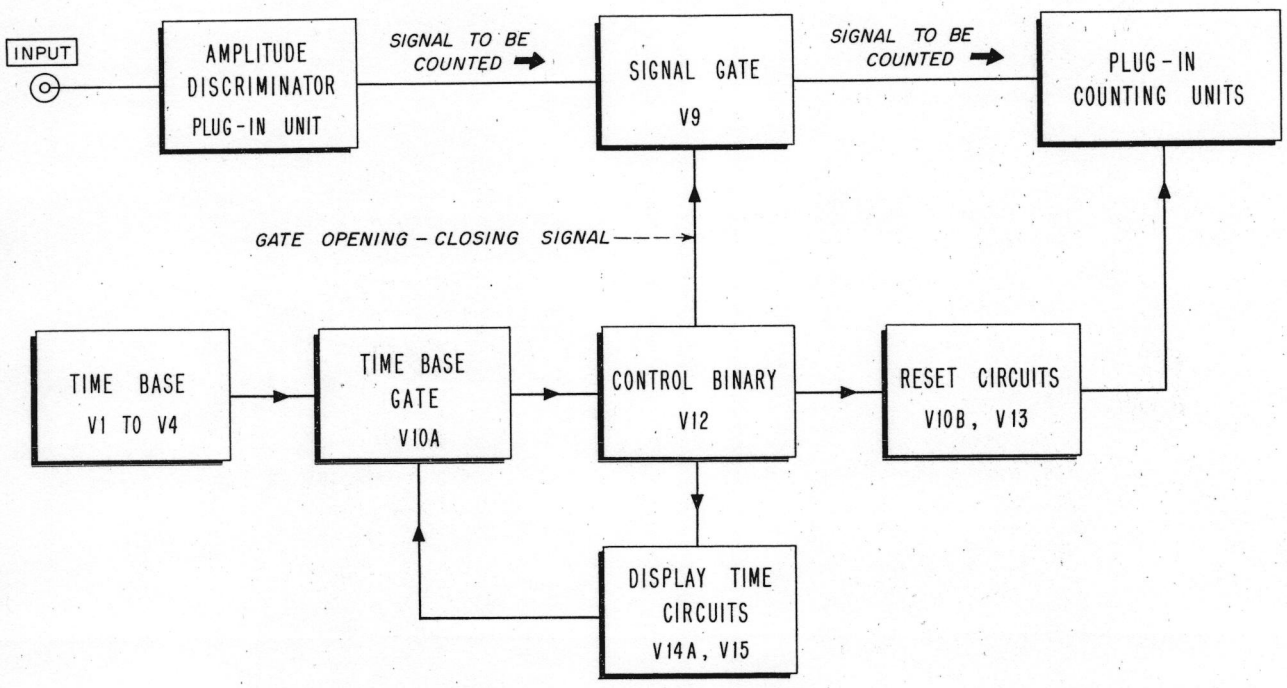


Fig. 8. Simplified Block Diagram of the 521A Electronic Counter

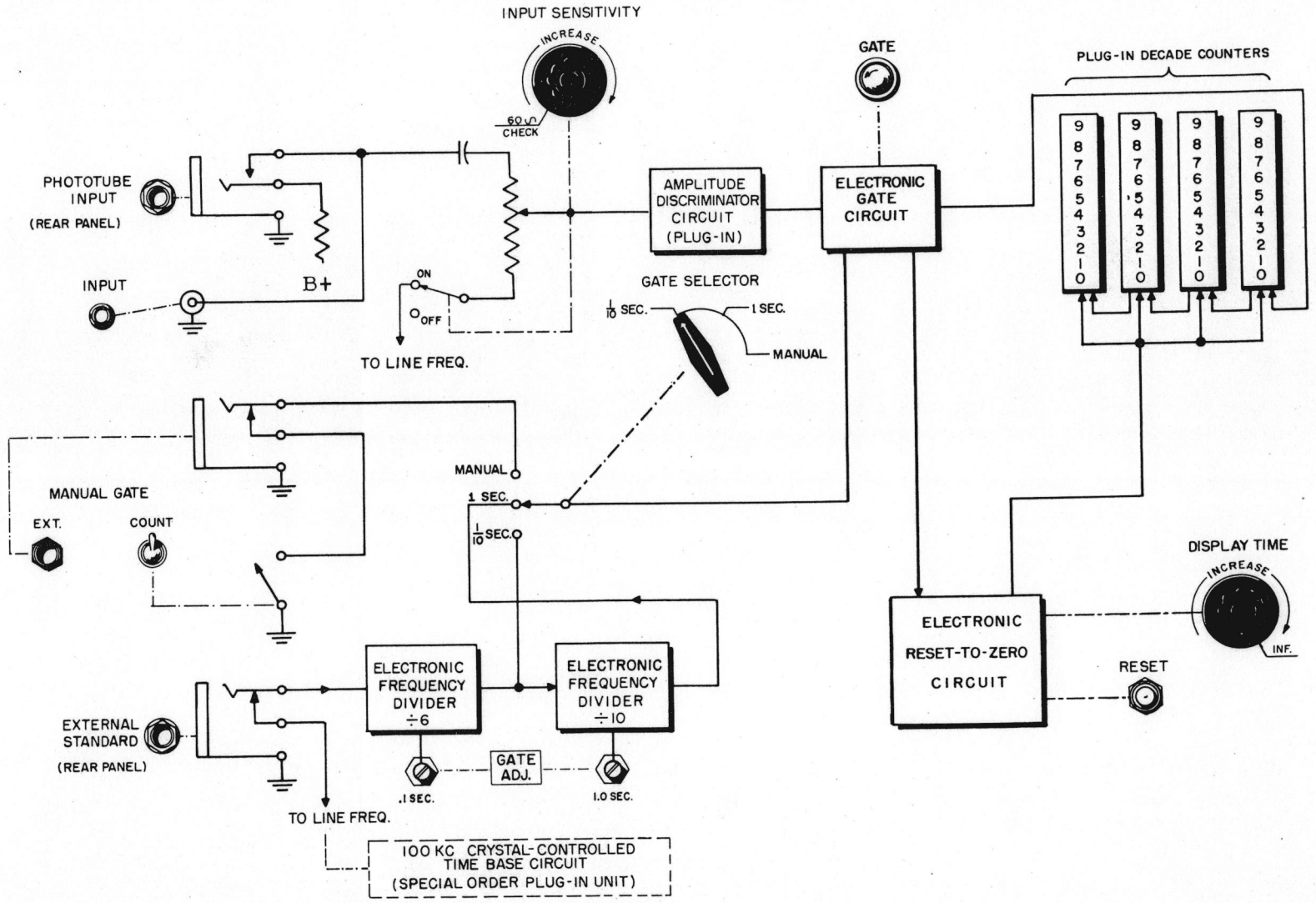


Fig. 9. Operational Block Diagram of the 521A

f. The Control Binary, V12, generates the signal that opens and closes the Signal Gate. When the Control Binary receives the start signal it applies a positive voltage to the Signal Gate to open it. The positive voltage remains until the Control Binary receives the stop signal, at which time it applies a negative voltage to the Signal Gate and closes it.

g. The Display Time Circuits determine the length of time an answer will be displayed on the counters. This is done by preventing passage of subsequent Time Base signals for a period of time set by the DISPLAY TIME control. So long as Time Base signals are blocked, the counters will continue to display the last count they received.

h. The Reset Circuits automatically apply a signal to each counter unit to bring its count back to 0 just before a new count is to be started.

4-2 OPERATION

Assume that the 521A is ready to start a new count; the first timing signal from the time base passes through the open Time Base Gate and triggers the one-shot Delay Multivibrator and produces a positive output pulse about 45 microseconds wide. This pulse is differentiated to form a positive pulse followed in 45 microseconds by a negative pulse. The positive pulse passes through the open Reset Gate and triggers the Reset Thyratron resetting the decade counters to zero. Forty-five microseconds later, time for reset transients to die down, the negative pulse triggers the Control Binary. Triggering of the Control Binary opens the Signal Gate, lights the neon gate lamp and closes the Reset Gate. The count is started.

The next timing signal from the Time-Base passes through the Time Base Gate and again fires the one-shot multivibrator. The positive portion of the differentiated multivibrator pulse passes through the open Reset Gate and is lost. The negative position of the pulse triggers the Gate Binary which closes the Signal Gate to end the count and extinguishes the neon gate lamp. The negative pulse also opens the Reset Gate and triggers the Display Time Phantastron. Triggering the display time phantastron closes the Time Base Gate and blocks the passage of the timing signals until the display time is finished. At the end of the display time, the Time Base Gate is opened and the system is ready to repeat the operation. The individual circuit groups are discussed in the following paragraphs.

4-3 AMPLITUDE DISCRIMINATOR (Plug-In Unit)

The Amplitude Discriminator Unit consists of a differential amplifier followed by a bistable multivibrator. This unit is used as a wave shaper to provide fast, constant amplitude pulses to operate the decade counters. A positive going input signal is amplified and triggers the bistable multivibrator causing it to flip to its other stable state. When the input wave returns toward negative it again triggers the multivibrator and causes it to flop back to its original state. Only positive pulses from the multivibrator will affect the counter units; the negative pulses represent the return to an original state and cause no further circuit action.

The bistable multivibrator is designed to flip when the input signal waveform passes +.2 volt going in a positive direction, and will flop when the voltage passes approximately +.2 volt going in a negative direction. It will again flip when the +.2 volt point on the following cycle appears. Thus a strong positive pulse is sent to the counters each time the input waveform rises past the +.2 volt level, or higher, as set by the INPUT SENSITIVITY control.

4-4 SIGNAL GATE

The Signal Gate, V9, is a type 5915 tube which is specially designed and constructed for gating purposes. The suppressor grid is rather closely wound and is used as a second control grid. By lowering the suppressor grid voltage, plate current is cut off. When this grid is driven beyond cut-off, any signal impressed on the main control grid, pin 1, does not appear in the plate circuit and the gate is closed. When the voltage on the suppressor grid approaches zero, with respect to cathode, the tube functions as an ordinary amplifier, the control grid signal appears in the plate circuit and the gate is open.

4-5 CONTROL BINARY

The Gate Binary, V12, opens and closes the Signal Gate by raising and lowering the potential on the suppressor grid, V9, through cathode follower V14B. In addition, the Gate Binary starts the counter reset signal and the display time. The binary is a bistable multivibrator designed to be triggered by negative pulses. One half of the twin triode is cut off while the other is conducting. The half employing pins 6, 7, and 8 is cut off during the display time and conducts during the time that the Signal Gate is open. The Signal Gate is controlled by the rise and fall of potential at the plate (pin 1) of V12. When the voltage at the plate (pin 1) of the control binary is low (conducting) the grid, (pin 7) of the Signal

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Gate tube is negative with respect to its cathode. This closes the Signal Gate and the input signals cannot pass through the Signal Gate to the counters. The electrical signal that causes the Gate Binary to switch from one stable state to the other is supplied from either the manual gate circuits or by the 45 μsec Delay Multivibrator.

4-6 DELAY MULTIVIBRATOR AND TIME BASE GATE

In order to allow time for the Reset Circuits to reset the counters, the triggering of the Gate Binary is delayed some 45 microseconds with respect to the timing signals from the time base. This delay is provided by the Delay Multivibrator which is a non-stable multivibrator with a free-running time of approximately 45 microseconds. The circuit operates in the following manner:

To start a count a signal from the Time Base passes through the open Time Base Gate, V10A, and triggers the Delay Multivibrator, V11, causing a 150V positive pulse of approximately 45 microseconds width at the plate (pin 6) of V11. Differentiation of this pulse (C209 and C210) provides a sharp, positive pulse followed in 45 microseconds by a sharp, negative pulse. The positive pulse has no effect on the Control Binary but does fire the Reset Thyratron, resetting the decade counters to zero. The negative pulse has no effect on the Reset Thyratron but triggers the Control Binary which opens the Signal Gate and starts the count. This delay allows time for all transients due to the reset operation to completely die down. The next timing signal from the Time Base passes through the open Time Base Gate and triggers the Delay Multivibrator causing the Control Binary to retrigger. This change of state of the Control Binary closes the Signal Gate, ends the count, and triggers the Display Time Phantastron and closes the Time Base Gate. The action of the Reset Gate prevents the firing of the Reset Thyratron at this time.

4-7 RESET CIRCUIT

Just before each new count is begun the decade counter units are reset to zero by a positive pulse from the cathode of the Reset Thyratron, V13. V13 is fired by the positive portion of the Delay Multivibrator pulse. To prevent firing the Reset Thyratron and resetting the counter at the end of the counting period, Reset Gate V10B is connected to the grid of V13 to cut off the positive triggering pulse that occurs at this time. The cathode of the reset gate is connected to the plate (pin 6) of the Control Binary V12. During the counting period, the plate (pin 6) of V12 is at a low potential and the resulting bias on the cathode of V10B allows

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it to absorb the positive thyratron triggering pulse.

The decade counters may be reset at any time, except while the instrument is counting, by pressing the RESET button on the front panel. When the RESET button is pressed, C213 and C218 discharge through R236, and apply a positive voltage to the grid of the reset thyratron. Due to the action of the Reset Gate just described, the positive voltage resulting from pressing the RESET button can trigger the reset thyratron only during the display time.

4-8 DISPLAY TIME CIRCUITS

These circuits control the length of time that a count is displayed by holding the Time Base Gate closed for a length of time selected by the operator. The action of the group is initiated at the time that the Control Binary closes the Signal Gate. The operation may be automatic, in that at the end of the display time a new count automatically is started, or the operation may be manual with the display time continuing until the operator presses the RESET button. The Display Time circuits are disconnected by the GATE SELECTOR when in the MANUAL position.

The automatic display time may be as long as 15 seconds but not less than the gate time employed, 1/10 second for 1/10 SEC. gate and one second for the 1 SEC. gate. The circuit employs a regular phantastron, V15, in which the swing of the plate potential is limited by the variable control of V14A.

In its quiescent state, the plate of Display Time Phantastron is cut off and the screen conducts. The suppressor, (pin 7), is connected to the plate, (pin 6), of the Control Binary through C217 and R256. At the end of the counting period the potential at the plate of V12 rises. This rise, differentiated by C217, triggers the Display Time Phantastron, causing the plate voltage of V15 and the cathode voltage of V14 to drop at a rate determined by the r-c time constant of C216 and R252.

The potential continues to drop until V14A conducts and causes the phantastron to return to its quiescent state. The DISPLAY TIME control R247 adjusts the grid voltage of V14A which determines the point on the phantastron plate voltage curve where V14A conducts, and in this manner selects the length of the display time.

The screen grid of V15 is connected through R244 and R245 to the cathode of the Time Base Gate, V10A. During the time that the Display Time Phantastron is in its quiescent state, the screen grid voltage is low and no blocking bias is applied to the Time

Base Gate. At the end of the counting period, the Control Binary closes the Signal Gate and triggers the Display Time Phantastron to begin the display time. Triggering the Display Time Phantastron drops the plate voltage as described, causing the screen grid voltage to rise sharply. The increased potential of the screen, applied to the Time Base Gate forms sufficient back bias to block the timing signals from the Time Base and prevent them from triggering the delay multivibrator until the delay time is over.

When the DISPLAY TIME control is set to the INF position the automatic operation is discontinued and the display is held until the RESET button is pressed. In this position switch S203 is closed, thus preventing V15 from operating as a phantastron. The tube operates as a bistable multivibrator to apply back bias to the Time Base Gate during the display time and to remove it when the RESET button is pressed. Pressing the RESET button resets the counters to zero and places a negative charge on C218. Releasing the RESET button applies a negative voltage to the grid of V15 and retriggers the tube. This action removes the back bias from the Time Base Gate and the instrument is ready to start a new count.

4-9 TIME BASE SECTION

The Time Base of the Model 521A is composed of four tubes and their related circuitry. V1 is a Schmitt Trigger circuit that serves to sharpen incoming timing signals so they accurately drive the first phantastron frequency divider. V1 is disconnected from the circuit when the accessory plug-in CRYSTAL CONTROLLED TIME BASE is in use. V2, a dual diode, serves as coupling diode for V3 and V4. V3 and V4 are identical phantastron frequency divider circuits differing only in their operating time constant. The repetition rates are, 1/10 of a second for the first phantastron and one second for the second phantastron. The output of both phantastrons is connected to the GATE SELECTOR switch, S102A, which connects the output of the first phantastron when a 1/10 SEC. gate time is selected, the output of the second phantastron when a 1 SEC. gate time is selected, and disconnects both phantastrons when the MANUAL GATE is used and the timing signals are not required.

4-10 DECADE COUNTER UNITS

Operation and servicing of the decade counter units discussed in the instruction manual for the Model AC-4A, which is attached to this booklet.

4-11 THE PHANTASTRON FREQUENCY DIVIDER

Two phantastron frequency dividers are used in the Time Base Section of the 521A to obtain 10 cycle and 1 cycle per second output frequencies from the 60 cycle line frequency. The first divider divides by six, the second one by 10. There are also three phantastron frequency dividers in the Crystal Controlled Time Base accessory plug-in unit, each dividing by 10. All of the phantastron circuits are alike, except for component values, to obtain appropriate time constants at the different working frequencies. The action of a typical 10:1 phantastron circuit is explained in the following paragraphs.

Each complete divider consists of a coupling diode which acts as a gate to the incoming signal and a type 5915 pentagrid amplifier acting as a one shot multivibrator. The operating time of the multivibrator is adjusted to be almost equal to the "period" of the desired output frequency. The gate, upon receiving a pulse of the incoming signal, passes the signal and starts the multivibrator in its one cycle of operation. During the cycle of operation the diode gate is biased so that it blocks the incoming signal for this period of time. When the multivibrator has completed its cycle of operation the gate will again be opened to receive another pulse of the incoming signal, and so on.

The cycle of operation of the multivibrator is timed by the coupling capacitor, series resistor, and voltage applied, to last just one period of the desired output frequency. It will thus divide any multiple of the desired frequency down to the desired frequency. During its cycle of operation the plate of the 5915 swings in a negative direction and closes the diode gate. After the cycle of operation, the plate voltage returns approximately to the supply voltage, thus opening the diode gate to incoming negative pulses of high enough amplitude to overcome the bias normally on the diode.

In the case of the 10:1 frequency divider every time the tenth cycle of the input frequency comes along the multivibrator produces one large pulse. If the frequency of the input signal is changed, the time constant of the multivibrator must also be changed so that its cycle of operation is made to last only as long as nine cycles of the new input frequency, or, if the phantastron is to divide by another number, such as 6, the time constant of the multivibrator need only be adjusted to last for five cycles of the input frequency. The divider will then produce one large pulse for every six cycles of the input frequency.

The action of the 5915 is similar to a one shot multivibrator, as follows: In the stable state the plate is not conducting and the voltage is at B+ potential. The screen grid is conducting and the screen

voltage is at a low potential. This state is maintained by a constant negative bias applied to the second control grid. When the first negative part of the incoming signal comes through the diode gate it charges the coupling capacitor and applies a negative voltage to the first control grid of the 5915. The cathode voltage follows this negative voltage to a point where the second control grid is positive relative to the cathode. This starts the switching action of the multivibrator; current through the screen grid stops and current through the plate begins; screen voltage goes up, plate voltage down. The process continues until the charge leaks off the coupling capacitor at which time switching again occurs, the tube current turns from the plate to the screen grid and the plate voltage rises to open the diode gate.

The time constant of coupling capacitor C1 and its 2.2 megohm series resistor and the voltage applied by potentiometer R1, determines the length of the cycle of operation. Figure 10 shows a typical phantastron circuit with a graph of the tube voltages during one cycle of operation.

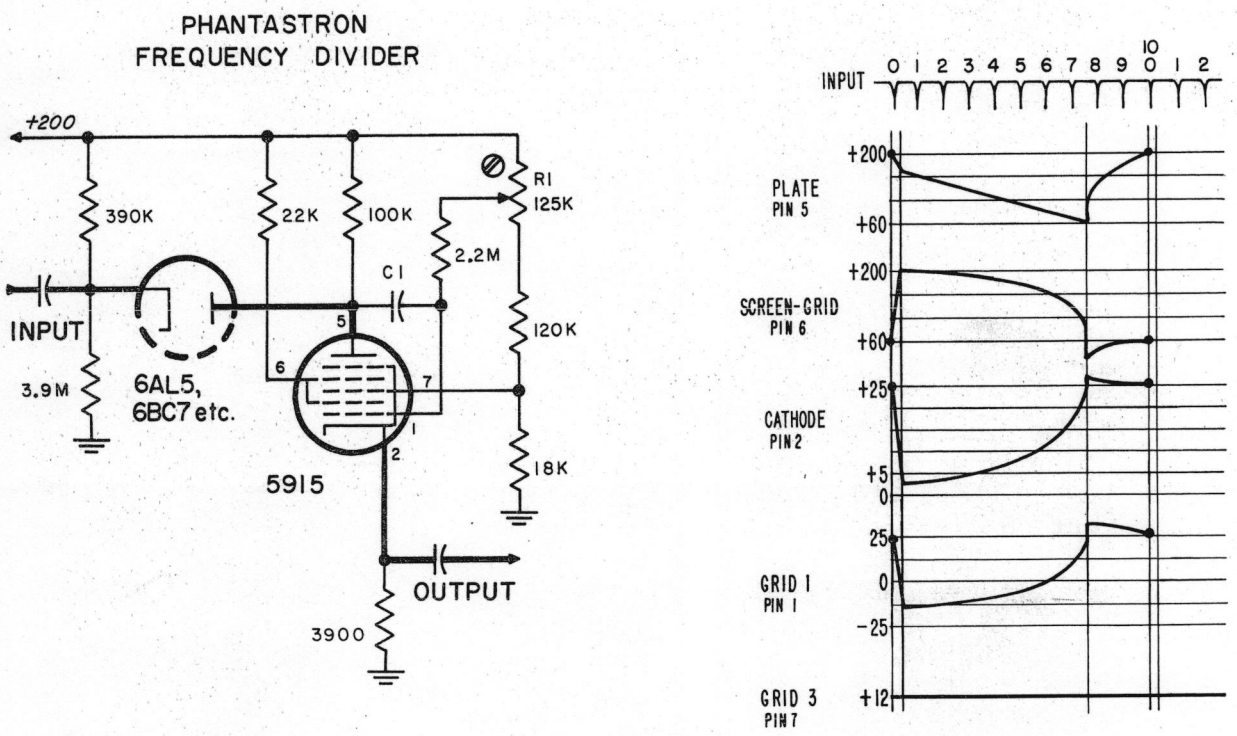

Fig. 10. Typical Circuit of Phantastron Frequency Divider with Graph Showing Tube Voltages During One Cycle of Operation

SECTION V

SERVICE INSTRUCTIONS

5-1 INTRODUCTION

This section contains instructions for replacing tubes, making circuit adjustments and trouble shooting the 521A Electronic Counter. At the rear of the manual are location diagrams, tube socket voltage-resistance diagrams and the schematic diagrams for complete equipment. All maintenance data for the Counter Units is contained in the complete manual for AC-4A at the end of this manual. A diagram and information on the accessory Crystal Controlled Time Base plug-in unit is also supplied in this manual.

The material in this section is as follows:

5-2 AIR FILTER SERVICE

The air filter element used in the 521A is a renewable type. To clean the filter element proceed as follows:

a. Remove the filter element from the instrument cabinet by snapping it out of the recess in the cabinet bottom.

b. Clean the filter element by washing in warm water and detergent.

c. Re-coat the filter with a light film of the filter oil that is supplied with the instrument.

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5-3 CABINET REMOVAL

To remove the instrument chassis from the cabinet:

a. Remove the two retaining screws at the rear of the cabinet.

b. Slide the instrument panel and chassis forward out of the cabinet. The bezel ring remains on the cabinet.

5-4 TUBE REPLACEMENT

The following chart lists the tubes in the 521A with their functions and adjustments required following replacement. The chart is in three parts, the main instrument, the amplitude discriminator plug-in unit and the accessory Crystal Controlled Time Base plug-in unit.

521A Electronic Counter

Symbol	Type	Function	Adjustment
V1	5963 twin diode	Schmitt Trigger	Trigger Bias (See para. 5-8)
V2	6AL5 twin diode	Coupling Diodes	Phantastron Frequency Divider adj. (See para. 5-6)
V3	5915 pentode	Phantastron Frequency Divider	Phantastron adj. (See para. 5-6)
V4	5915 pentode	Phantastron Frequency Divider	Phantastron adj. (See para. 5-6)
V5	5U4G dual diode	Rectifier Full Wave	None
V6	6AV5 power pentode	Series Regulator	+200 volts dc (See para. 5-5)
V7	6CB6 pentode	Control tube	+200 volts dc (See para. 5-5)
V8	OB2 Gaseous Regulator	Voltage Reference	+200 volts dc (See para. 5-5)

521A Electronic Counter (Con't.)

Symbol	Type	Function	Adjustment
V9	5915 hexode	Signal Gate	None
V10	6AL5 dual diode	Diode Gates	None
V11	5963 dual triode	Multivibrator	None
V12	5963 dual triode	Gate Gontrol Binary	None
V13	5696 thyratron	Reset Pulse Shaper	None
V14	5963 dual triode	A. Clamp B. Cathode Follower	None

Amplitude Discriminator Plug-In Unit

Symbol	Type	Function	Adjustment
V1	5963 dual triode	Differential Amplifier	Ampl. Disc. Adj. (See para. 5-7)
V2	5963 dual triode		Ampl. Disc. Adj. (See para. 5-7)

Crystal Controlled Time Base Plug-In Unit

Symbol	Type	Function	Adjustment
V1	dual triode	Oscillator	Osc. Freq. Adj. (See para. 5-9)
V2	triple diode	Coupling diodes	Phantastron Frequency Divider Adj. (See para. 5-7)

Crystal Controlled Time Base Plug-In Unit (Cont'd.)

Symbol	Type	Function	Adjustment
V3	hexode	10 KC Phantastron Frequency Divider	Phantastron Frequency Divider Adj. (See para. 5-7)
V4	hexode	1 KC Phantastron Frequency Divider	Phantastron Frequency Divider Adj. (See para. 5-7)
V5	hexode	100 cps Phantastron Frequency Divider	Phantastron Frequency Divider Adj. (See para 5-7)

5-5 REGULATED POWER SUPPLY VOLTAGE ADJUSTMENT

The regulated power supply voltage should be checked prior to making any other adjustments in the instrument and whenever tubes in the power supply are replaced; proceed as follows:

a. Connect an accurate voltmeter to pin 3 of V6.

b. If necessary adjust R134, 200 volt adj., until the meter reads +200 volts, and check for regulation with ±10% line voltage change.

c. If this adjustment cannot be made or if regulation is poor, check V6, V7 and V8.

5-6 PHANTASTRON FREQUENCY DIVIDER ADJUSTMENTS

Need of phantastron adjustment is indicated by failure of the 521A to self-check properly. The two adjustment potentiometers for these circuits are located on the rear chassis and are accessible without removing the cabinet. Set the TIME BASE switch (located behind the front panel) to LINE or EXT. Next, set the instrument controls for self-check as described in paragraph 2-3, using the 0.1 sec gate time. Adjust the 0.1 gate adjustment (on rear of the instrument) until the displayed count is 0006. Set the adjustment potentiometer to the middle of the range in which the correct answer is obtained. Now, reset the GATE SELECTOR switch to the 1 SEC position and adjust the 1 SEC gate adjustment until the

displayed count is consistently 0060. Set this adjustment to the center of the range that provides the correct reading.

5-7 AMPLITUDE DISCRIMINATOR SENSITIVITY (BIAS ADJ.) ADJUSTMENT

The amplitude discriminator bias should be adjusted when either of the tubes in the amplitude discriminator are replaced or whenever the maximum sensitivity of the instrument does not meet the 0.2 volt specification. Proceed as follows:

a. Set the GATE SELECTOR switch to 1 SEC GATE and INPUT SENSITIVITY control on maximum.

b. Apply a 1 KC input signal of about 3 volts rms amplitude to the INPUT jack. Consistent operation of the counter should now be obtained, if not, rotate R205 (BIAS ADJ.) to its maximum counterclockwise position.

c. Adjust R2 (located on top of the Discriminator plug-in) using a small screwdriver that will not short the shaft to ground, to the center of the range that produces a stable indication. Watch the flashing gate lamp to make certain the instrument is operating properly.

d. Decrease the input voltage amplitude to .6 volts rms and rotate R205 (BIAS ADJ.) clockwise until a stable count just begins. Again watch the neon lamp.

e. Repeat steps c and d with reduced input voltage of .1 volt.

5-8 TIME BASE SCHMITT TRIGGER BIAS ADJUSTMENT

The trigger bias should be adjusted whenever V1 is replaced. To adjust, set the instrument for self check. Set the TIME BASE selector switch (behind the panel) to the LINE or EXT. position. Connect an external signal (frequency any multiple of 10∿, to 100∿) of several volts magnitude to the EXTERNAL STANDARD jack at the rear of the instrument. Adjust Trigger Bias potentiometer until the counter indicates correctly. Reduce the magnitude of the standard voltage in small steps, readjusting the Trigger Bias after each step so that consistent operation is obtained. Continue this process until further reduction in the voltage is not possible. Minimum operating voltage should be approximately 1 volt.

5-9 CRYSTAL CONTROLLED TIME BASE PLUG-IN ADJUSTMENT

Need of adjustment of the frequency dividers in the Crystal Controlled Time Base plug-in unit will be evident by the displayed number shown when self-checking the 521A.

On 1/10 SEC. gate the count should be 1000.
On 1 SEC. gate the count should be 0000.

Improper adjustment will produce counts such as 990, 9900, 8900, 0100, etc. To adjust the frequency dividers in the plug-in time base, proceed as follows:

a. Set the TIME BASE selector switch to LINE or EXT. position.

b. Self-check the 521A as shown in paragraph 2-3 and if necessary, adjust the phantastron frequency dividers at the rear of the 521A chassis as shown in paragraph 5-6.

c. Connect a jumper lead from the 10 KC output, pin 6, on the 521A-59B socket to the INPUT jack.

d. Turn the INPUT SENSITIVITY control to maximum clockwise.

e. Turn the GATE SELECTOR switch to 1/10 SEC. gate and adjust the DISPLAY TIME as desired.

f. The displayed count should be 1000, if not, loosen the potentiometer lock nut on the 10 KC divider (R15) and adjust the potentiometer until the proper count is obtained.

g. Move the jumper lead to the next lower output frequency, 1 KC, pin 7, on the 521A-59B socket. The displayed count should be 0100 on the 1/10 SEC. gate or 1000 on the 1 SEC. gate. If it is not, adjust the 1 KC potentiometer, R25.

h. Move the jumper lead to the 100 cps output, pin 8. The displayed count should be 0100 on the 1 SEC. gate. If it is not, adjust the 100∿ potentiometer R34. Remove the jumper lead.

i. This completes the adjustment of the frequency dividers in the TIME BASE plug-in unit.

j. Set the TIME BASE selector switch to the CRYSTAL position. Turn the INPUT SENSITIVITY control to CHECK. The 521A should now count 10 KC and display 1000 on the 1/10 SEC. gate.

A trimmer capacitor C10 is provided in the TIME BASE plug-in unit to set the 100 KC frequency "on". This adjustment has been made at the factory, and should not be readjusted unless a standard frequency of 100 KC is available, and a comparison indicates that adjustment is necessary. The simplest procedure is to connect the 100 KC standard frequency to the INPUT jack, read its frequency with the 521A, and then adjust trimmer C10 until the displayed frequency is 0000 (100,000 cps).

5-10 TROUBLE LOCALIZATION

a. Turn on the counter and set the controls as follows:

SENSITIVITY - CHECK
GATE SELECTOR - MANUAL
MANUAL GATE - COUNT

b. The Gate indicator lamp should light and the counters should count continuously. Counting should progress until each number in each column will have been lighted. If one number fails to light the Counter Unit containing that light has a faulty circuit or tube. Tubes in the counters may be replaced without need for readjustment.

c. If the pilot light does not light, check the power cord connections, fuse, pilot lamp, etc.

d. If all decade counter units fail to count, check the power supply voltages shown on the schematic diagram, the Amplitude Discriminator tubes, V9, V12, V14 and Decade Counter Unit Z-205.

e. Set the GATE SELECTOR switch to the 1 SEC. position. The counter should count to 60 repeatedly, when the TIME BASE selector switch is on LINE or EXT.

f. If the neon gate lamp fails to function, check the gate and time base circuits.

g. If the neon gate lamp operates correctly, but the displayed count is wrong, check the Time Base circuit adjustments described in this section.

h. If the neon gate lamp operates correctly and no count is obtained, check the input connections, Amplitude Discriminator, Signal Gate, and the UNITS Decade Counter Unit.

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i. Set the controls for frequency measurement. Set the INPUT SENSITIVITY control to max. position. With a 1 KC signal input, reduce the magnitude of the input signal to 0.2 volts to test the instrument's sensitivity. If the instrument lacks sensitivity, the Amplitude Discriminator requires adjustment (See paragraph 5-7).

j. Check operation with frequencies from 1 cycle to 120 KC. Do not readjust disc. bias at any of these frequencies.

SERVICING PRINTED CIRCUIT BOARDS

CAUTION

When servicing printed circuits DO NOT push or pull wires in such a way as to raise the printed wiring from the board.

When soldering leads, use 50 watt iron or smaller. Apply heat sparingly to the leads on the part to be replaced, not to the printed wiring on the board.

Before installing new parts, clean holes to receive new part without forcing. Have new leads tinned and if necessary fluxed to receive solder quickly with a minimum of heat and without residue.

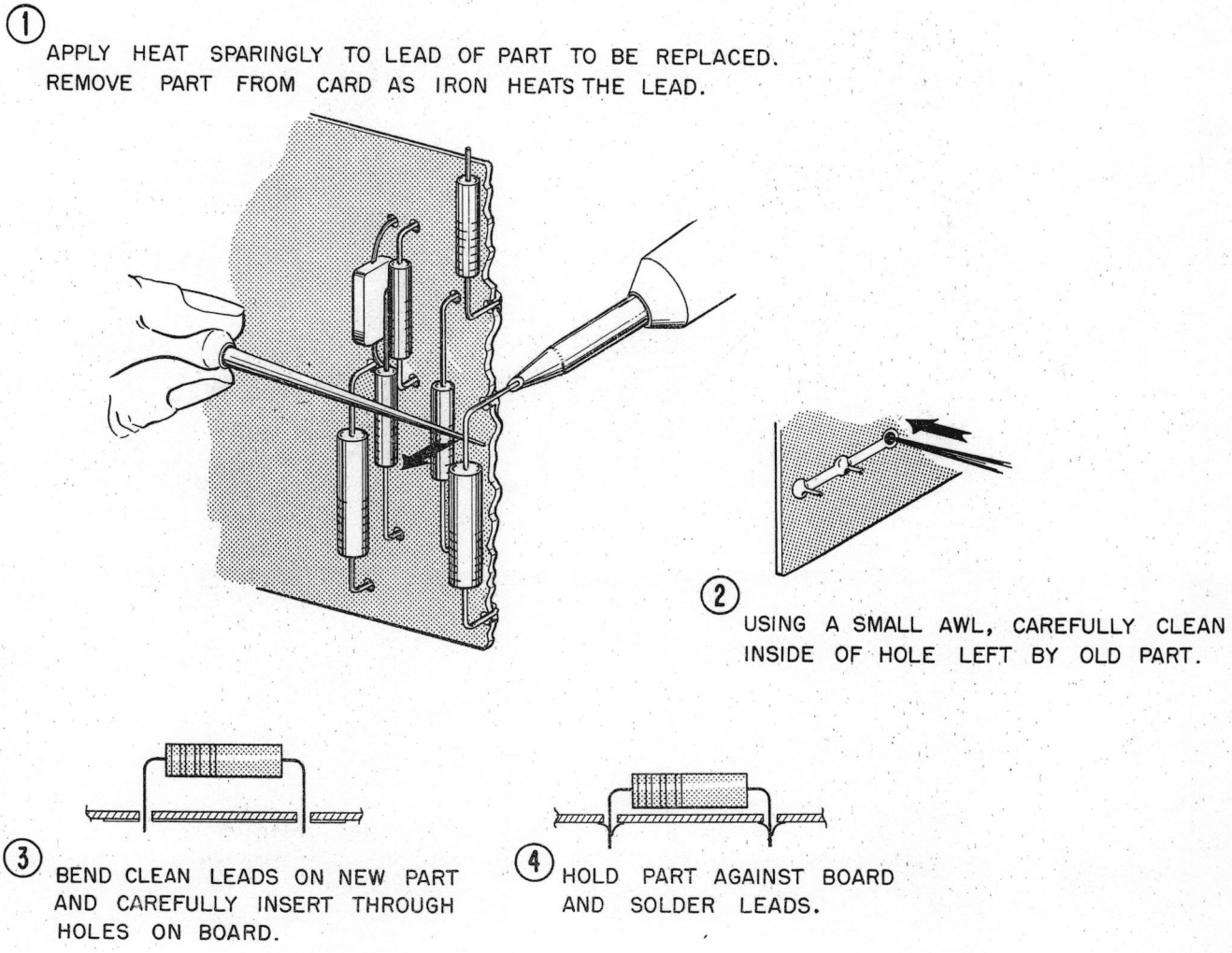


Fig. 11. Diagram showing replacement of parts mounted on printed Circuit Boards

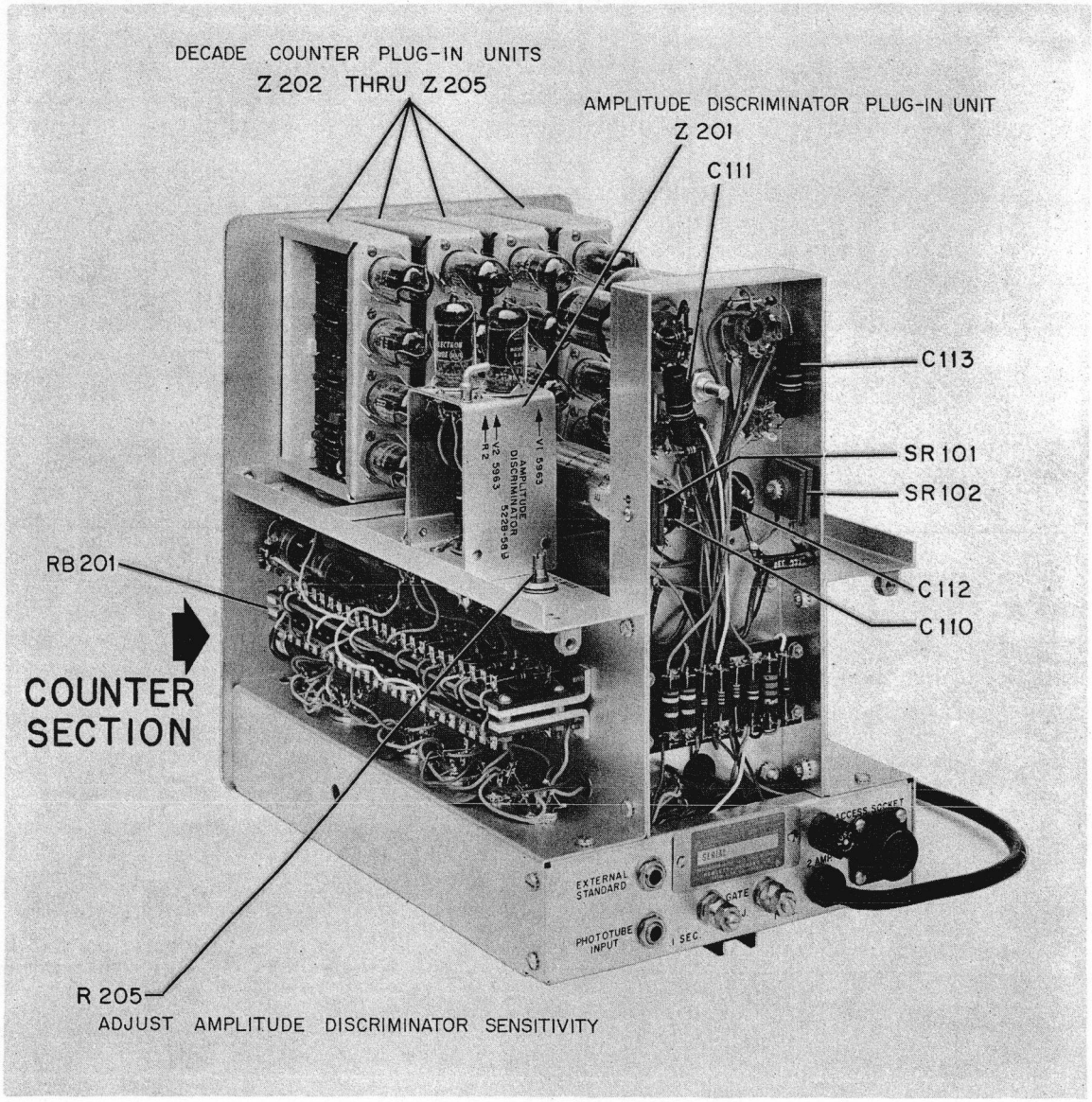


Fig. 12. Model 521A Electronic Counter, right oblique view, cabinet removed to locate adjustments and components

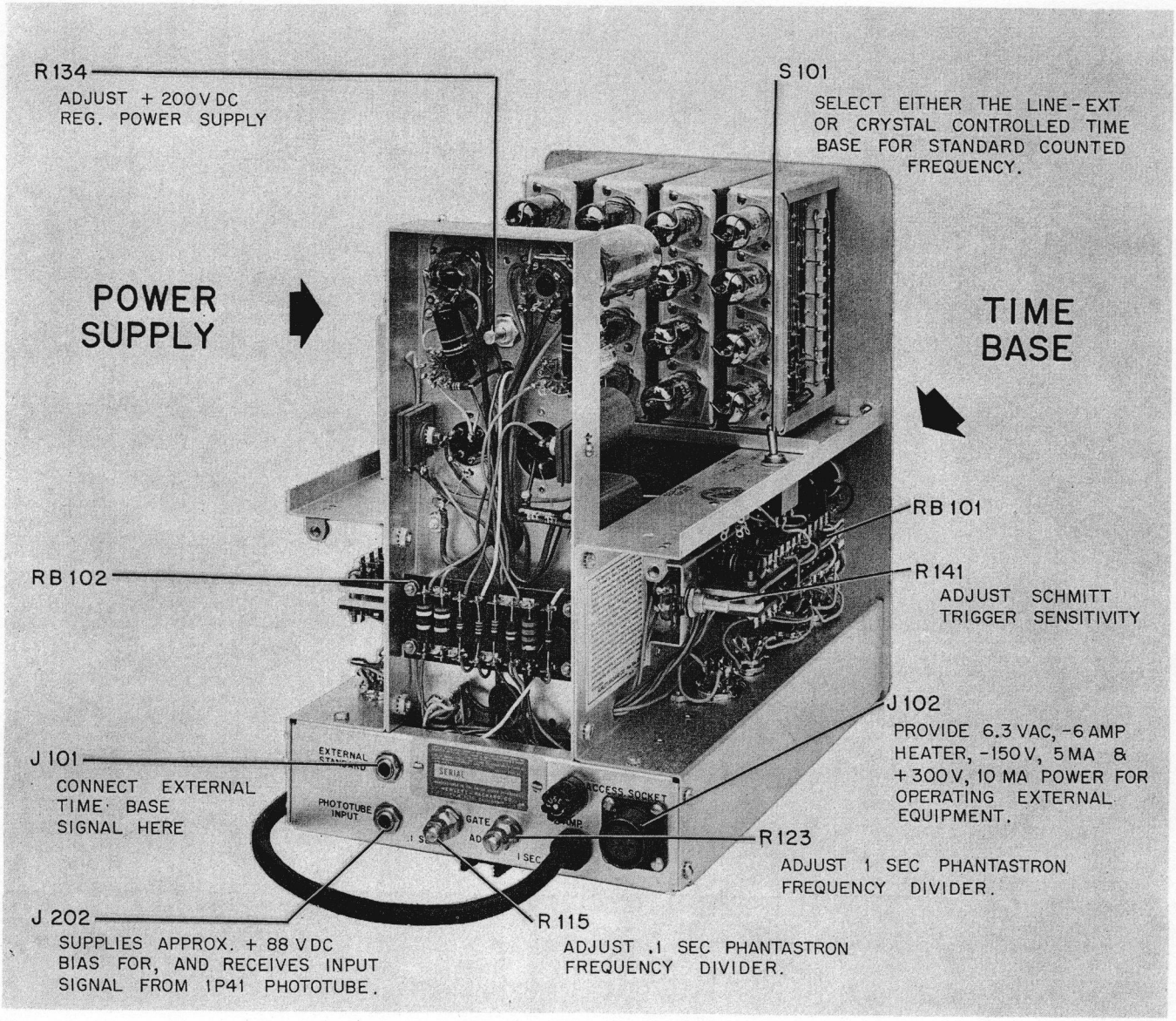


Fig. 13. Model 521A, left oblique view, cabinet removed to locate adjustments and components

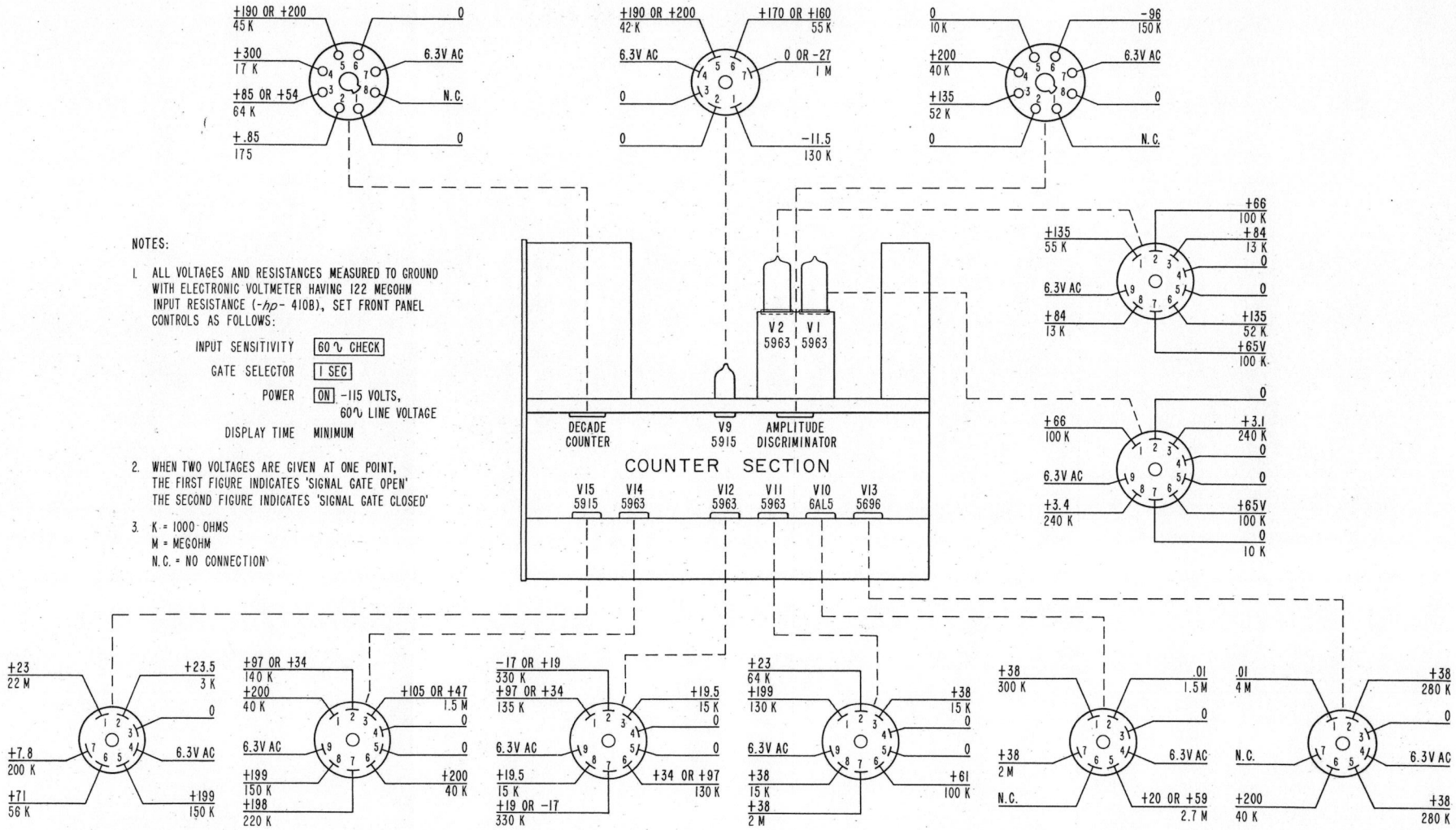
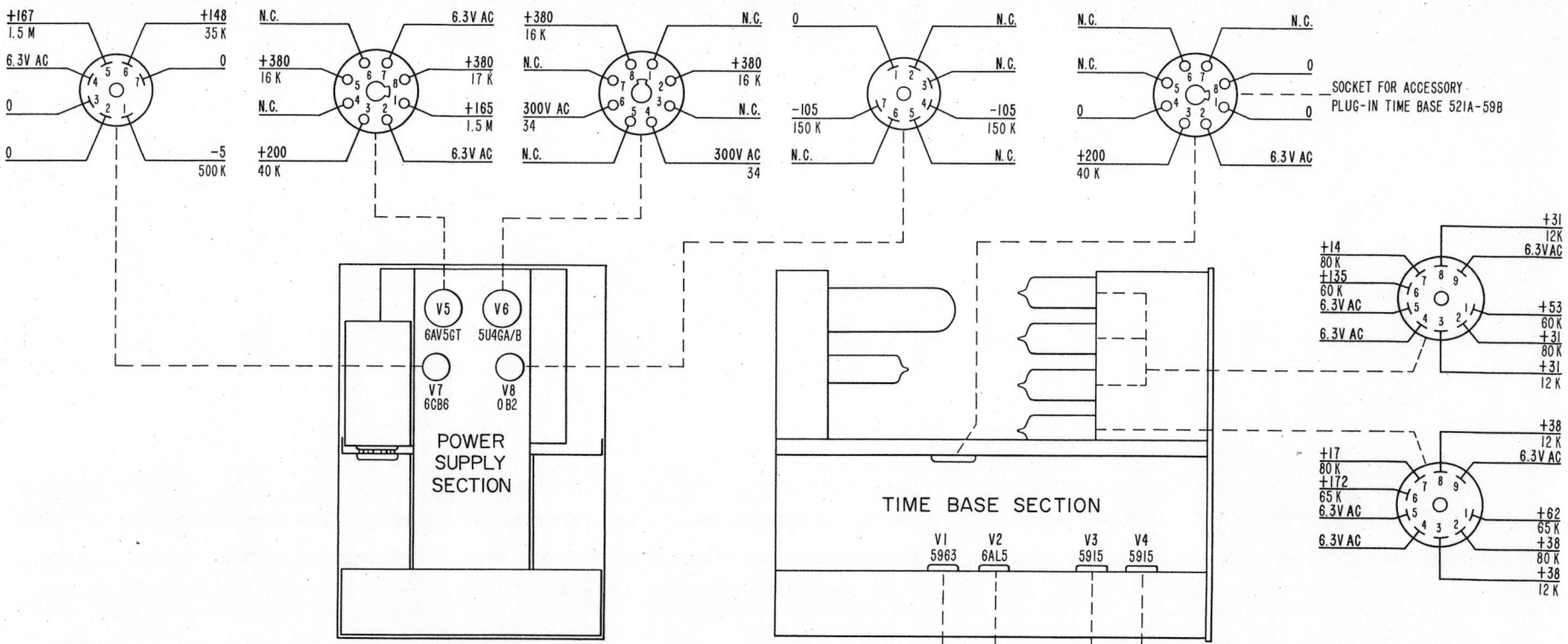


Fig. 14. Tube Socket Voltage-Resistance Diagram for the Counter Section (Signal Gate Circuits)



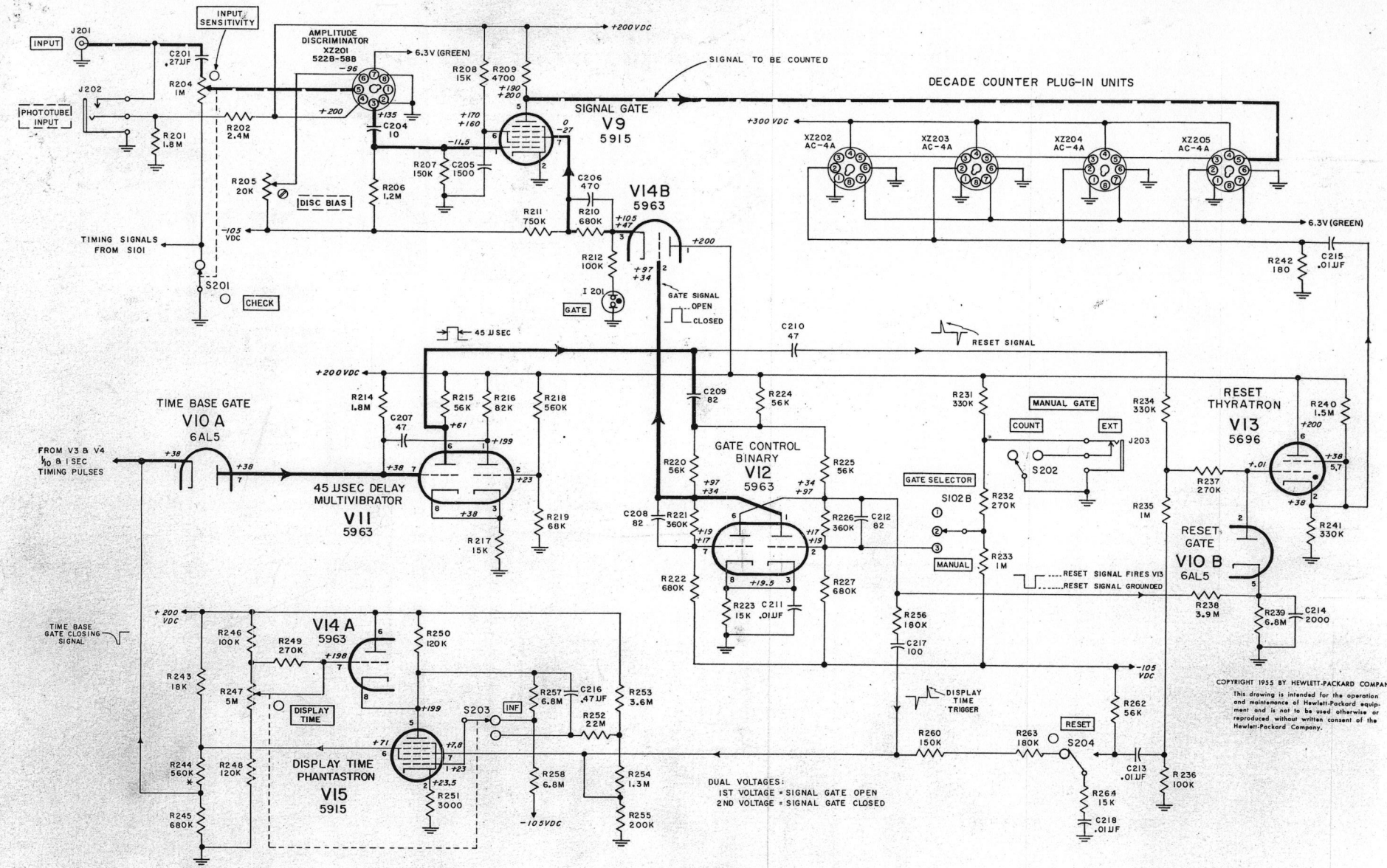
NOTES:

1. ALL VOLTAGES AND RESISTANCES MEASURED TO GROUND WITH ELECTRONIC VOLTMETER HAVING 122 MEGOHM INPUT RESISTANCE (*-hp-* 410B), SET FRONT PANEL CONTROLS AS FOLLOWS:

INPUT SENSITIVITY	60∿ CHECK
GATE SELECTOR	1 SEC
POWER	ON -115 VOLTS, 60∿ LINE VOLTAGE
DISPLAY TIME	MINIMUM

2. K = 1000 OHMS
   M = MEGOHM
   N.C. = NO CONNECTION

Fig. 15. Tube Socket Voltage-Resistance Diagram for the Time Base Section and Power Supply

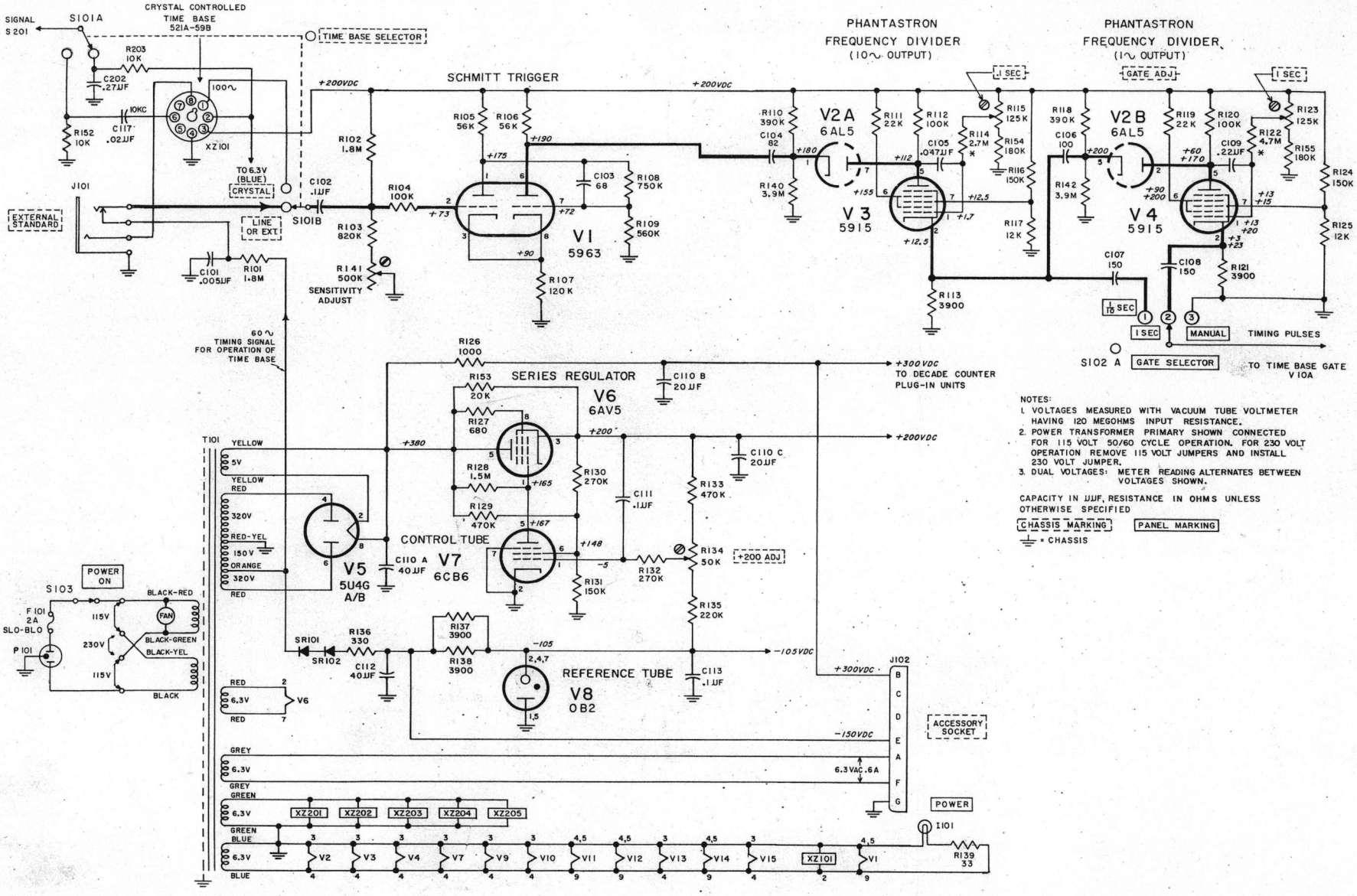


MODEL 521A

COUNTER SECTION

SERIAL 397 & ABOVE

Fig. 16

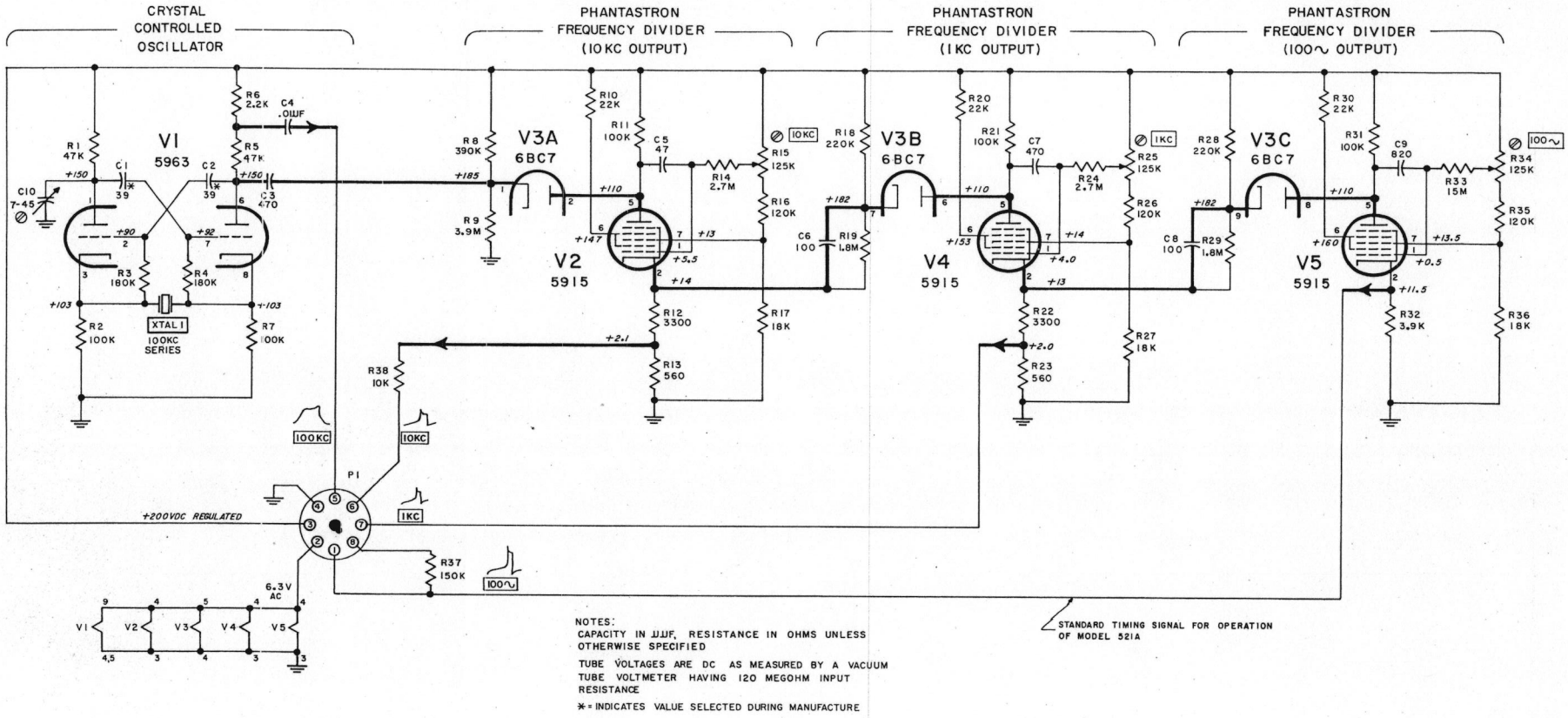


MODEL 521A

POWER SUPPLY & TIME BASE

SERIAL 397 & ABOVE

Fig. 17.

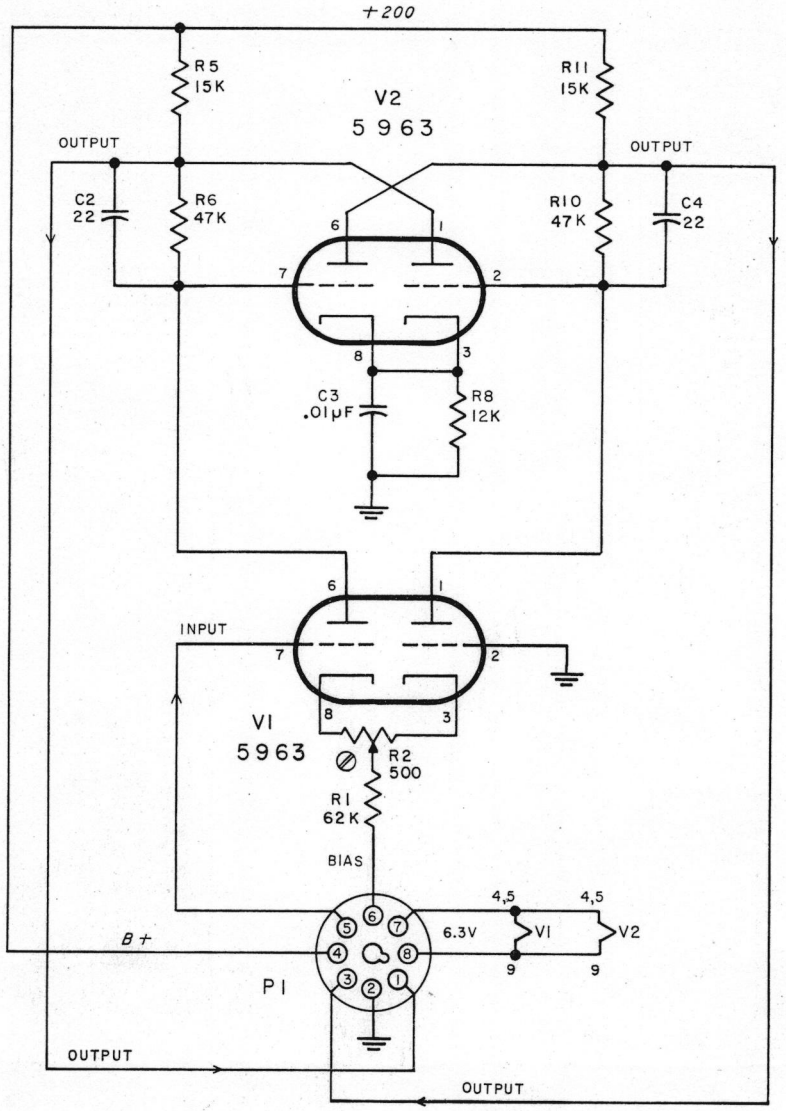


hp 521A-59B

CRYSTAL CONTROLLED TIME BASE ACCESSORY PLUG-IN UNIT Z101

ADC 1389

Fig. 18

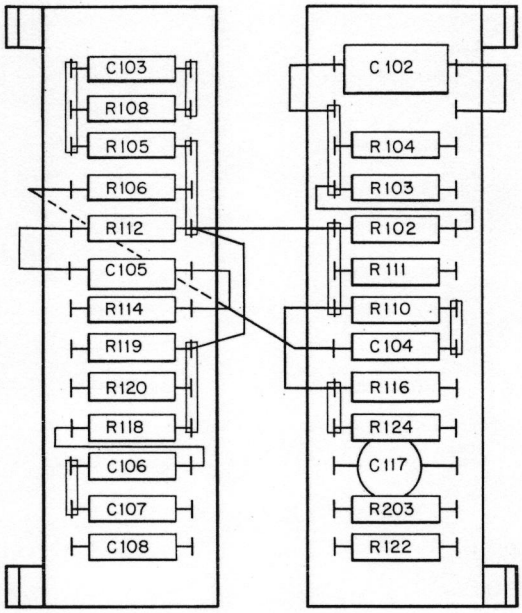


hp 522B-58-B

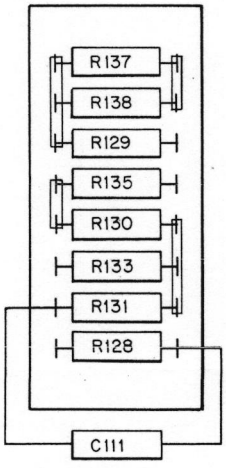
AMPLITUDE DISCRIMINATOR ACCESSORY PLUG-IN UNIT Z201

ADC 1241

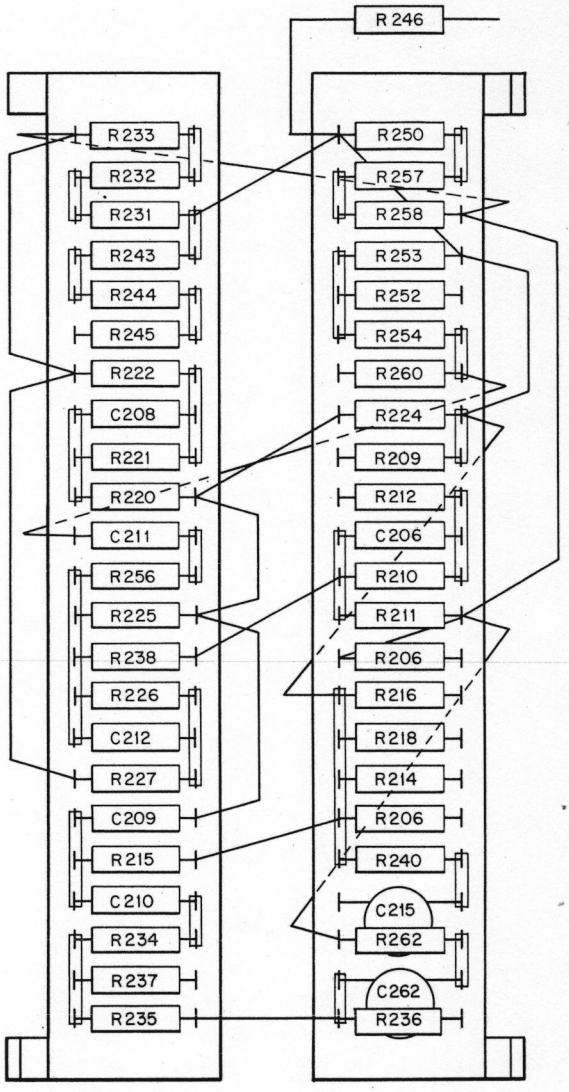
Fig. 19.



RB 101



RB102



RB201

Resistor-Capacitor Mounting Board,
Location Diagram

SECTION VI

TABLE OF REPLACEABLE PARTS

NOTE

Any changes in the Table of Replaceable Parts will be listed on a Production Change sheet at the front of this manual.

When ordering parts from the factory always include the following information:

Instrument model number
Serial number
-hp- stock number of part
Description of part

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
B L101A	Blade: motor	314-3	HP
BL101B	Blade: fan	314-6	HP
C105	Capacitor: fixed, paper dielectric .033 mfd, ±10%, 600 vdcw	16-13	CC #73P3396 P688
C101	Capacitor: fixed, ceramic, dielectric .005 μμf, 500 vdcw	15-47	KBPD .005
C102, C111, C113	Capacitor: fixed, paper dielectric, .1 μf, ±10%, 400 vdcw	16-35	CC 67P10494
C103	Capacitor: fixed, mica, 68 μμf, ±10%, 500 vdcw	14-60	V RCM15B680K
C104, C107, C108	Capacitor: fixed, mica, 150 μμf, ±10%, 500 vdcw	14-150	V Type OXM
C106, C217	Capacitor: fixed, mica, 100 μμf, ±10%, 500 vdcw	14-100	V OXM
C109	Capacitor: fixed, paper dielectric, .22 μf, ±10%, 400 vdcw	16-48	CC 67P22494
C110	Capacitor: fixed, electrolytic, 3 sections 20/20/40 μf, 450 vdcw	18-42S	CC D1665
C112	Capacitor: fixed, electrolytic, 40 μf, 450 vdcw	18-40S	CC D16653
C117	Capacitor: fixed, ceramic, .02 μf, +100%, -0%, 600 vdcw	15-85	G DD-203
C201	Capacitor: fixed, paper dielectric, .27 μf, +20%, -15%, 600 vdcw	16-83	Z Type 33
C202	Capacitor: fixed, paper dielectric, .27 μf, ±10%, 200 vdcw	16-79	CC 67P27492
C203	This circuit reference unassigned		
C204	Capacitor: fixed, mica, 10 μμf, ±10%, 500 vdcw	14-10	V Type W
C205	Capacitor: fixed, paper dielectric, .0015 μf, ±10%, 600 vdcw	16-32	A Type P688
C206	Capacitor: fixed, mica, 470 μμf, ±10%, 600 vdcw	14-62	V Type O

521A 003-2 4/18/56 Serial 397 and above

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C207, C210	Capacitor: fixed, mica, 47 μμf, ±10%, 500 vdcw	14-67	V Type OXM
C115, C116	These circuit references unassigned		
C208, C209 C212	Capacitor: fixed, mica, 82 μμf, ±10%, 500 vdcw	14-19	V Type OXM
C214	Capacitor: fixed, silver mica, 500 μμf, ±10%, 500 vdcw	15-18	Z Type M-24
C215, C211, C213, C218	Capacitor: fixed, ceramic, .01 μf, +100%, -0%, 500 vdcw	15-43	K Type BPD 0.01
C216	Capacitor: fixed, paper, dielectric, .47 μf, ±10%, 200 vdcw	16-37	CC 67P47492A
F101	Fuse: cartridge, 2 amps opens in 25 secs., 200% overload	211-16	E MDL2
I101	Lamp: Incandescent	211-47	O #47
I201	Lamp: Glow	211-27	O NE-51
J010	Jack: telephone	124-10	KK 2S-1230
J102	Connector:	125-66	----
J201	Connector:	125-UG-1094/U	L L-UG-1094/U
J202	Jack: telephone	124-12	2J1331
J203	Jack: telephone	124-3	X A2A
P101	Cable: power	812-56	----
R101, R102, R214	Resistor: fixed, composition, 1.8 megohms, ±10%, 1/2 W	23-1.8M	B EB 1851
R103	Resistor: fixed, composition, 820,000 ohms, ±10%, 1/2 W	23-820K	B EB 8241
R104	Resistor: fixed, composition, 100 ohms, ±10%, 1/2 W	23-100K	B EB 1011

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R105	Resistor: fixed, composition, 56,000 ohms, ±5%, 1/2 W	23-56K-5	B EB 5635
R106	Resistor: fixed, composition, 56,000 ohms, ±10%, 1/2 W	23-56K	B EB 5631
R107	Resistor: fixed, composition, 120,000 ohms, ±10%, 1/2 W	23-120K	B EB 1241
R108	Resistor: fixed, composition, 750,000 ohms, ±5%, 1/2 W	23-750K	B EB 7545
R109	Resistor: fixed, composition, 560,000 ohms, ±5%, 1/2 W	23-560K-5	B EB 5645
R110, R118 **R143	Resistor: fixed, composition, 390,000 ohms, ±10%, 1/2 W	23-390K	B EB 3941
R111, R119 **R145	Resistor: fixed, composition, 22,000 ohms, ±10%, 2 W	25-22K	B HB 2231
R112, R120 **R146	Resistor: fixed, composition, 100,000 ohms, ±10%, 1 W	24-100K	B GB 1041
R113, R121 **R147	Resistor: fixed, composition, 3900 ohms, ±10%, 1/2 W	23-3900	B EB 3921
R114	Resistor: fixed, composition, 2.7 megohms, ±5%, 1/2 W	23-2.7M	B EB 2755
R115, R123 **R149	Resistor: variable, composition, 125,000 ohms, linear taper	210-110	HP
R116, R124	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W	24-150K	B GB 1541
R117, R125	Resistor: fixed, composition, 12,000 ohms, ±10%, 1/2 W	23-12K	B EB 1231
R122	Resistor: fixed, composition, 4.7 megohms, ±10%, 1/2 W	23-4.7M	B EB 4751
R126	Resistor: fixed, wirewound 1000 ohms, ±10%, 20 W	27-12	S Type 2R
R127	Resistor: fixed, composition, 680 ohms, ±10%, 1/2 W	23-680	B EB 6811
R128, R240	Resistor: fixed, composition, 1.5 megohms, ±10%, 1/2 W	23-1.5M	B EB 1551
	** In counters having 10 sec. gate time.		

***See "List of Manufacturers Code Letters For Replaceable Parts Table."**

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R129	Resistor: fixed, composition, 470,000 ohms, ±10%, 1 W	24-470K	B GB 4741
R130	Resistor: fixed, composition, 270,000 ohms, ±10%, 1/2 W	23-270K	B EB 2741
R131	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W	24-150K	B GB 1541
R132, R249 R232, R237	Resistor: fixed, composition, 270,000 ohms, ±10%, 1/2 W	23-270K	B EB 2741
R133	Resistor: fixed, composition, 470,000 ohms, ±10%, 1/2 W	23-470K	B EB 4741
R134	Resistor: variable, composition, 50,000 ohms, ±20%, linear taper	210-18	HP
R135	Resistor: fixed, composition, 220,000 ohms, ±10%, 1/2 W	23-220K	B EB 2241
R136	Resistor: fixed, wirewound, 330 ohms, ±10%, 5 W	26-75	S Type 1-1/4L
R137, R138	Resistor: fixed, composition, 3900 ohms, ±10%, 2 W	25-3900	B HB 3921
R139	Resistor: fixed, composition, 33 ohms, ±10%, 1 W	24-33	B GB 3301
R140, R142 R238 **R144	Resistor: fixed, composition, 3.9 megohms, ±10%, 1/2 W	23-3.9M	B EB 3951
R141	Resistor: variable, composition, 500,000 ohms, ±20%, linear taper	210-20	HP
**R150	Resistor: fixed, composition, 120,000 ohms, ±10%, 1/2 W	23-120K	B EB 1241
**R151	Resistor: fixed, composition, 18,000 ohms, ±10%, 1/2 W	23-18K	B EB 1831
R153	Resistor: fixed, glass, 20,000 ohms, ±10%, 4 W	334-20K	Corning Glass Type LP-4
R154, R155	Resistor: fixed, composition, 180,000 ohms, ±10%, 1 W	24-180K	B GB 1841
	** In counters having 10 sec. gate time.		

***See "List of Manufacturers Code Letters For Replaceable Parts Table."**

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R201	Resistor: fixed, composition, 1.8 megohms, ±5%, 1/2 W	23-1.8M 5	B EB 1855
R202	Resistor: fixed, composition, 2.4 megohms, ±5%, 1/2 W	23-2.4M5	B EB 1555
R203, R152	Resistor: fixed, composition, 10,000 ohms, ±10%, 1/2 W	23-10K	B EB 1031
R204	Resistor: variable, composition, 1 megohm, ±30%	210-104	HP
R205	Resistor: variable, composition, 20,000 ohms, ±20%, linear taper	210-16	HP
R206	Resistor: fixed, composition, 1.2 megohms, ±10%, 1/2 W	23-1.2M	B EB 1251
R207	Resistor: fixed, composition, 150,000 ohms, ±10%, 1/2 W	23-150K	B EB 1541
R208	Resistor: fixed, composition, 15,000 ohms, ±10%, 2 W	25-15K	B HB 1531
R209	Resistor: fixed, composition, 4700 ohms, ±10%, 1 W	24-4.7K	B GB 4721
R210, R222 R227	Resistor: fixed, composition, 680,000 ohms, ±5%, 1/2 W	23-680K-5	B EB 6845
R211	Resistor: fixed, composition, 750,000 ohms, ±5%, 1/2 W	23-750K-5	B EB 7545
R212, R236 R246	Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 W	23-100K	B EB 1041
R213	This component does not appear in instruments above Serial 207		
R215, R224	Resistor: fixed, composition, 56,000 ohms, ±10%, 1 W	24-56K	B GB 5631
R216	Resistor: fixed, composition, 82,000 ohms, ±10%, 1 W	24-82K	B GB 8231
R217, R223 R263	Resistor: fixed, composition, 15,000 ohms, ±10%, 1/2 W	23-15K	B EB 1531
R218, R244	Resistor: fixed, composition, 560,000 ohms, ±10%, 1/2 W	23-560K	B EB 5641

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R219	Resistor: fixed, composition, 68,000 ohms, ±10%, 1/2 W	23-68K	B EB 6831
R220, R225 R262	Resistor: fixed, composition, 56,000 ohms, ±10%, 1/2 W	23-56K	B EB 5631
R221, R226	Resistor: fixed, composition, 360,000 ohms, ±5%, 1/2 W	23-360K-5	B EB 3645
R228, R229 R230	These circuit references not assigned		
R231, R234 R241	Resistor: fixed, composition, 330,000 ohms, ±10%, 1/2 W	23-330K	B EB 3341
R233, R235	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W	23-1M	B EB 1051
R239	Resistor: fixed, composition, 6.8 megohms, ±10%, 1/2 W	23-6.8M	B EB 6851
R242	Resistor: fixed, composition, 180 ohms, ±10%, 1 W	24-180	B GB 1811
R243	Resistor: fixed, composition, 18,000 ohms, ±10%, 2 W	25-18K	B HB 1831
R245	Resistor: fixed, composition, 680,000 ohms, ±10%, 1/2 W	23-680K	B EB 6841
R247	Resistor: variable, composition, 5 megohms	210-97	HP
R248, R250	Resistor: fixed, composition, 120,000 ohms, ±10%, 1/2 W	23-120K	B EB 1241
R251	Resistor: fixed, composition, 3000 ohms, ±5%, 1 W	24-3000-5	B GB 3025
R252 **R148	Resistor: fixed, composition, 22 megohms, ±10%, 1/2 W	23-22M	B EB 2261
R253	Resistor: fixed, composition, 3.6 megohms, ±5%, 1/2 W	23-3.6M-5	B EB 3655
R254	Resistor: fixed, composition, 1.3 megohms, ±5%, 1/2 W	23-1.3M-5	B EB 1355
R255	Resistor: fixed, composition, 200,000 ohms, ±5%, 1/2 W	23-200K	B EB 2045
	** In counters having 10 sec. gate time.		

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R256, R264	Resistor: fixed, composition, 180,000 ohms, ±10%, 1/2 W	23-180K	B EB 1841
R257, R258	Resistor: fixed, composition, 6.8 megohms, ±10%, 1/2 W	23-6.8M	B EB 6851
R259, R261	This circuit reference not assigned		
R260	Resistor: fixed, composition, 150,000 ohms, ±10%, 1/2 W	23-150K	B EB 1541
S102	Switch:	210-155	HP
S101	Switch: toggle	310-54	HP
S103, S202	Switch: toggle	310-11	HP
S204	Switch: push	310-53	KK 1003
SR101, 102	Selenium Rectifier: 130-volt, 65 ma	212-60	M 1002A
T101	Transformer: power	910-125	HP
V1, V11, V12 V14	Tube: 5963	212-5963	ZZ
V2, V10	Tube: 6AL5	212-6AL5	ZZ
V3, V4, V9, V15	Tube: 5915	212-5915	ZZ
V5	Tube: 5U4GA/GB	212-5U4-GA/GB	ZZ
V6	Tube: 6AV5	212-6AV5	ZZ
V7	Tube: 6CB6	212-6CB6	ZZ
V8	Tube: OB2	212-OB2	ZZ
V13	Tube: 5696	212-5696	ZZ
XF101	Holder-Fuse:	140-16	T, 342003
XI101	Light, Indicator:	145-2	
XI102	Light, Indicator:	145-6	
Z101	Crystal controlled time base Plug-In Unit	521A-59B	
Z201	Amplitude Discriminator Plug-In Unit	522B-58B	
Z202, 203, 204, 205	Decade Counter Plug-In Unit	AC-4A	
	Filter, Air:	G-46A	
	Cable:	521A-16A	
	Handle, Leather:	144-8	Specialty Leather Prod. Co. #573
	Cable, Power:	812-56	Cornish 2143
	Special Adapter	125-68	Cornish 1482

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
	AMP. DISC. PLUG-IN UNIT No. 522B-58-B		
C1	This circuit reference not assigned		
C2, C4	Capacitor: fixed, mica, 22 μμf, ±5%, 300 vdcw	14-69	V Type RQ
C3	Capacitor: fixed, ceramic dielectric, 0.01 μf, +100%, -0%, 500 vdcw	15-43	K Type BPD 0.01
P1	Power Cable:	125-31	HH, 86-877
R1	Resistor: fixed, composition, 62,000 ohms, ±5%, 1 W	24-62K-5	B GB 6235
R2	Resistor: variable, 500 ohms, ±20%, 1/2 W, linear taper	210-115	G B19790
R3, R4, R7, R9	These circuit references not assigned		
R5, R11	Resistor: fixed, composition, 15,000 ohms, ±10%, 1 W	24-15K	B GB 1531
R6, R10	Resistor: fixed, composition, 47,000 ohms, ±10%, 1/2 W	23-47K	B EB 4731
R8	Resistor: fixed, composition, 12,000 ohms, ±10%, 1 W	24-12K	B GB 1231
V1, V2	Tube: 5963	212-5963	ZZ
	Amplitude Discriminator, Unit complete	522B-58B	HP

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
	CRYSTAL CONTROLLED TIME BASE No. 521A-59B		
C1, C2	Capacitor: fixed, mica, 39 μμf, ±5%, 300 vdcw	14-70	V Type PQ
C3, C7	Capacitor: fixed, mica, 470 μμf, ±10%, 500 vdcw	14-62	V Type O
C4	Capacitor: fixed, ceramic dielectric, 0.01 μf, +100%, -0%, 500 vdcw	15-43	K Type BPD 0.01
C5	Capacitor: fixed, mica, 47 μμf, ±5%, 300 vdcw	14-74	V Type PQ
C6, C8	Capacitor: fixed, mica, 100 μμf, ±5%, 300 vdcw	14-76	V Type PQ
C9	Capacitor: fixed, mica, 820 μμf, ±10%, 500 vdcw	14-28	V Type OXM
C10	Capacitor: variable, ceramic dielectric 7-45 μμf, 500 vdcw	13-1	L #TS2A
R1, R5	Resistor: fixed, composition, 47,000 ohms, ±10%, 1/2 W	23-47K	B EB 4731
R2, R6	Resistor: fixed, composition, 100,000 ohms, ±10%, 1/2 W	23-100K	B EB 1041
R3, R 4, R37	Resistor: fixed, composition, 180,000 ohms, ±10%, 1/2 W	23-180K	B EB 1841
R7	Resistor: fixed, composition, 2200 ohms, ±10%, 1/2 W	23-2.2K	B EB 2221
R8	Resistor: fixed, composition, 390,000 ohms, ±10%, 1/2 W	23-390K	B EB 3941
R9	Resistor: fixed, composition, 3.9 megohms, ±10%, 1/2 W	23-3.9M	B EB 3951
R10, R20, R30	Resistor: fixed, composition, 22,000 ohms, ±10%, 2 W	25-22K	B HB 2231
R11, R21, R31	Resistor: fixed, composition, 100,000 ohms, ±10%, 2 W	24-100K	B HB 1041

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R12, R22	Resistor: fixed, composition, 3300 ohms, ±10%, 1/2 W	23-3.3K	B EB 3321
R13, R23	Resistor: fixed, composition, 560 ohms, ±10%, 1/2 W	23-560	B EB 5611
R14, R24	Resistor: fixed, composition, 2.7 megohms, ±10%, 1/2 W	23-2.7M	B EB 2751
R15, R25, R34	Resistor: variable, 125, 000 ohms, linear taper	210-110	G Model #2
R16, R26, R35	Resistor: fixed, composition, 120, 000 ohms, ±10%, 1/2 W	23-120K	B EB 1241
R17, R27, R36	Resistor: fixed, composition, 18, 000 ohms, ±10%, 1/2 W	23-18K	B EB 1831
R18, R28	Resistor: fixed, composition, 220, 000 ohms, ±10%, 1/2 W	23-220K	B EB 2241
R19, R29	Resistor: fixed, composition, 1.8 megohms, ±10%, 1/2 W	23-1.8M	B EB 1851
R32	Resistor: fixed, composition, 3900 ohms, ±10%, 1/2 W	23-3.9K	B EB 3921
R33	Resistor: fixed, composition, 15 megohms, ±10%, 1/2 W	23-15M	B EB 1561
R38	Resistor: fixed, composition, 10, 000 ohms, ±10%, 2 W	24-10K	B HB 1031

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

521A003-2 4/18/56 s/n 397 and above

LIST OF MANUFACTURERS CODE LETTERS FOR REPLACEABLE PARTS TABLE

Code Letter	Manufacturer
A	Aerovox Corp.
B	Allen-Bradley Co.
C	Amperite Co.
D	Arrow, Hart and Hegeman
E	Bussman Manufacturing Co.
F	Carborundum Co.
G	Centralab
H	Cinch Manufacturing Co.
HP	Hewlett-Packard
I	Clarostat Manufacturing Co.
J	Cornell Dubilier Electric Co.
K	Hi-Q Division of Aerovox Corp.
L	Erie Resistor Corp.
M	Federal Telephone and Radio Corp.
N	General Electric Co.
O	General Electric Supply Corp.
P	Girard-Hopkins
R	International Resistance Co.
S	Lectrohm, Inc.
T	Littelfuse, Inc.
V	Micamold Radio Corp.
X	P.R. Mallory Co., Inc.
Z	Sangamo Electric Co.
AA	Sarkes Tarzian
CC	Sprague Electric Co.
DD	Stackpole Carbon Co.
EE	Sylvania Electric Products, Inc.
FF	Western Electric Co.
HH	Amphenol
II	Dial Light Co. of America
KK	Switchcraft, Inc.
LL	Gremar Mfg. Co.
MM	Carad Corp.
ZZ	Any tube having RETMA standard characteristics

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

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

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY
Laboratory Instruments for Speed and Accuracy
275 PAGE MILL ROAD PALO ALTO, CALIF. U.S.A.
CABLE "HEWPACK"

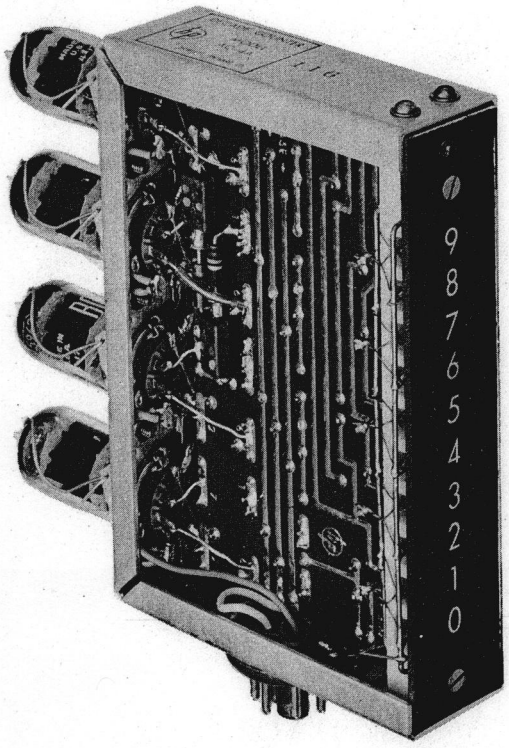
OPERATING AND SERVICING INSTRUCTIONS

FOR

MODEL AC-4A

DECADE COUNTER

COPY



HEWLETT-PACKARD COMPANY
275 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

0134A006-2

SECTION I

GENERAL DESCRIPTION

1-1 DESCRIPTION

The Model AC-4A Decade Counter is a general purpose, plug-in electronic counter that counts electrical pulses applied to its input terminal and indicates the number of the last pulse received in a column of numerals from "0" to "9" on the front panel.

The AC-4A produces one output pulse each time the registered counts steps from "9" to "0", i.e., produces one output pulse for every ten input pulses. Consequently, any desired count storage capacity can be obtained by connecting the units in series and by placing them side by side so that the first units provide the "units" digit, the second unit provides the "tens" digit, and so on. The final answer is then read directly as a number across the row of counter units.

The count is indicated on the panel of the AC-4A by illuminating the correct numeral in the number column with a neon lamp. Engraved numerals and special reflecting surfaces behind the neon lamps insure good readability.

A second output signal, the "Staircase" output, is provided for operating certain types of external indicating devices. This output signal consists of nine equal steps of voltage, one step for each count indicated in the number column.

The AC-4A utilizes etched circuits which provide good production uniformity and very low capacity wiring and result in a very stable, fast counting unit. The open-frame construction lowers operating temperatures and simplifies parts inspection and servicing.

The AC-4A requires 300 volts dc at approximately 15 milliamperes and 6.3 volts ac at 1.2 amperes for operation, neither voltage requiring regulation. The unit plugs into a standard octal socket and is secured by a single mounting screw at the top of the number column.

The AC-4A is directly replaceable with any other plug-in-counter unit used in Hewlett-Packard Electronic Counter instruments, and in addition, it is also directly interchangeable with many similar decade counter units of other manufacturers.

SECTION II

INSTALLATION

2-1 SOCKET CONNECTIONS

The pins on the octal plug for the AC-4A are listed below with their functions:

Pin 1 - Pins 1 and 7 receive filament power, 6.3 volts, ±10% 1.2 amperes and should not contain transient pulses of sufficient amplitude to cause erratic counting. Either side of the filament circuit may be grounded externally.

Pin 2 - Pin 2 provides for resetting the AC-4A to "0" when a new count is to be started. For the AC-4A to count, this pin must be connected to ground through a resistance not more than 750 ohms. To reset the AC-4A to "0" this circuit may be momentarily opened, or a positive pulse of 150 volts peak may be applied to pin 2. (See note 1.)

Diagrams of typical reset circuits are available from the Hewlett-Packard Company upon request.

Pin 3 - Pin 3 provides the output signal (input signal ÷ 10) from the AC-4A. The output connection is direct-coupled and has from 50 to 140 volt d-c potential on it. The output signal is a negative-going wave from the 140-volt level to the 50-volt level which occurs when the unit passes the count of "9". The load placed on pin 3 should not be less than 300,000 ohms, or 6000 ohms in series with 100 μμf. (See OUTPUT WAVEFORM in Maintenance Section - page 12.)

Pin 4 - Pin 4 receives the d-c operating power, 300-volt dc ±10% at approximately 15 milliamperes. This voltage does not have to be regulated, but it must not contain transient pulses or ripple of sufficient amplitude to produce random counts.

Pin 5 - Pin 5 receives the input signal to be counted. The AC-4A counts negative-going wave fronts having approximately 80 volts peak amplitude and 1 microsecond rise time. Faster rise times decrease the amplitude required. (See note 2.)

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Pin 6 - Pin 6 is the Ground and B - connection and is connected to chassis or ground bus.

Pin 7 - Filament circuit, see Pin 1.

Pin 8 - Pin 8 provides the "Staircase" output voltage. The staircase voltage is proportional to the digit displayed and may be used to operate a remote indicating device. The open circuit voltage varies from +138 volts for a displayed count of "0" to +54 volts for a displayed count "9" in approximately equal steps. (See STAIRCASE OUTPUT waveform in Section 4.)

The staircase output circuit has an internal impedance of approximately 700,000 ohms and the output voltage depends upon the external load connected to this circuit. The load connected to this circuit does not affect the normal counting of the unit.

CAUTION

Suitable precautions must be taken to prevent coupling transient voltages through any of the external connections to the AC-4A, or erratic counting may result.

NOTE 1

The displayed count on the AC-4A may be reset to "0" manually with a switch or electronically by pulse. A pulse used for reset must have a fast rise and slow decay; pulse width is unimportant. The rise time must be approximately one μ sec 150 volts as applied to 750 ohms maximum between pin 2 and ground. The unit can be reset to "9" with a negative reset pulse.

NOTE 2

The -hp- Amplitude Discriminator Unit, Model 522B-58B generates a suitable driving pulse for the AC-4A, and has a maximum sensitivity of 0.2 volt on any waveform. Complete details of this plug-in-unit are available from the Hewlett-Packard Company.

SECTION III

THEORY OF OPERATION

3-1 GENERAL

The AC-4A Decade Counter plug-in unit consists of four bi-stable multivibrators (binaries) and a bank of 10 neon lighted numerals on the front panel. As the binaries sense the input pulses, certain combinations of voltages are set up between halves of the binaries which light the appropriate neon lamp for each pulse.

The state of the first binary determines whether an odd or even numbered lamp will be lighted by applying one necessary voltage to the even lamps, or to the odd lamps. The other voltage is obtained as the difference-voltage existing across two specific halves of two different binaries. As subsequent input pulses are received the difference-voltage lighting the lamps procedes from one pair of binaries to the next, lighting subsequent lamps.

The four binaries are connected in cascade so the output from the first is fed to the input of the second, and so on. Each binary is designed to respond only to negative-going input pulses. Each binary produces alternately positive and negative output pulses for a series of negative input pulses. Since the next binary senses only the negative pulses, the effect is to divide by two.

With four such binaries 16 input pulses would be required to obtain one negative output pulse (overall division would be 16). However, by the use of two feedback loops 6 extra "counts" are added within the unit so that only 10 input pulses are required to obtain one negative output pulse to make the total division 10. The feedback circuits used in counters are not to be confused with feedback circuits used in amplifier design. Counter feedback circuits are used only to apply a pulse from one of the binaries in a chain to another in the same chain. If the feedback pulse is of the correct polarity, it will trigger the binary, producing the same result as additional pulses at the input. The action of an individual binary is described below followed by a discussion of the operation of four such binaries connected in series.

3-2 THE BI-STABLE MULTIVIBRATOR, OR BINARY

The circuit of a typical bi-stable multivibrator is shown in Figure 1. This circuit has two stable states; one, with "A" side conducting, two, with "B" side conducting. All input pulses are applied equally to both the "A" and "B" sides, however, only negative going pulses can start the switching action.

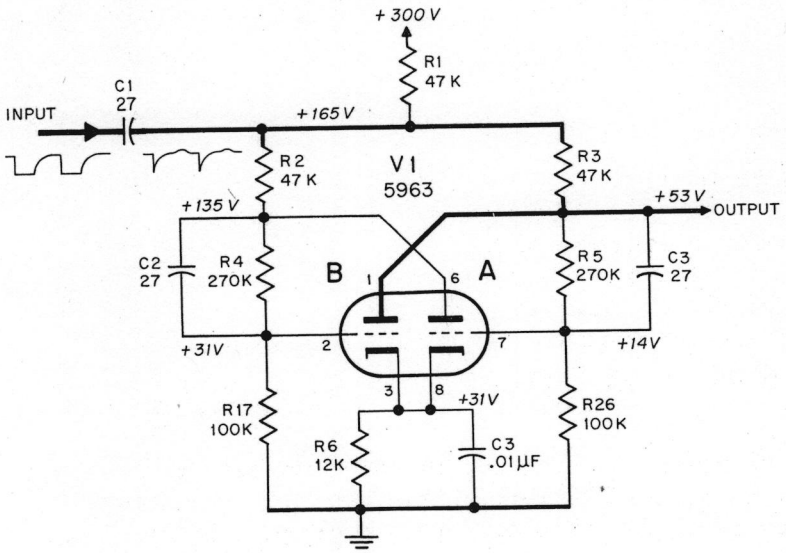


Fig. 1. Circuit of binary used in AC-4A Counter Unit

Prior to receiving an input pulse a binary rests in one of its two stable states; one side is conducting, one side is not. The high positive voltage at the plate of the non-conducting tube maintains a high charge on the coupling capacitor to the grid of the conducting tube, while the low plate voltage on the conducting tube maintains only a small charge on the capacitor to the grid of the non-conducting tube.

An input signal is applied to a point in the plate load resistors at R1 which is common to the plate loads of both sides of the binary. This pulse lowers the plate voltage of both tubes, but lowers the plate voltage of the non-conducting tube by almost the full value of the input pulse, whereas the plate voltage of the conducting tube is only slightly affected as it was already at a very low value. Consequently, the negative input pulse coupled from the plate of the non-conducting tube to the grid of the conducting tube will be large; the negative pulse coupled from the plate of the conducting tube to the grid of the non-conducting tube will be very small and is of no importance. A positive input pulse following the same path has no affect upon the grid of the conducting tube and causes no switching action.

The negative input pulse, for a portion of its duration, holds both sides of the binary in a state of non-conduction, and applies a high negative bias to the grid of the previously conducting tube (essentially reversing the relative grid bias for the two halves of the binary). Consequently, when the input pulse is ended, the capacitor to the grid of the previously non-conducting stage and the high plate voltage to which it is now connected cause this grid to go positive very quickly, before

the opposite capacitor can return from its potential far beyond cutoff. The binary has thus returned to a state opposite to that which it held prior to receiving the negative input pulse.

A strong, sharp output pulse is obtained from one plate circuit and coupled to the next binary. The output pulse is positive when the output half of the binary is switched out of conduction, and negative when it is switched into conduction. The amplitude of the output pulses from the 2nd, 3rd and 4th binaries in the AC-4A are equal, and should be approximately 82 volts (from +53 to +135), while the output from the 1st binary is approximately 110 volts, (from +62 to +172).

3-3 OPERATION OF FOUR CASCADED BINARIES

The operation of four binaries connected in cascade and the operation of the neon lighting circuits is described in the following paragraphs with the aid of the diagram in Figure 2. In these diagrams, the waveforms are the d-c potential at the output of each binary. The actuating pulse that is applied to the next binary consists of the rise and decay portions of the waveform shown due to being differentiated by the coupling capacitor.

Diagram A shows the waveforms obtained from a system of four binaries with no feedback. The top row represents the pulses applied to the input, and each subsequent row is the output of a succeeding binary. Waveforms are oriented in relation to the frequency applied to the input. Reading from left to right, each down-going line is a negative pulse which causes the next binary to switch its state. Each up-going line in the waveform is a positive pulse and is without effect. As shown, one positive output pulse is obtained after 8 input pulses and one negative output pulse after 16 input pulses. Such a system would require a column of 16 numbers for the readout, a complex system to read if more than one counter is used.

A more useful indicating system, "0" through "9", can be obtained when the division ratio of the set of four binaries is made to be 10 instead of 16. The readout can then be a direct reading decimal number when more than one counter unit is used, one beside the other. To make the system produce one output pulse for every ten input pulses (instead of 16) the extra six pulses are effectively supplied internally by feeding the required pulses from one binary to another. Diagram B shows such a system in operation. Two feedback paths are used, the first one retriggers the second binary and positions it two input pulses farther along. The second feedback path retriggers the third binary and positions it four input pulses farther along, thus the effect of six additional input pulses is duplicated within the unit to make the unit divide by ten.

Diagram C shows how the readout of 10 neon lighted numbers are made to light in their proper sequence. As input pulses enter, they cause the first binary to continually switch from one state to the other. One

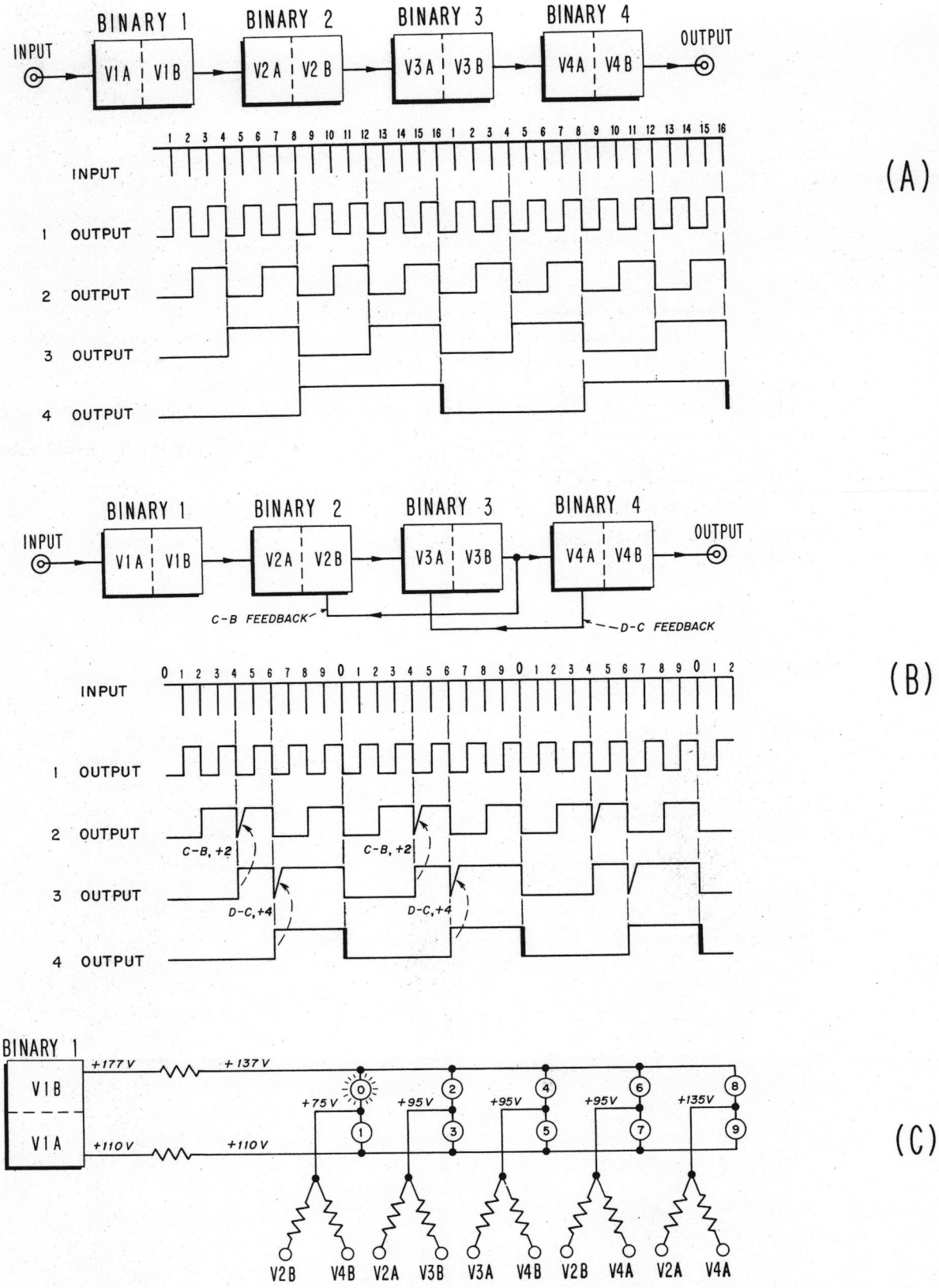


Fig. 2. Output Waveforms of Each Binary in a 4-Binary System:
(a) Without feedback to divide by 16
(b) With feedback to divide by 10
(c) The lighted numeral readout system

half of the binary is connected to one side of all the even numbered lamps. The other half is connected to one side of all the odd numbered lamps. As the binary switches back and forth it alternately supplies one needed voltage to light the odd, then the even numbered lamps. The difference voltage that determines which odd or even lamp is lighted is obtained from combinations of the various halves of the remaining three binaries, and consists of a resultant voltage when two different binary halves are combined. Three resultant voltages are possible: when both halves are conducting, when both halves are non-conducting and when one is conducting and one is not. Only when both halves are conducting and the voltage is at its lowest is the voltage difference between this combination and that established by the input binary sufficient to light a neon. This voltage of approximately 75 volts gradually moves down the bank of neons shown in the diagram as succeeding input pulses switch the binaries and the odd and even lamps are alternately given the necessary voltage.

SECTION IV

SERVICING THE AC-4A PLUG-IN COUNTER UNIT

4-1 GENERAL

A majority of failures in counter units can be remedied by tube replacement. Systematically replace one tube at a time to prevent masking other possible circuit failures. If a tube is replaced without improvement in operation, return the original tube to its socket.

Any AC-4A Counter may be exchanged with any other AC-4A Counter without adjustment or change in operation; therefore to determine if a counter is faulty, replace it with one known to be operating properly. An improvement in operation then indicates the original counter to be defective. When exchanging counters in this manner keep in mind that a defective counter can upset the operation of cascaded counters that follow. If several counters seem to operate improperly service the first one in line (see schematic diagram for sequence of counter units.)

4-2 CHECKING AN INDIVIDUAL COUNTER UNIT AT LOW SPEED

Some failures can be analyzed by applying single pulses to a counter unit and observing the counting sequence that results. Figure 3 shows a circuit which will apply a reliable pulse for low-speed operation of the AC-4A Counter. Ten pulses should light each numberal in the column in its correct sequence to complete one cycle of operation. A failure may be indicated by a number lighting in an incorrect sequence or by some unstable state such as one or more numbers flashing on and off.

If the counting sequence is incorrect, but the Counter still has ten stable indications for ten pulses applied, first check the lamp connections and the printed wiring for short circuits then check for a defective lamp which does not light with the normal applied voltage.

If the counter has 12 or 16 stable states one or both of the two feedback networks is open.

If the counter has less than 10 stable states one of the four tubes can be defective. Replace one tube at a time and check for correct operation.

The following chart shows various incorrect indications obtained when making a low-speed operational check and gives the circuit most likely to be at fault. The counter may also be analyzed by measuring the voltages and waveforms throughout the circuit and comparing the measurement indications against the ideal waveforms and the voltages on the schematic diagrams.

TABLE I

RESETS TO	COUNTING CYCLE	FAULTY CIRCUIT
0	0, 1, 8, 9, then repeats 6, 7, 8, 9	V3
0	0, 2, 4, 6, 8	V1
0	0, 1, 2, 3, 4, 5	V4 or output circuit grounded.
0	0, 1, 2, 3, 6, 7, 8 & 2, 9 & 3	V3
0	0, 1, 2, 3, 4, 5, 4, 5, 6, 7, 8, 9,	Feedback between V2 and V3.
0	0, 1, 2, 3, 4, 5, 6, 7, 8 & 2, 9 & 3, 8, 9	Feedback between V4 and V3.
0	0, 1, 2, 3, 4, 5, 4, 5, 6, 7, 8 & 2, 9 & 3, 6, 7, 8, 9	Both feedback loops.
1	Will not count	V1
2	2, 3	V4 or V2
4	4, 5	V2 or V3
6	6, 7, 8 & 2, 9 & 3, 8, 9	V4

4-3 CHECKING AN INDIVIDUAL COUNTER AT HIGH SPEED

Some kinds of circuit failures can cause counter units to count incorrectly or fail at high counting rates, particularly approaching 120,000 cps. This type of trouble can sometimes be corrected by the same remedies as for low-speed failures, however, if a failure persists at high counting rates only, the trouble should be analyzed by observing waveforms throughout the circuit, using a high-speed synchroscope. Begin by measuring the output of the first binary and proceed with each succeeding binary. Adjust the

input signal frequency just below and above the frequency where the counting failure occurs and observe the difference in the waveforms at the output of each binary. Compare the oscilloscope patterns with the ideal waveforms shown in Figure 2. The waveform picture which changes as the counting failure appears usually indicates the proceeding circuit in the printed wiring, changing values in resistors, leakage in capacitors, weak tubes, etc. Any part can be replaced with another part having the same value, tolerance and physical size without circuit adjustment or change in unit operation.

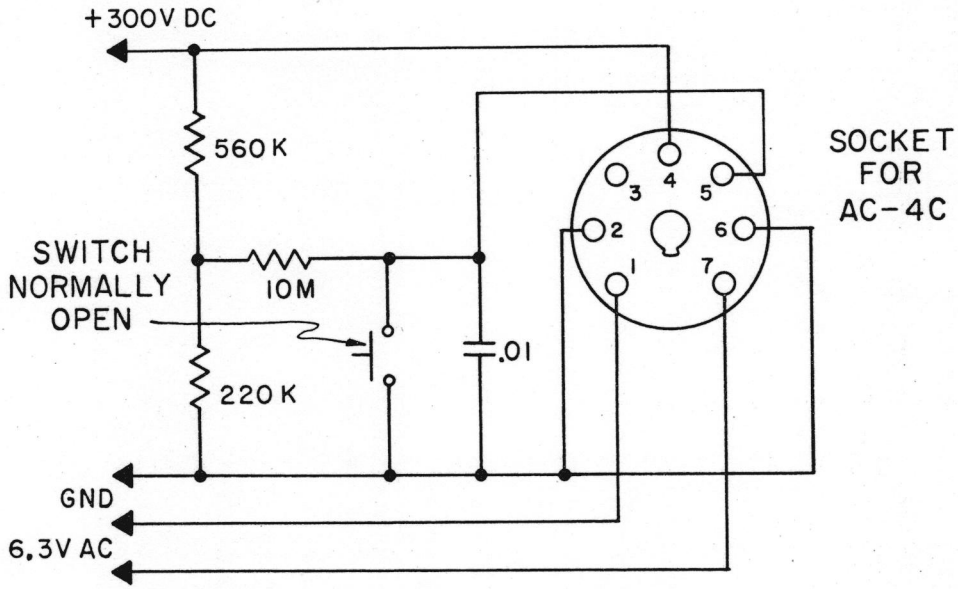


Fig. 3 Manual Trigger Circuit for low-speed testing of the AC-4A

WAVEFORM DATA

Waveform oscillograms taken at the plate of each tube in the AC-4A are shown in the following illustration. The left-hand column shows typical waveforms obtained when the AC-4A is counting low frequencies; the right-hand column when counting frequencies near the upper frequency limit of the AC-4A. At counting rates above 100 kilocycles the waveforms deteriorate in the manner indicated by the difference between the two columns to a point where counting a higher frequency is not possible.

Some circuit failures can cause the waveform deterioration illustrated at frequencies below 100 kc. Such a trouble can be isolated by comparing waveforms obtained from an unsatisfactory counter unit with the waveforms in the illustration. If a binary produces a waveform with excessive deterioration check the tube by replacement with a new tube; check circuit resistances; check the capacity, "Q" and leakage of capacitors, and check for leakage between conductors on the printed circuit board.

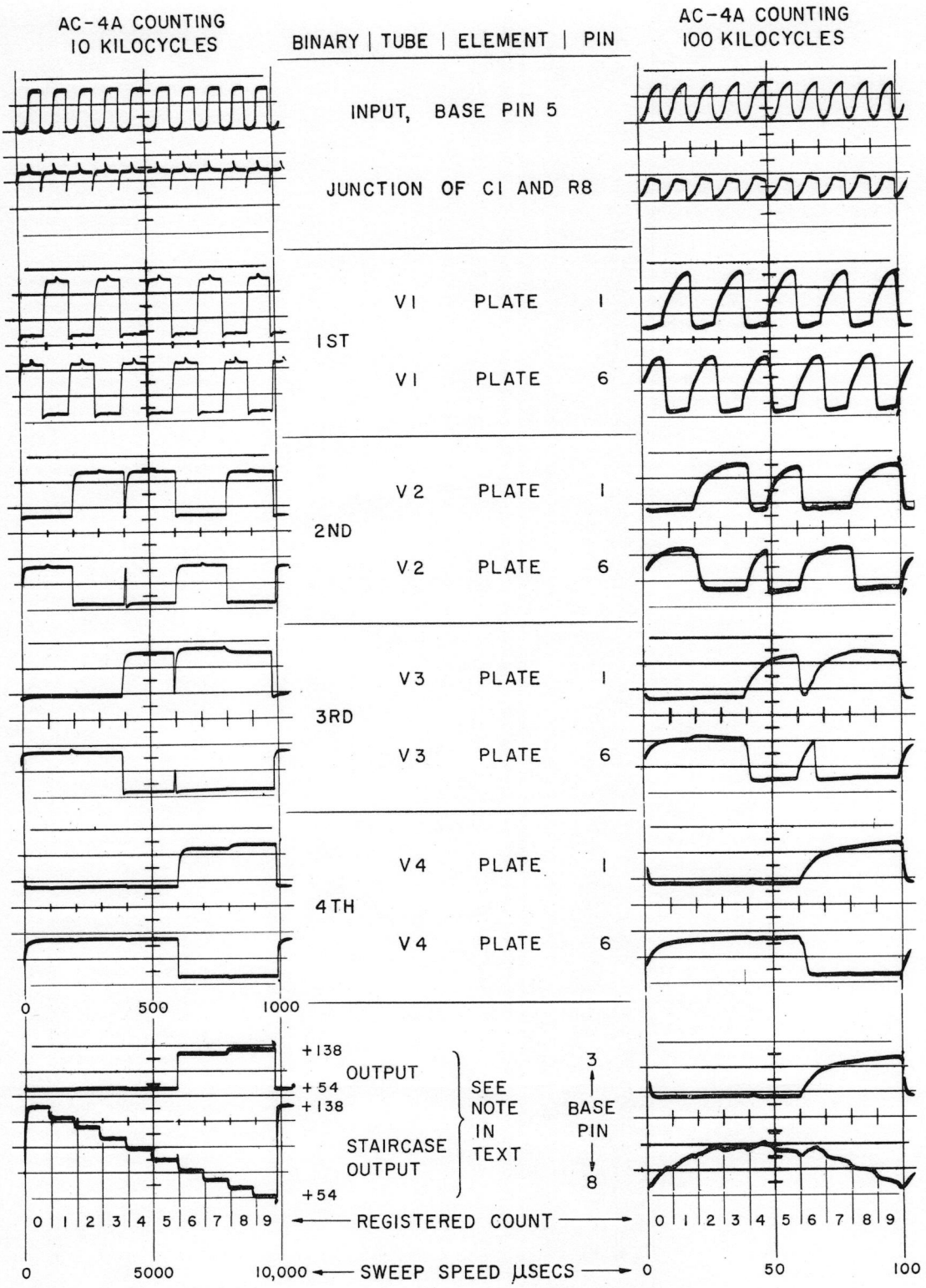


Fig. 4. Oscillograms obtained from an AC-4A Decade Counter
(A) counting a low frequency
(B) counting a high frequency

Amplitude Calibration 50 volts/cm unless otherwise noted.
Oscilloscope synchronized with negative portion of the output from the AC-4A

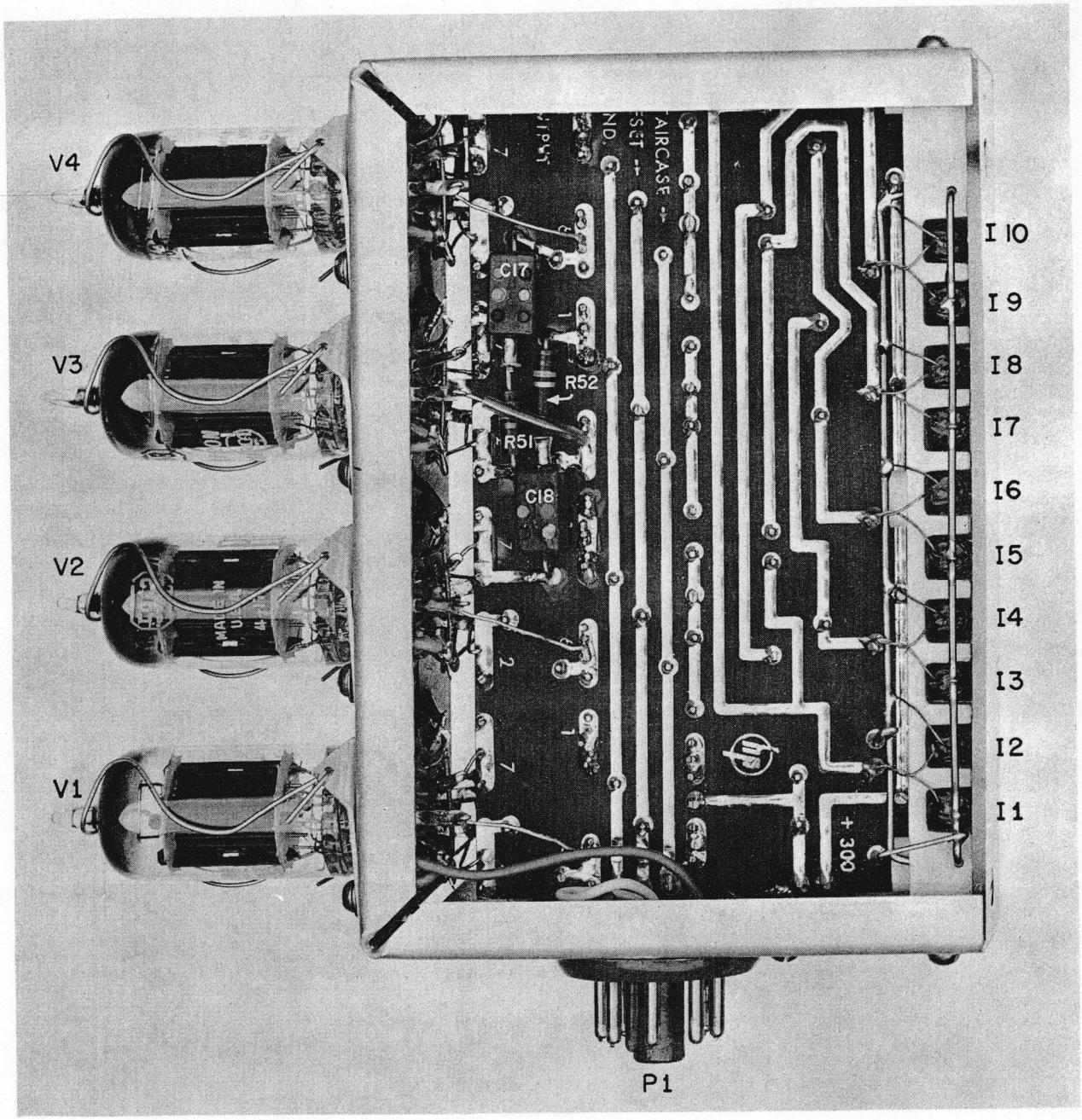


Fig. 5. Left Side of the Model AC-4A

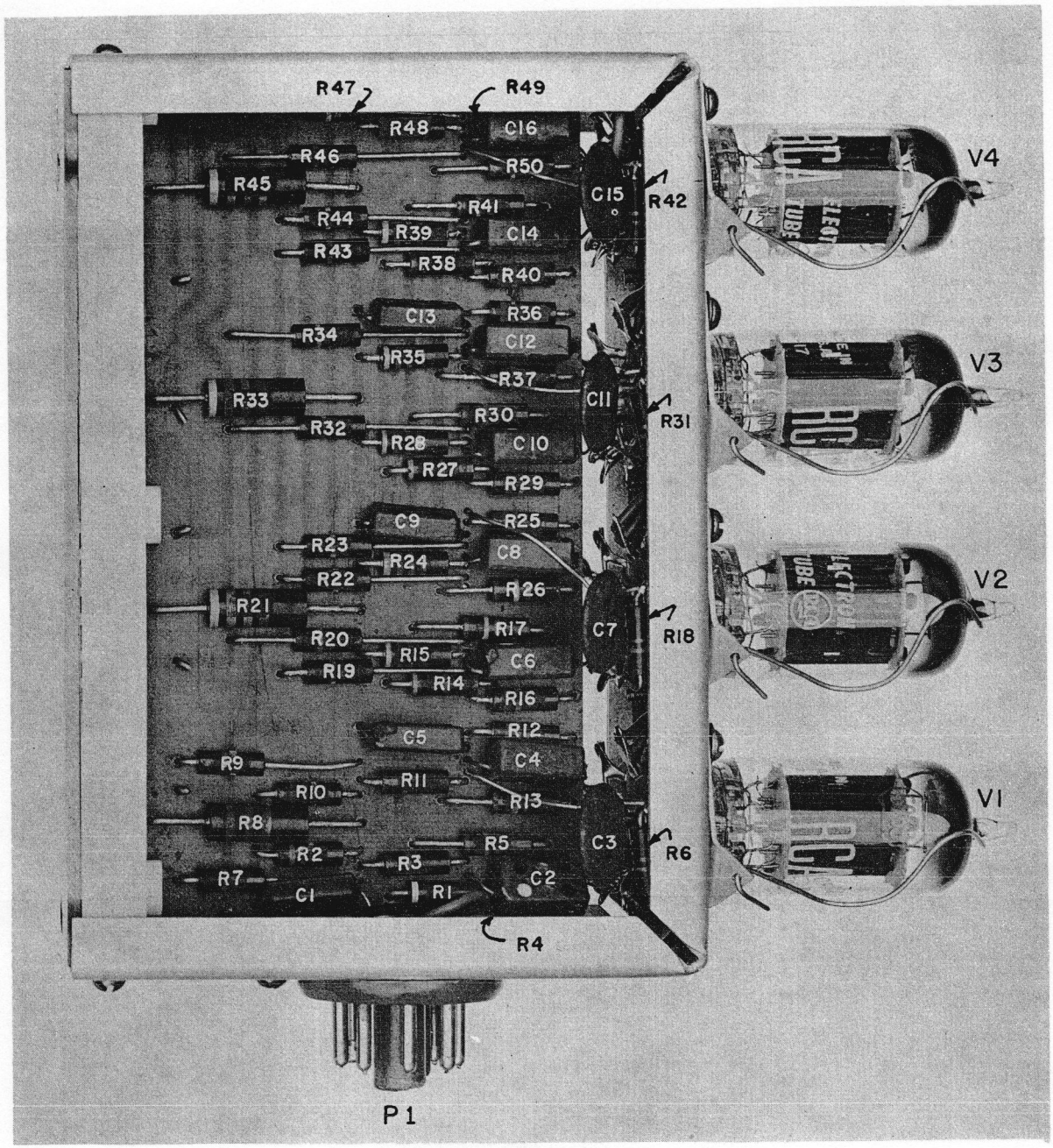
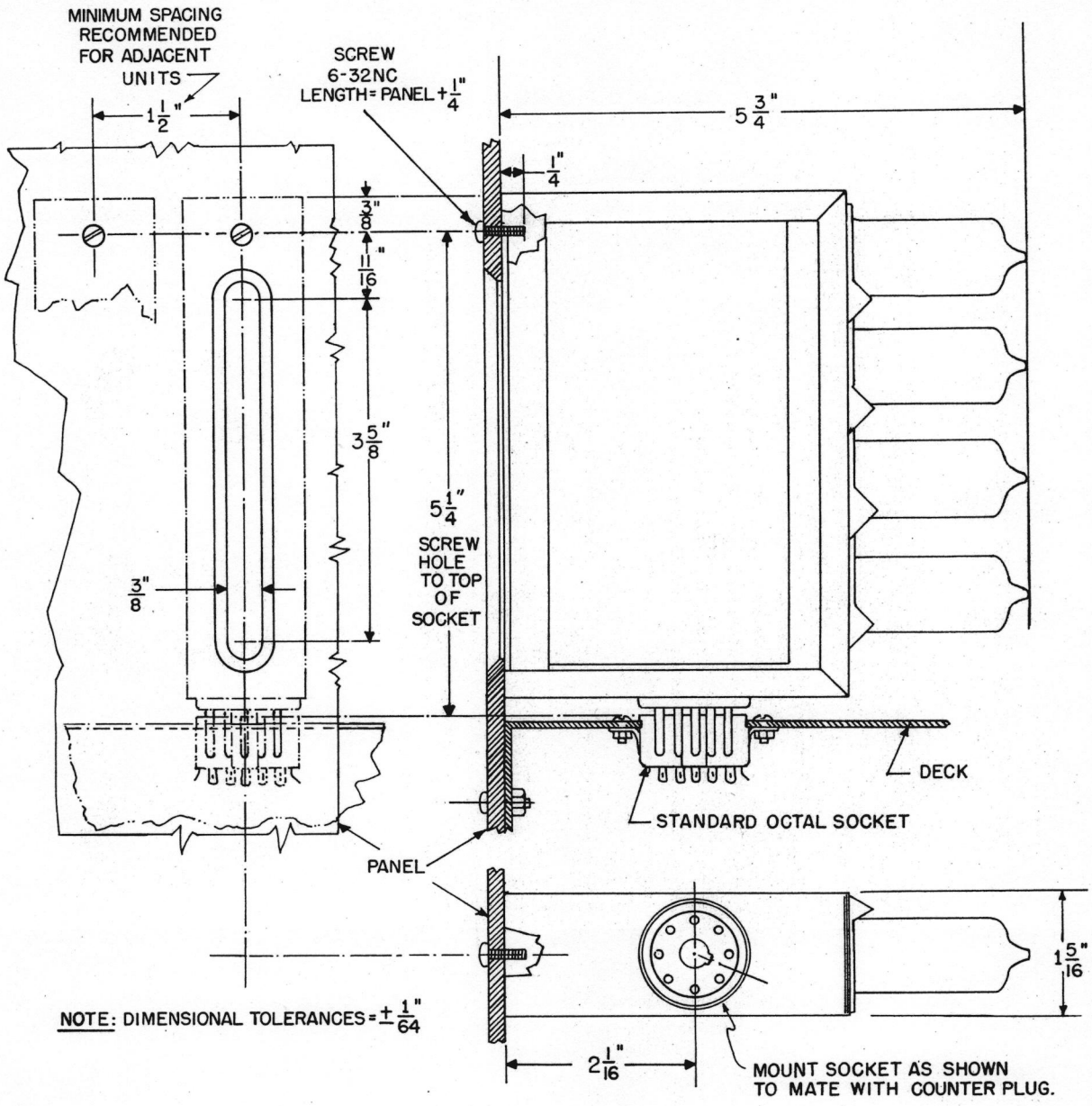
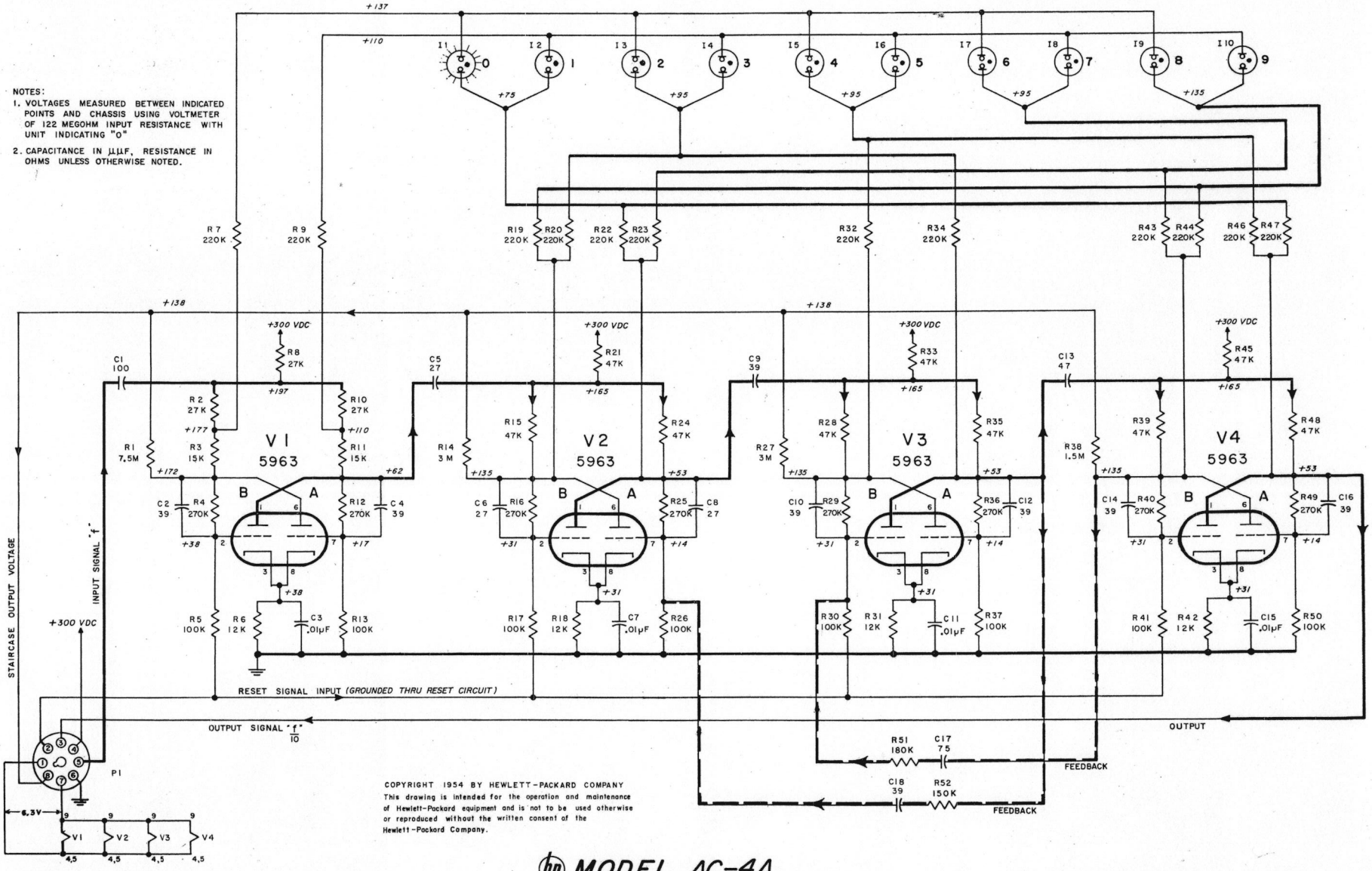


Fig. 6. Right Side of the Model AC-4A



Model AC-4A Mounting Dimensions

Fig. 7



MODEL AC-4A

DECADE COUNTER

SERIAL 5391 & ABOVE

SECTION V

TABLE OF REPLACEABLE PARTS

NOTE

Any changes in the Table of Replaceable Parts will be listed on a Production Change sheet at the front of this manual.

When ordering parts from the factory always include the following information:

Instrument model number
Serial number
-hp- stock number of part
Description of part

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C1	Capacitor: fixed, mica, 100 μμf, ±5%, 300 vdcw	14-76	V Type PQ
C2, 4, 9, 10, 12, 14, 16, 18	Capacitor: fixed, mica, 39 μμf, ±5%, 300 vdcw	14-70	V Type PQ
C3, 7, 11 15	Capacitor: fixed, ceramic, .01 μf, +100%, -0%, 500 vdcw	15-43	K BPD .01
C5, 6, 8	Capacitor: fixed, mica, 27 μμf, ±5%, 300 vdcw	14-78	V Type RPQ
C13	Capacitor: fixed, mica, 47 μμf, ±5%, 300 vdcw (preferred value)	14-74	V Type PQ
C17	Capacitor: fixed, mica, 75 μμf, ±5%, 300 vdcw	14-75	V Type PQ
R1	Resistor: fixed, composition, 7.5 megohms, ±5%, 1/2 W	23-7.5M-5	B EB 7555
R2, 10	Resistor: fixed, composition, 27,000 ohms, ±5%, 1/2 W	23-27K-5	B EB 2735
R3, 11	Resistor: fixed, composition, 15,000 ohms, ±5%, 1/2 W	23-15K-5	B EB 1535
R4, 12, 16, 25, 29, 36, 40, 49	Resistor: fixed, composition, 270,000 ohms, ±5%, 1/2 W	23-270K-5	B EB 2745
R5, 13, 17, 26, 30, 37, 41, 50	Resistor: fixed, composition, 100,000 ohms, ±5%, 1/2 W	23-100K-5	B EB 1045
R6, 18, 31, 42	Resistor: fixed, composition, 12,000 ohms, ±5%, 1/2 W	23-12K-5	B EB 1235
R7, 9, 19, 20, 22, 23, 32, 34, 43, 44, 46, 47	Resistor: fixed, composition, 220,000 ohms, ±5%, 1/2 W	23-220K-5	B EB 2245
R8	Resistor: fixed, composition, 27,000 ohms, ±5%, 1 W	24-27K-5	B GB 2735

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

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TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R14, 27	Resistor: fixed, composition, 3.0 megohms, ±5%, 1/2 W	23-3M-5	B EB 3055
R15, 21, 24, 28, 33, 35, 39, 48	Resistor: fixed, composition, 47,000 ohms, ±5%, 1/2 W	23-47K-5	B EB 4735
R38	Resistor: fixed, composition, 1.5 megohms, ±5%, 1/2 W	33-1.5M-5	B EB 1555
R45	Resistor: fixed, composition, 47,000 ohms, ±5%, 1 W	24-47K-5	B GB 4735
R51	Resistor: fixed, composition, 180,000 ohms, ±10%, 1/2 W	23-180K	B EB 1841
R52	Resistor: fixed, composition, 150,000 ohms, ±10%, 1/2 W	23-150K	B EB 1541
I1-I10	Lamp, neon: NE2, (pair, aged) (single, aged)	AC-4A-8 AC-4A-9	HP HP
V1-V4	Tube: 5963	212-5963	ZZ
P1	Connector: octal, male	125-31	HH #86-877
	Clamp, tube:	140-12	HP
	Numeral Plate:	AC-4A-6	HP

*See "List of Manufacturers Code Letters For Replaceable Parts Table."

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LIST OF MANUFACTURERS CODE LETTERS FOR REPLACEABLE PARTS TABLE

Code Letter	Manufacturer
A	Aerovox Corp.
B	Allen-Bradley Co.
C	Amperite Co.
D	Arrow, Hart and Hegeman
E	Bussman Manufacturing Co.
F	Carborundum Co.
G	Centralab
H	Cinch Manufacturing Co.
HP	Hewlett-Packard
I	Clarostat Manufacturing Co.
J	Cornell Dubilier Electric Co.
K	Hi-Q Division of Aerovox Corp.
L	Erie Resistor Corp.
M	Federal Telephone and Radio Corp.
N	General Electric Co.
O	General Electric Supply Corp.
P	Girard-Hopkins
R	International Resistance Co.
S	Lectrohm, Inc.
T	Littelfuse, Inc.
V	Micamold Radio Corp.
X	P.R. Mallory Co., Inc.
Z	Sangamo Electric Co.
AA	Sarkes Tarzian
CC	Sprague Electric Co.
DD	Stackpole Carbon Co.
EE	Sylvania Electric Products, Inc.
FF	Western Electric Co.
HH	Amphenol
II	Dial Light Co. of America
KK	Switchcraft, Inc.
LL	Gremar Mfg. Co.
MM	Carad Corp.
ZZ	Any tube having RETMA standard characteristics

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

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

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY

Laboratory Instruments for Speed and Accuracy

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