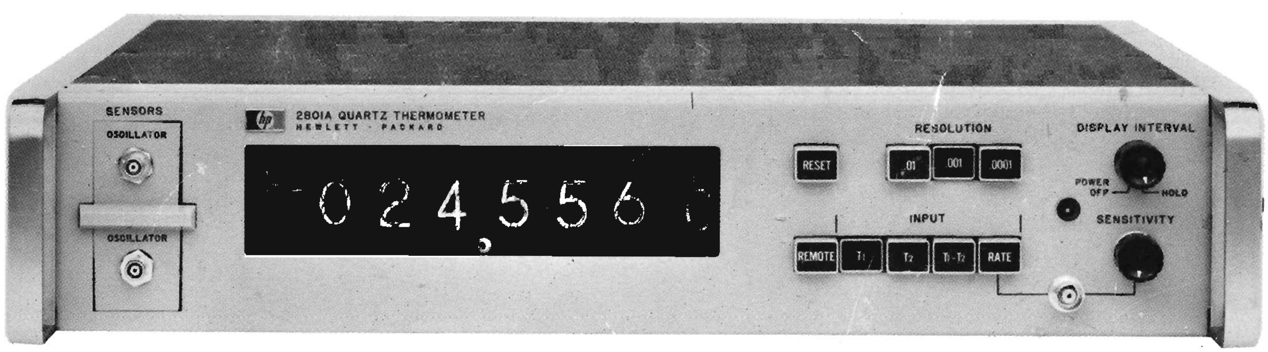
Series 25-505

HP 2801A

OPERATING AND SERVICE MANUAL

QUARTZ THERMOMETER

2801A



HEWLETT hp PACKARD

HP 2801A

CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

Service contracts or customer assistance agreements are available for Hewlett-Packard products that require maintenance and repair on-site.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

OPERATING AND SERVICE MANUAL

(HP PART NO. 02801-9039)

MODEL 2801A
QUARTZ THERMOMETER

WARRANTY EXCEPTIONS

The Warranty Policy statement on the inside front cover of this manual indicates that for certain components listed in the manual the warranty will not be one year, but as specified in the manual. Some of the Model 2801A parts and supplies are expendables or may have a normal life of less than one year. The following paragraphs indicate exceptions to the one year warranty.

PARTS AND SUPPLIES. Lamps, fuses, and any other items of an expendable nature will not be warranted unless received defective or destroyed by the malfunctioning of a warranted component. Probes are warranted for direct replacement only (no labor) and must be returned in their original plastic container surrounded by shock-absorbing material (3 to 4 inches of tightly packed material such as polyurethane foam) placed in a double-walled carton. Probe container and packaging material are available at the nearest Hewlett-Packard Sales/Service Office listed in the back of this manual.

MAINTENANCE. This manual contains information for the performance of adjustments and calibration. These procedures are considered to be part of the responsibility of the operator and are not warranted.

ABUSE. Components or assemblies that require replacement or repair due to obvious abuse are excluded from warranty coverage. This includes the operation of the Model 2801A outside the published specifications (Table 1-1). Also, probes that are returned with broken crystals will not be warranted.

HEWLETT-PACKARD/AVONDALE DIVISION
ROUTE 41 AND STARR ROAD
AVONDALE, PENNSYLVANIA 19311

0-2434 Printed: January 1969

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MODEL 2801A

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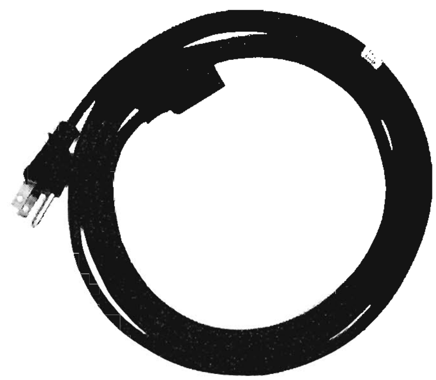
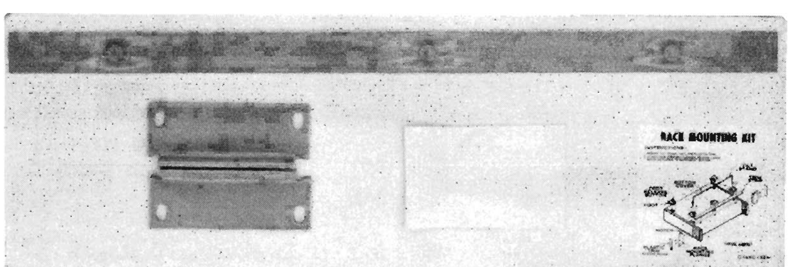




ART 0927

RACK MOUNTING KIT

Figure 1-1. Model 2801A and Accessories

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. DESCRIPTION.

1-3. The HP-2801A Quartz Thermometer (Figure 1-1) indicates temperature as a consequence of frequency changes exhibited by temperature sensitive quartz crystals used as sensing elements.

1-4. Because the Quartz Thermometer converts temperature into frequency rather than to resistance or voltage, it is free of the problems of lead resistance and noise pick-up inherent in other types of temperature measuring systems. Consequently, the probes, sensor oscillators, and amplifiers may be installed where convenient without special care in regard to cable length, proximity to electrical equipment, ground loops, and so forth.

1-5. The parent instrument contains the majority of operating circuits in the Quartz Thermometer. Sensor oscillators are separately cased in small die-cast aluminum enclosures that are watertight when properly closed. For this reason they can be immersed in compatible liquids for some applications. Sensor oscillators can be used remotely from the parent instrument though they are usually inserted into a recess provided for them on the parent instrument's front panel. When so installed, bayonet type coaxial connectors are mated before the sensor oscillator is pushed into its recess. Sensor probes are then connected to the sensor oscillator via 12-foot coaxial cables. The several types of probes are discussed further in Paragraphs 1-11 through 1-18.

1-6. The parent instrument case is designed so it can be either rack mounted or used on a table or bench top. Both the top and bottom of the case are removable to expose the printed circuit boards and connectors. Refer to the Specifications section for dimensional details.

1-7. The Quartz Thermometer is equipped with two temperature-sensing probes, connected by thin, flexible electrical cables to the parent instrument. The HP-2801A will display the temperature at either probe or the temperature difference between the probes; the temperature to be measured can be selected either by pushbuttons or external signals.

1-8. Readout in degrees Celsius (Centigrade) from -80 to +250°C is standard; readout in degrees Fahrenheit is alternately available as Option M1 (at no additional cost). A 6-place display is provided, with a choice in measurement resolution of .01, .001 or .0001°. The resolution required may be selected by pushbuttons or external signals. Polarity indication (+ or -) is included in the temperature display.

1-9. The Quartz Thermometer is an integrating device, providing an average value of the probe temperature over a fixed reading time (sample period). Reading times are related to the resolution selected. For resolutions of .01, .001 and .0001°C the sample periods are, respectively, 0.1, 1, and 10 seconds. Corresponding resolutions in °F are obtained with sample periods increased by a factor of 1.8. Measurements may be initiated by pushbutton or external signal, or self-initiated at time intervals variable from approximately 0.2 to 5 seconds by a front panel control.

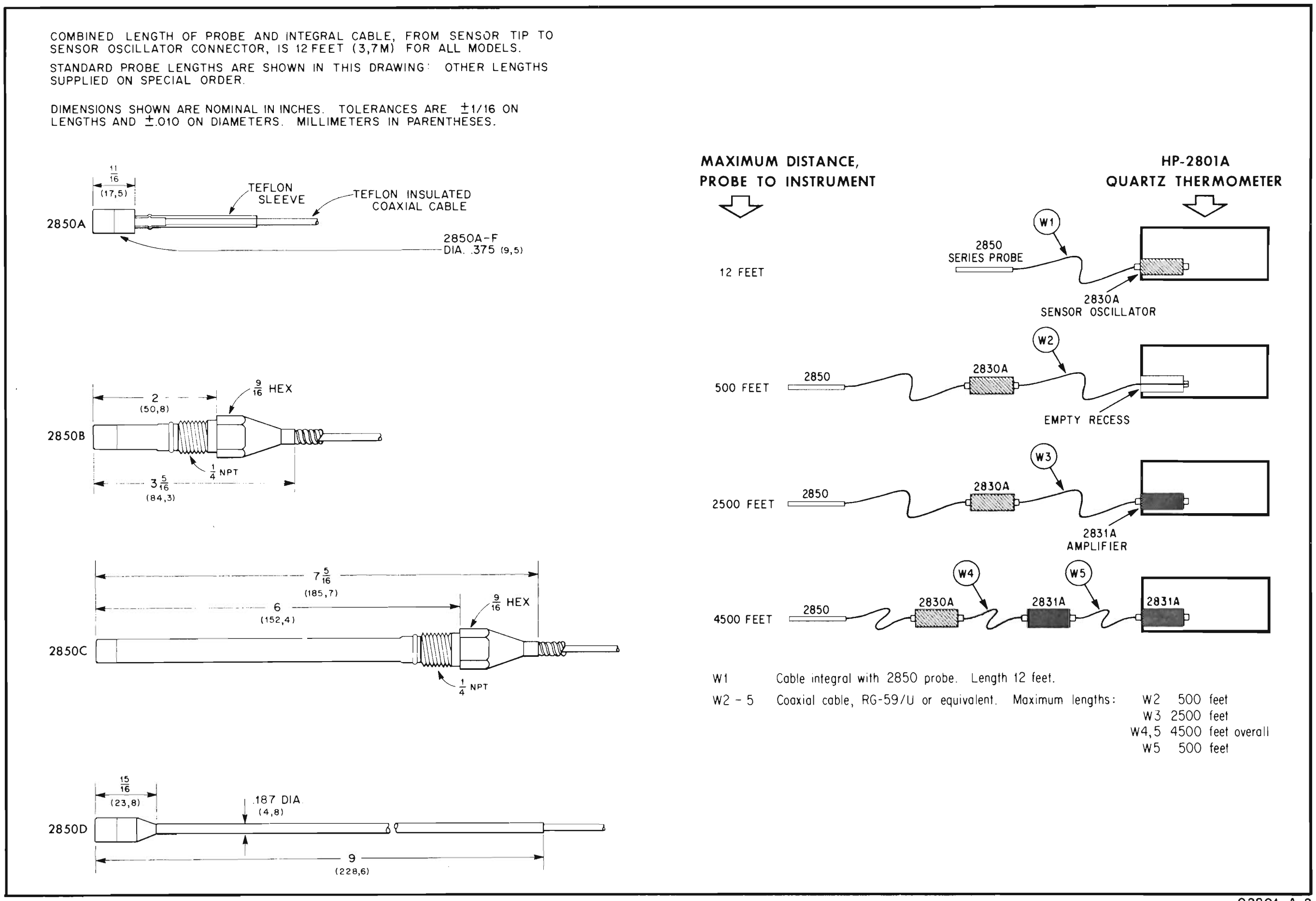
1-10. Some applications, principally calorimetric measurements, require the determination of very small temperature changes occurring over periods of several minutes or longer. For this type of measurement, the HP-2801A can be furnished with sample periods of 1, 10 and 100 seconds (in place of the standard values of 0.1, 1 and 10 seconds). The 100-second sample period provides a resolution of 10^{-5}°C. The modified sample periods are available as Option M40.

1-11. Temperature Sensing Probes. Four standard probe configurations are available for the Quartz Thermometer. These are Models HP-2850A through 2850D, illustrated in Figure 1-2.

1-12. In all probe models, the sensor crystal is hermetically sealed in a cylindrical stainless steel case, in a helium atmosphere. This case is attached to a stainless steel tubular body which varies in length with the probe model. The only probe material in contact with the measurand is therefore stainless steel. Type 304 is standard; other materials, such as 316 stainless steel, can be supplied on special order. The sensitive quartz disc is situated parallel to and about .010 inch away from the interior flat end of the probe.

1-13. The crystal end of the probe has the same configuration for all models, and is 3/8 inch outside diameter. Probe lengths range from 11/16 inch for the HP-2850A to 9 inches for the HP-2850D (see outline drawings). The HP-2850B and HP-2850C probes are equipped with a 1/4 inch NPT fitting and hexagonal end piece for easy insertion into pipes and tanks. The HP-2850 probes may be used at pressures to 3000 psi.

1-14. With all models, a 12-foot length of flexible coaxial cable is permanently attached to the probe. TFE Teflon is used both as the dielectric and outer sheath; this material can withstand temperatures as high as 250°C. The cable is sealed to the probe body, and is terminated at the other end with a watertight connector mating with the associated sensor oscillator (See Remote Operation of Probes below). With the



02801-A-2

Figure 1-2. Probe Configurations and Extension Cable Arrangements

HP-2850B, C probes, the cable is enclosed in a stainless steel, strip-wound, flexible hose to prevent the kinking or crushing that could occur during frequent handling or in exposed installations.

1-15. Remote Operation of Probes. For each temperature sensing probe, conversion from temperature to frequency is performed by a HP-2830A Sensor Oscillator. This is a transistorized device enclosed in a small die-cast aluminum housing.

1-16. The sensor oscillators are normally installed in the parent instrument, flush-mounted in a front panel recess. As mentioned earlier, a 12-foot cable connects each probe to its associated sensor oscillator; this cable forms part of the tuned circuit and cannot be altered in length. However, the sensor oscillators may be unplugged from the instrument and connected to it by standard 75-ohm (e.g., RG-59/U) coaxial cable up to 500 feet in length, with no loss in measurement accuracy. For cabling convenience, duplicate signal input connectors are provided on the rear panel of the Quartz Thermometer, for external use of the sensor oscillator.

1-17. For greater distances, one or two accessory HP-2831A Amplifiers may be used to boost the signal. One amplifier compensates for the signal attenuation in approximately 2000 feet of RG-59/U cable, so with two amplifiers as much as a mile of cable can be connected between the probe and the Quartz Thermometer.

1-18. Various arrangements for remote operation of probes are shown in Figure 1-2. The HP-2831A Amplifier is housed in the same type of case as the HP-2830A Sensor Oscillator, and may therefore be installed in the Quartz Thermometer's front panel recess in place of the oscillator. If a second amplifier is used, it may be connected in series with the signal cable at any convenient point between the Quartz Thermometer and the sensor oscillator.

1-19. FREQUENCY MEASUREMENTS.

1-20. The HP-2801A Quartz Thermometer includes the capability for operation as a frequency or rate counter to 300 kHz. The instrument is switched to this mode of operation by a pushbutton. Inputs are applied to a front panel connector; a sensitivity control is also provided. When operated in this mode the instrument expresses measurements in kilocycles and a "KC" indicator is illuminated.

1-21. DATA RECORDING.

1-22. Digital Printout. As a standard feature, the HP-2801A Quartz Thermometer provides electrical (binary-coded decimal) outputs for each displayed digit, polarity, decimal position, and for the operating mode (i.e., T_1, T_2, $T_1 - T_2$). Temperature readings can therefore be recorded on paper tape (by connecting these outputs directly to an HP-562A or HP-5050A Digital Recorder) and punched card, punched tape, or magnetic tape (by connecting to an HP-2547A Coupler with appropriate output recorder). Maximum recording rate is five readings per second.

Table 1-1. HP 2801A Specifications

TEMPERATURE RANGE

-80 to +250°C (-112 to +482°F with Option M1).

RESOLUTION

READING ① RESOLUTION °C or °F	FULL SCALE DISPLAY ②		SAMPLE PERIOD (Seconds)	
	°C	°F	°C Readout	°F Readout
.01	0250.00	0480.00	.1	.18
.001	250.000	480.000	1.0	1.8
.0001 ③	(2)50.0000	(4)80.0000	10.0	18.0
.00001 ④	(25)0.00000	(48)0.00000	100.0	180.0

① ±1 digit ambiguity in least significant displayed digit for all sample periods.
② Digits in parentheses not displayed when using sample periods of 10 seconds and longer.
③ Instruments cannot normally resolve readings between +.001° and -.001°. To use .0001 mode in this region, zero offset can be introduced with simple screwdriver adjustment.
④ With Option M40.

ABSOLUTE ACCURACY

Absolute accuracy is equal to sum of calibration, linearity and stability errors listed below.

CALIBRATION ACCURACY

Thermometer-probe combination calibrated at factory to within .02°C (.04°F) absolute, traceable to NBS. (For differential measurements, maximum combined probe calibration error is .04°C.)

LINEARITY

Frequency-temperature relationship is smooth curve, such that non-linearity decreases in proprotion to operating range. Maximum linearity deviations are:

0 to +100°C (32 to +212°F)
.05°C (.09°F) referred to best-fit straight line through 0°C.

-80 to +250°C (-112 to +482°F)
.15°C (.27°F) over range -40°C (-40°F) to +250°C (+482°F), referred to best-fit straight line through 0°C. Increases to .7°C below -40°C, referred to same line.

Note: response of each probe is checked at 8 temperatures from -80°C to +250°C; calibration chart furnished with probe gives non-linearity corrections for best straight lines (above) at 10°C increments. Pairs of probes are matched to within ±.05% of straight line slope. Instrument can be trimmed precisely to match slope of either probe or mean slope. If trimmed to mean slope maximum error on differential measurements is ±.025% of reading ±linearity correction.

STABILITY

Short Term: Reading-to-reading variation at constant probe temperature is less than .0001° (i.e., less than normal display ambiguity of ±1 count in least significant digit.

Long-Term: Zero drift less than ±.01°C (.018°F) at constant probe temperature for 30 days.

Hysteresis: When used over range from -80° to +250°C (-112° to +482°F) readings may differ from calibrated values by no more than ±.05°C (.09°F). Deviation decreases with reduced operating span.

Ambient Temperature: Less than .002° per ° change in instrument environment, with HP 2830A sensor oscillator installed in instrument. Instrument alone does not exceed .001° per °; sensor oscillator alone does not exceed .002° per °. Sensor oscillator error can be eliminated by placing it in constant temperature environment, e.g., ice bath.

NARROW RANGE OPERATION

Calibration Accuracy: Since HP 2801A can be calibrated to accuracy of user's temperature reference, absolute accuracy at given temperature can be enhanced by calibrating close to that temperature, e.g., ±.001°C in region of 0°C, using good ice-point reference.

Linearity: .002°C, over any 10°C span between 0° and 100°C.

Hysteresis: .001°C typical, over any 10°C span between -80° and +250°C.

INTEGRATION TIME

Defined by sample period selected; see 'Resolution'.

Table 1-1. HP 2801A Specifications (Cont'd)

SAMPLE RATE

Readings are taken in response to pushbutton or external signal, or automatically at self-regulated intervals. Time interval between readings can be adjusted at front panel from approximately .2 to 5 sec. (Typical variation for .2 sec interval, less than 0.5 ms/°C change in ambient. Error in sample rate, when taking 10-second samples, amounts to less than .03%.)

DISPLAY

6-digit Nixie® readout in °C, or °F with Option M1. Decimal point, °C (°F), and polarity indication included. Readout and units indication in KC in counter mode of operation. Storage feature holds display until completion of next reading.

DIGITAL RECORDING OUTPUT

BCD, 4-2'-2-1 or 8-4-2-1 (Option M6), positive-true, for each displayed digit, decimal point (exponent), polarity and operating mode. Compatible with HP-562A and HP-5050A Digital Recorders for paper tape, and HP-2547A Couplers for punched card, punched tape, and magnetic tape recorders. In second table, change "REFERENCE (for 562A Printer)" to "REFERENCE (for recorder)." Change last paragraph to Connector: Amphenol 57-40500, 50 pin, (mates directly with recorder cable).

DATA	POLARITY	RESOLUTION	MODE	LOGIC ① 4	2'	2	1
0				0	0	0	0
1	+	②	T_1	0	0	0	1
2	−	.01 (.001)	T_2	0	0	1	0
3		.001 (.0001)	$T_1 - T_2$	0	0	1	1
4		.0001 (.00001)		0	1	1	0
5			RATE	0	1	1	1
6				1	1	0	0
7				1	1	0	1
8				1	1	1	0
9				1	1	1	1

① Equivalent digits are employed for polarity, resolution and mode with optional 8-4-2-1 output, except code for RATE is digit 7.
② With Option M40.

		0	1
DATA, MODE AND FUNCTION OUTPUTS	LEVEL	-35 to -24.5v	-2.5 to 0v
	IMPEDANCE	100K	100K
	MAX. CURRENT	0.3 MA	0.3 MA
RESOLUTION OUTPUT	LEVEL	-35 to -24.5v	0v
	IMPEDANCE	1.8K	0Ω
	MAX. CURRENT	1MA	100 MA
RECORD COMMAND ('1' for record and '0' during sample, or vice-versa)	LEVEL	-31 to -28v	-5 to -3v
	IMPEDANCE	100K	0Ω
	MAX. CURRENT	0.3 MA	5 MA
REFERENCE (for 562A Printer)	LEVEL	-18.5 to -16.5v	-10.5 to -8.5v
	IMPEDANCE	1.6	1.3K
	MAX. CURRENT	0.5 MA	0.5 MA

Connector: Amphenol 57-40500, 50 pin, (Mates directly with HP 562AR printer cable).

EXTERNAL PROGRAMMING

Following functions can be selected by contact closures or transistor circuit closures to ground:

Measurement initiation (counter reset)
Probe selection (T_1, T_2, or T_1-T_2)
Resolution (.01, .001 or .0001)
Connector: Winchester MRAC-50S

COUNTER OPERATION

Frequency Range: 2 Hz to 300 kHz.

READING ① RESOLUTION (Hz)	FULL SCALE DISPLAY (KC)	SAMPLE PERIOD (Seconds)
10	0300.00	.1
1	300.000	1.0
0.1	(3)00.0000 ②	10.0

① ±1 digit ambiguity in least significant displayed digit for all sample periods.
② 'Hundreds' digit not displayed when using 10-second sample period.

Time Base Stability: Short term stability is better than 0.1 Hz. Drift is less than $1/10^7$ per month. Temperature effect is less than 1 Hz per °C change in ambient.

Sensitivity: 0.5 to 10v rms.
Input Impedance: 1M, 50 pf shunt.
Gate Time (sample period): 0.1, 1 and 10 sec.
Connector: Front panel BNC.

POWER REQUIRED

115/230v ±10%, 50 to 60 Hz, 85w approx.

INSTRUMENT ENVIRONMENT

Ambient temperatures from 0 to +55°C (+32 to +130°F), at relative humidity to 95% at 40°C.

SENSOR OSCILLATOR ENVIRONMENT

(Specifications apply also to HP-2831A Amplifier.) Ambient temperatures from -5 to +55°C (+23 to +130°F). May be totally immersed; pressure not to exceed 5 psi (equivalent to about 12 feet of water). Constituent materials are aluminum, nickel, neoprene, Teflon, enamel paint.

FINISH

HP-2801A front panel finished in grey baked enamel, with black silkscreening. HP-2830A Sensor Oscillator and HP-2831A Amplifier finished in matching grey enamel paint.

Table 1-1. HP 2801A Specifications (Cont'd)

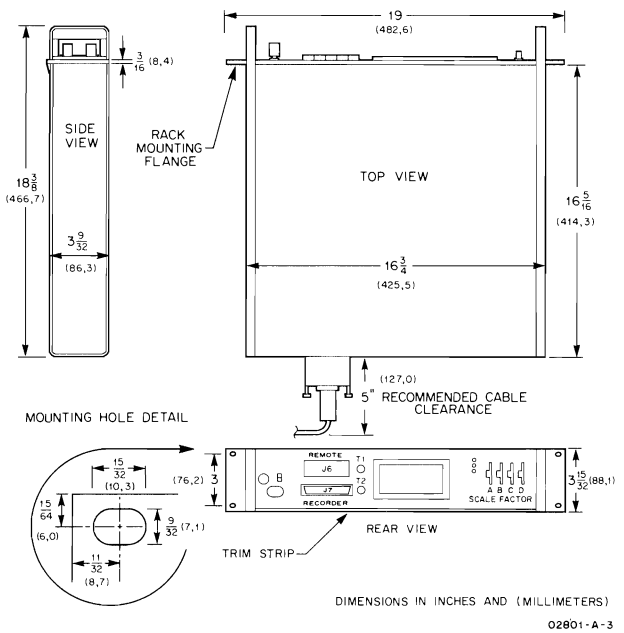
WEIGHT

	Net	Ship
HP 2801A	22.5 lb. (10,1 kg)	35 lb. (15,9 kg)
HP 2830A / HP 2831A	4 oz. (110 gm)	8 oz. (230 gm)

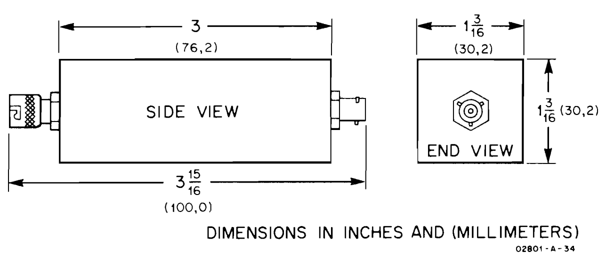
DIMENSIONS

HP 2801A is fully enclosed for use on bench. Adapter kit furnished for 19-inch rack mounting; panel height 3-1/2 inches. Slides available under Option M10.

2801A QUARTZ THERMOMETER
(Note: Rack-mount adapter kit furnished. Slides available as Option M10.)



2830A SENSOR OSCILLATOR AND 2831A AMPLIFIER



PRINTER FOR HP 2801A (with 4-2'-2-1 output)

An HP 562AR Printer which includes a double-column printwheel for recording the HP 2801A 'MODE' is available as R86-562AR. The format is as follows:

PRINTER COLUMN	11	10	9	8	7	6	5	4	3	2	1
PRINTWHEEL	STD	No. 4686		No. 4610	STD	STD	STD	STD	STD	STD	STD
INFORMATION RECORDED	BLANK	MODE		POLARITY	6 DIGIT READING						RESOLUTION

MODE
T_1
T_2
ΔT ($T_1 - T_2$)
R (RATE)

RESOLUTION
2 = .01
3 = .001
4 = .0001

115/230v, 60 Hz	R86-562AR
115/230v, 50 Hz	S23-562AR

Analog Output, Option 41.

OPTIONAL MODIFICATIONS

M1. Readout in °F (Instead of °C).

M6. 8-4-2-1 Positive-True BCD Output (Instead of 4-2'-2-1).

M10. Rack-Mounting Slides: For 19-inch rack. Pivot type, allows instrument to be withdrawn and rotated for convenient acces to underside of chassis.

M40. 100-Second Sample Period: Instrument provides sample periods of 1, 10, 100 seconds (instead of 0.1, 1, 10 seconds).

ACCESSORIES AVAILABLE

1. Temperature Sensor. With integral 12 foot cable. Model HP2850A through D.
2. Sensor Oscillator. Model HP 2830A
3. Amplifier. Model HP 2831A
4. Extension Cable: For interconnecting sensor oscillators and accessory amplifiers with quartz thermometer; connectors are included. May be used for W2 through W5 in Figure 1-2. Standard length 50 feet, stock no. 5060-5008. Longer cables made to order – see Figure 1-2 for recommended maximum lengths.

ACCESSORIES FURNISHED

1. Power cord, 7-1/2 feet, 8120-0078.
2. Accessory kit, 5060-5727 (contains rack-mount kit, connector pins, etc.).

SECTION II
INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains information on unpacking and inspection, storage and shipment, and installation.

2-3. UNPACKING AND INSPECTION.

2-4. If the shipping carton is damaged, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument for damage (scratches, dents, broken knobs, etc). If the instrument is damaged or fails to meet specifications (Performance Check, Section V), notify the carrier and the nearest Hewlett-Packard field office immediately (field offices are listed at the back of this manual). Retain the shipping carton and the padding material for the carrier's inspection.

2-5. STORAGE AND SHIPMENT.

2-6. To protect valuable electronic equipment during storage or shipment always use the best packaging methods available. Your Hewlett-Packard field office can provide packing material such as that used for original factory packaging. Contract packaging companies in many cities can provide dependable custom packaging on short notice. Here are a few recommended packaging methods:

CAUTION

It is recommended that the temperature-sensing probes be shipped and stored in the original shipping container. Any probes returned during the warranty period must be shipped in a probe shipping container (stock number 5060-5818), otherwise warranty will be void.

a. Rubberized Hair. Cover painted surfaces of instrument with protective wrapping paper. Pack instrument securely in strong corrugated container (350 lb/sq. in. bursting test) with 2-inch rubberized hair pads placed along all surfaces of the instrument. Insert fillers between pads and container to ensure a snug fit.

b. Excelsior. Cover painted surfaces of instrument with protective wrapping paper. Pack instrument in strong corrugated container (350 lb/sq. in. bursting test) with a layer of excelsior about 6 inches thick packed firmly against all surfaces of the instrument.

2-7. Environmental conditions during storage and shipment should normally be limited as follows:

a. Maximum altitude 20,000 feet.

b. Minimum temperature -40°F (-40°C).

c. Maximum temperature 167°F (75°C).

2-8. INSTALLATION.

2-9. Quartz Thermometers are normally used within 12 feet of the point to be measured. There the instrument may be placed on a table top or workbench or it may be permanently installed in an electronic equipment rack. Special brackets are furnished to be attached to the instrument case when rack mounting is required. Figure 2-1 identifies the parts used for rack mounting; attach them as follows:

a. Remove tilt stand.

b. Remove feet (press the foot-release button, slide foot toward center of instrument, and lift off).

c. Remove adhesive-backed trim strips at front end of slides.

d. Attach filler strip along bottom edge of front panel.

e. Attach flanges to front end of sides (larger corner-notch toward bottom of instrument).

2-10. When installed in a rack, air flow to the cooling fan must not be obstructed. Modification M10 provides factory installed rack slides that allow easier access to the top and back of a rack mounted instrument.

2-11. When operation at distances greater than 12 feet is required, special probes, or oscillator amplifiers, and cables are available as accessories. Some of these are briefly described in Section 1 of this manual. Contact any HP field office for further information on special applications.

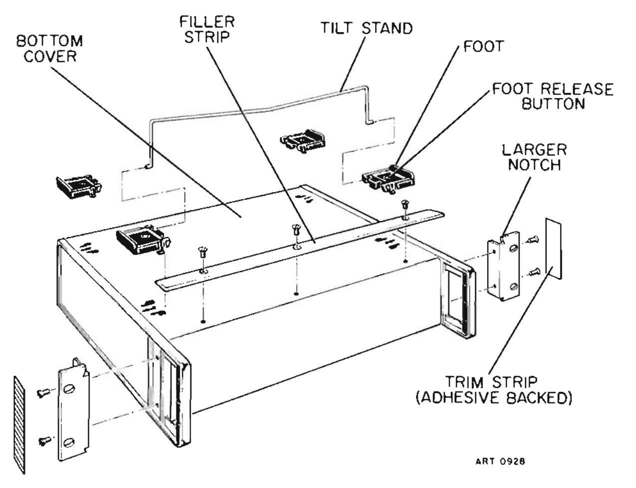


Figure 2-1. Rack Mounting Adapter Kit Installation

Note

It is not possible to extend the length of cable between the probe and the sensor oscillator as the normal 12-foot cable forms part of the tuned circuit. Changing its length will inhibit oscillation.

2-12. Either 115 vac or 230 vac may be used to operate the Quartz Thermometer. Direct current cannot be used and must never be connected to the instrument power input receptacle.

CAUTION

Do not connect this instrument to a 230 volt AC line unless the voltage selector switch (S2) is set to 230 volts. Failure to heed this caution may damage the instrument.

2-13. Before installing the power cable, be sure the voltage selector switch is set to the position that exposes the legend signifying the voltage on which the instrument is to be operated. This will be either 115 or 230 volts. (See Figure 2-2). Connect the power cable to the instrument chassis receptacle; then plug the other end into a standard 3-wire (ground-pin) receptacle. If a standard 3-wire receptacle is not available, use a 3-wire adapter making sure the adapter ground wire is properly attached to a reliable earth ground. Operation without a ground connection is permissible but is not recommended.

2-14. Fuse F1, in series with the power transformer primary winding, is a 2-ampere, 250-volt, fastblow type; Stock Number 2110-0002. This fuse is on the rear panel (Figure 2-2). Fuse F2 is a similar 1-ampere type having Stock Number 2110-0001. This fuse is in series with the -35 volt power supply output, and is located inside the equipment enclosure. When the AC line is 230 volts, a 1 ampere fuse identical to F2 should be used for F1.

2-15. If the digital information presented on the display panel is to be used in peripheral equipment, connect the interconnecting cable assembly to J7 (Figure 2-2). If remote control of the Quartz Thermometer is intended, connect the appropriate cable assembly to J6.

2-16. When sensor oscillators are to be used at the instrument (instead of being connected via an extension cable) they are connected directly to the connector on the front panel oscillator drawer cover plate. Connection is made by mating the bayonet connectors and making a partial turn clockwise after pressing the connector collar foward. After making this connection, the cover plate latch is released by pressing it away from the connector; then the oscillator assembly can be pushed into the drawer space behind the instrument's front panel. To avoid possible damage to the connectors, a connected oscillator assembly should never be left completely withdrawn but should be at least partially inserted into its drawer. Withdrawal of the oscillator assembly requires moving aside the drawer latch; then removal is the reverse of insertion.

2-17. Sometimes it is desirable to stabilize the temperature of the sensor oscillator to attain highest accuracy. Because the sensor oscillator enclosure is watertight, the entire sensor oscillator can be immersed in either liquid or dry baths provided the liquid is not deleterious to aluminum, TFE teflon, and epoxy enamel. The bath temperature should not, in this case, exceed limits of -5°C to +55°C. Of course, oscillator stability can also be attained by immersing the sensor oscillator in an ice bath; it is not essential that the stabilizing bath be at the temperature of the measurand. However, this procedure is not needed to achieve the absolute accuracy guaranteed by the factory calibration.

2-18. If the instrument cannot be positioned within 12 feet of the measurand, an extension cable of RG-59/U Stock Number 5060-5008 may be installed between the Dage Type DM connector on the front panel plate

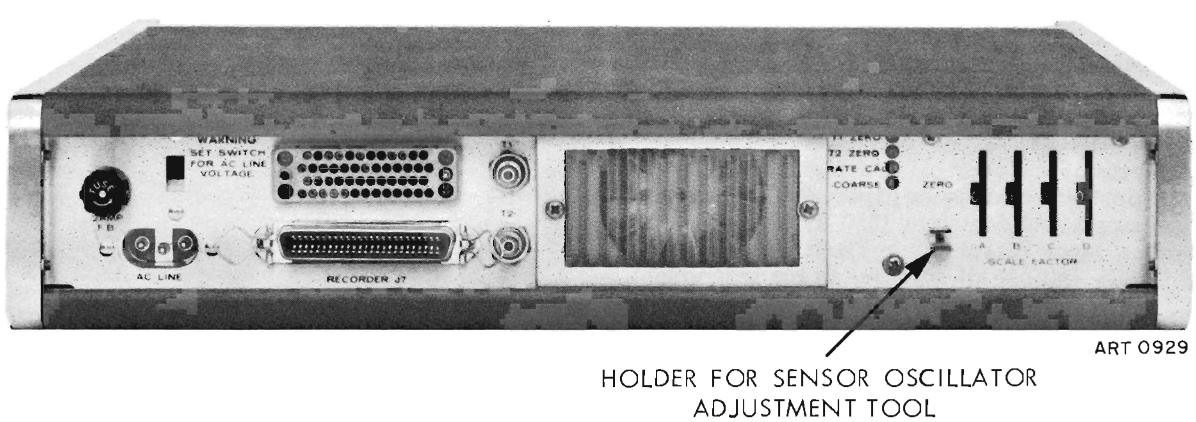


Figure 2-2. Rear Panel of Quartz Thermometer

and the corresponding connector on the body of the sensor oscillator. This cable is normally 50 ft. long but may be made up to 1000 feet long.

2-19. Installation of the sensor probes may or may not require special procedure. Ordinarily the probe end is merely immersed in the measurand.

CAUTION

To prevent twisting-damage to the probe cables, make sure that threaded probes (2850B and C) are mounted before connecting the cable to the instrument.

2-20. When sensor probes are installed, the thumbwheel switches on the rear panel (Figure 2-2) of the Quartz Thermometer must be set to agree with the probe's response curve slope. The numbers to which the thumbwheels must be set are given in the calibration chart that comes with each probe. Ordinarily, probes furnished for use with the HP-2801A are matched to within .05% in slope so the same thumbwheels setting is usable for both probes. If two probes with different response curve slopes are used, the thumbwheels setting will be appropriate for only one of them. A compromise setting is achieved by using numbers halfway between those listed in the two calibration charts.

CAUTION

Although the probes are of rugged construction, they are sensitive precision instruments and must be treated as such. They cannot withstand hammer blows or impact on hard surfaces. They must not be treated carelessly; however, any mistreatment that does not completely disable a probe will probably not affect its accuracy. If it works at all, it is fairly safe to assume it is working right.

2-21 PROBE IMMERSION

2-22. Sensor probes are designed for complete probe case immersion. The point where the cable connects with the probe, the shrinkable tubing in the A and D probes and threaded section in the B and C probes, is not designed for prolonged immersion. Figure 2-3 illustrates the point of maximum immersion. For applications where complete probe and cable immersion is required, contact your local HP field office listed in the back of this manual.

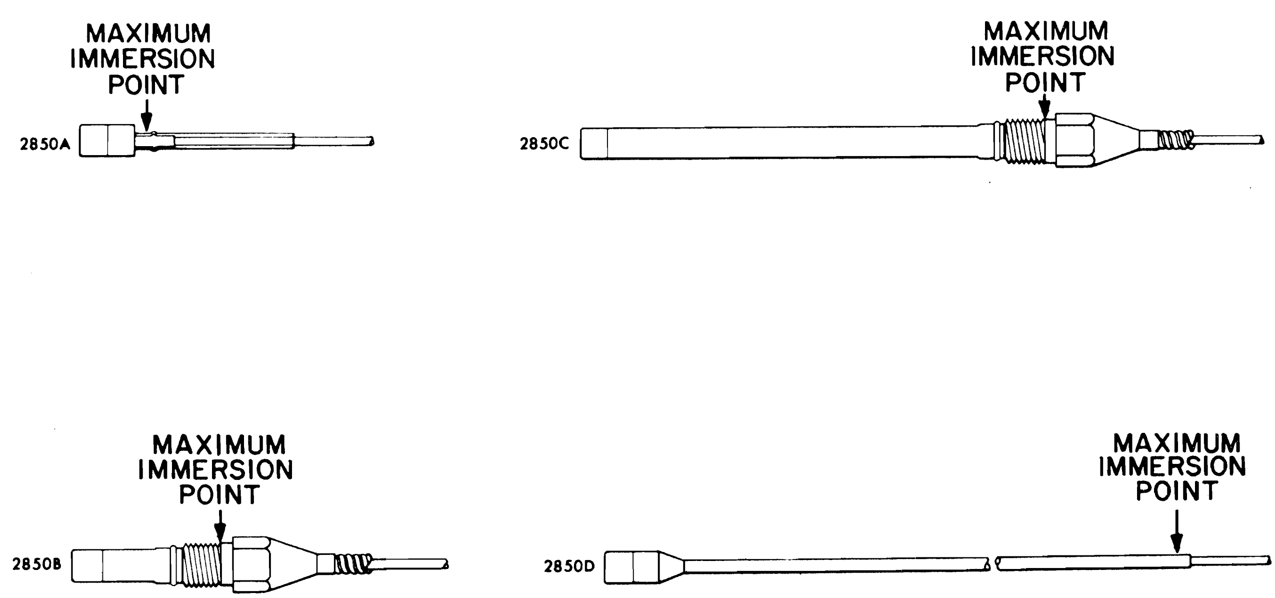


Figure 2-3. Point of Maximum Probe Immersion.

Table 3-1. Operating Controls

1. SENSORS: On the front panel, two rectangular connector plates accept the sensor probe oscillators associated with T_1 and T_2. When probes employing self-contained oscillators are used, the probe cable is attached directly to the plate mounted connector.

2. DIGITAL DATA DISPLAY: Six digital indicators are used to display the numerals 0 to 9 with a + or - sign to indicate the relative magnitude of temperature. The scale on which measurements are indicated is shown by a letter; either C or F for temperatures; when frequency or rate is being measured, the indication given is KC. A decimal point is also displayed; it shifts position to indicate changes of scale factor or resolution.

3. RESET: A momentary contact pushbutton that zeros the existing indication in the data display window. When released, the result of any measurement made subsequent to that previously displayed becomes visible.

4. RESOLUTION: These three pushbuttons are mutually exclusive latching types. Each determines the number of decimal places to be indicated in the result. The legend on each pushbutton signifies the fraction of a degree of temperature to which a result may be read.

5. DISPLAY INTERVAL: This control is a rotary potentiometer combined with a power switch. In leftmost position the power switch is off and no AC power is applied to the instrument. Clockwise rotation past the detent applies power. Further rotation increases the display time (and the interval at which measurements are taken) to value in the range of 0.2 to about 6 seconds. At the rightmost position the display is held indefinitely. This position is designated HOLD. Pressing the RESET pushbutton overrides the HOLD function.

6. SENSITIVITY: This control is a rotary potentiometer that adjusts the instrument's response to the input signal amplitude when a RATE measurement is being made. In leftmost position the sensitivity is about 10 volts rms; rightmost, about 0.5 volts.

7. RATE Connector: A BNC connector to which ac signals may be applied for frequency or rate measurements.

8. INDICATOR LAMP: Directly above the BNC connector, this lamp glows during the time the counter gate is open and a count is, or can be, accumulating. The frequency and duration of gating intervals is controlled by the DISPLAY INTERVAL knob.

9. INPUT: These four pushbuttons are mutually exclusive latching types. They function as follows:

   RATE: Establishes a counter mode of operation for frequency or rate measurements.

   T_1-T_2: Connects the two sensor probes so their frequency difference (and consequently their temperature difference) is indicated in the digital data display. If the temperature sensed by T_1 is lower than that sensed by T_2, a minus sign will be attached to the result; otherwise a plus sign will appear in the result.

   T_1: Connects sensor probe T_1 to measure absolute temperature relative to the self-contained frequency standard representing either 0° C or 0° F.

   T_2: Connects sensor probe T_2 instead of T_1 to perform as described for T_1.

10. REMOTE: An alternate action latching type pushbutton. This pushbutton removes control of RESET, RESOLUTION, and INPUT functions from the instrument front panel and extends control of these functions to an external control device. Operating current of a maximum 20 milliamperes at +14 vdc and -35 vdc is also extended to the external control device.

11. SCALE FACTOR TRIM SWITCHES: These four thumbwheel switches are located on the rear of the Quartz Thermometer. They are set to selected numbers appropriate for correcting the slope of a probe's temperature/frequency curve.

12. RATE, T_1 and T_2 ADJUSTING SCREWS: These four screws on the rear panel control the settings of potentiometers used to make adjustments to the reference oscillator frequency, thereby altering the time scale or zero beat frequency.

SECTION III
OPERATION

3-1. INTRODUCTION.

3-2. Operation of the Quartz Thermometer entails selection of an appropriate sensor probe for the application, and calibration of the probe (or probes) before recording the observed data. These instructions do not include information concerning the selection of probes; only their calibration and their use in general. Probe selection is treated in application notes and data sheets which your HP factory representative will be pleased to furnish upon request.

3-3. The extent to which calibration procedures should be carried depends on the accuracy with which measurements are to be made. However, all the calibration procedures normally used in the operation (as opposed to standardization) of the Quartz Thermometer are given here. You may select those procedures that are essential to your application and omit the others. You must allow the Quartz Thermometer at least 15 minutes warm-up after operating power is applied before making any adjustments or measurements. We recommend keeping power on at all times to maintain stability in the reference oscillator. Before operating the Quartz Thermometer, you should become familiar with the location and function of the controls and indicators listed in Table 3-1. Figure 3-1 shows the front panel of the Quartz Thermometer. All the operating controls as well as the data display window are shown in this illustration.

3-4. CALIBRATION.

3-5. Because the slope of the curve relating temperature to frequency is established once and for all by the angle at which the crystal is cut, it does not change with time. However, manufacturing tolerances result in production of crystals that vary from the ideal of 1000 Hz per °C. To take account of these variations, each crystal is installed in a sensor probe and then batches of probes are subjected to a factory calibration procedure. In this procedure the response curve of each probe is plotted by a digital computer to produce an individual calibration chart. This chart accompanies each probe on delivery. It is used to establish the appropriate settings for the scale factor trim (thumbwheel) switches that compensate for deviations from the ideal slope. The chart also provides linearity corrections to be added to the indicated temperature to achieve the specified accuracy.

3-6. It should be made clear, however, that no adjustments to the Quartz Thermometer are needed to obtain measurements that are fully acceptable in many applications. You need only verify that the thumbwheel switches are set as prescribed in the individual probe calibration chart. If two matched probes are being used, you can, if you wish, split the difference between the two sets of figures given in the charts, although either set of figures may be used without exceeding the limits of specified accuracy. When used in this way, the deviation from exact temperature will not exceed 70 millidegrees C.

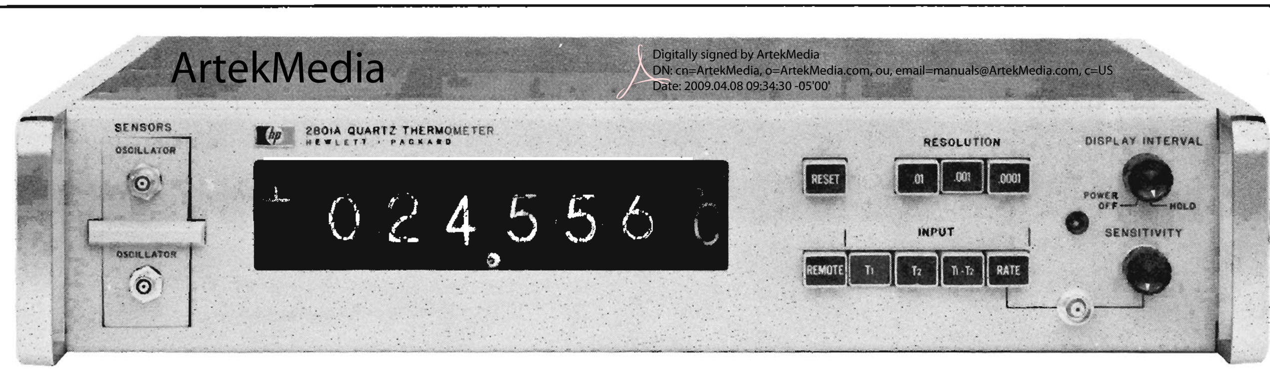
3-7. By performing a simple one-point calibration using an ice bath as a reference point, it is possible to obtain absolute temperature measurements within ±.02°C. This is the guaranteed accuracy of the factory calibration. To achieve this accuracy, the arithmetic corrections specified in the calibration chart must be added to the indicated results. Accomplish the ice-bath calibration as follows:

a. Prepare the ice bath as described in Paragraph 3-27.

b. Set the thumbwheel switches as prescribed in the calibration chart for each probe.

Note

Do not confuse slope and preset entries on the calibration chart. Slope is used to determine the preset number. Set the scale factor trim switches as indicated by the entry under PRESET.



ART 0930

Figure 3-1. Front Panel of Quartz Thermometer

c. Immerse the probe (or probes) at the temperature to be measured but do not take a reading. Then immerse the probe(s) in the ice bath. Observe the indicated temperature. Cycle the probe(s) through alternate exposure to these two extremes of temperature until the temperature indication of the ice bath does not exhibit changes between cycles. The purpose is to stabilize the probe(s) for the temperature range of interest.

d. Using the FINE ADJUST control on the back of the instrument, set the indication to zero when the probe is immersed in the ice bath. (This adjustment need not be made if the amount of offset is noted and subsequent readings appropriately treated arithmetically.)

e. Add offset and linearity corrections to achieve accuracy of ±.02°C.

3-8. For measuring to higher accuracy, the instrument must be calibrated against an NBS certified platinum resistance thermometer (PRT) or in a fixed-point bath as explained in later paragraphs on special calibration. (See Paragraphs 3-12 through 3-27.)

3-9. When using two probes for differential temperature measurements, a zero offset may exist when they are both exposed to the same temperature. That is to say, they do not zero beat because of minor frequency differences. Because the amount of offset will remain constant after the matched probes have been stabilized by cycling them between the two temperature extremes of the range of interest, this offset need not ordinarily be adjusted out. Doing so can be tedious; it requires removal of the sealing screw in the oscillator case; and its value is questionable for the following reason: the higher order of accuracy implied in the need for such adjustment means that arithmetic processing will doubtless be applied to the results to account for linearity and hysteresis errors. Therefore, the offset could as well be included in this processing.

3-10. We feel, therefore, that unless there is a pressing reason for adjusting the sensor oscillator frequencies to zero-beat, this adjustment is best left undone. But if it must be accomplished, here's how to do it:

a. Immerse both probes in the ice bath.

b. Observe T_1 and T_2 indications individually to determine which probe exhibits the greater deviation from zero.

c. Withdraw from the instrument's front panel that sensor oscillator showing more deviation and remove the sealing screw from the top of the oscillator case (See Figure 3-2).

d. Engage the tip of the adjusting tool with the slot in the adjusting screw (Figure 3-2). Turn the screw as needed to bring the indication in the display window to 000.000 when the T_1-T_2 pushbutton is latched. Although the screw may be turned without limit, only 1/2 turn encompasses the effective range of adjustment. If zero beat cannot be attained by adjusting only one oscillator, back up the adjusting screw about 1/4 turn from the closest adjustment; then perform the adjusting procedure on the other oscillator.

3-11. If both oscillators have required adjustment, it may be necessary to readjust the COARSE and FINE controls on the back of the instrument. Do that as follows:

a. Immerse both sensor probes in the ice bath.

b. Latch the T_1 pushbutton.

c. Rotate the T_1 FINE control until further turning of the screw produces no further change in the indication displayed.

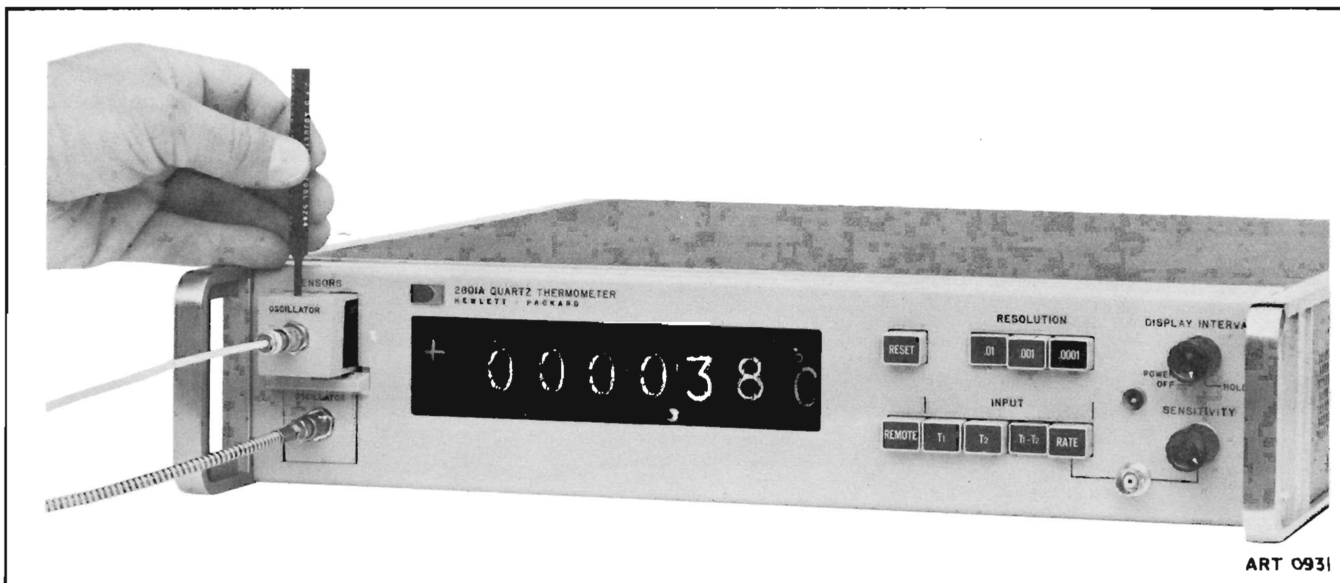


Figure 3-2. Sensor Oscillator Adjustment

d. Back the T_1 adjusting screw 10 turns.

e. Latch the T_2 pushbutton.

f. Turn the T_2 FINE control until the displayed indication is the same as that observed for T_1 after reverse turning the T_1 FINE control.

g. Adjust the COARSE control until the indication displayed is close to 000.000 (this need not be exact).

h. Adjust both FINE controls to obtain individual indications of 000.000.

3-12. SPECIAL CALIBRATION TECHNIQUES.

3-13. Published accuracy specifications for the Quartz Thermometer and the individual calibration data furnished with each probe are intended for a broad range of measurement conditions. The results that can be expected have been conservatively stated. Two additional steps can be taken to achieve even higher accuracy in the results of measurement. These steps involve making a special calibration directed toward a specific application, and control of the environment in which the instrument is used. Environmental control might be nothing more than using the instrument in an air conditioned space but most effective control results from immersing the sensor oscillator in a constant temperature bath. An ice bath is an excellent means of stabilizing the sensor oscillator frequency. The entire sensor oscillator can be immersed in water or any other non-destructive liquid because it is watertight. When the temperature of the sensor oscillator is stabilized, the effect of environmental temperature changes on other parts of the instrument will be less than ±.001°C per °C change in environment.

3-14. In general, the accuracy of any special calibration will depend on:

a. Accuracy of the reference thermometer.

b. Stability of the calibration environment (i.e., constant temperature bath, triple point cell, etc.)

c. Hysteresis of the sensor probe crystal. Control over (1) and (2) is in the hands of the calibrator; hysteresis is a relatively repeatable phenomenon of which we can say the following:

(1) Hysteresis is a characteristic of the quartz resonator itself. It is exhibited as a frequency offset when the probe is returned to a given temperature after a temperature excursion. The resultant error is specified to be less than ±0.05°C when the probe is used anywhere within its operating range (-80°C to +250°C).

(2) Hysteresis can be minimized by restricting the range over which the probe is used.

(3) Hysteresis will always occur to some extent, and should be determined for each probe for each temperature range over which a special calibration is desired.

3-15. These considerations lead to the following basic rule: SPECIAL QUARTZ THERMOMETER CALIBRATIONS SHOULD ALWAYS BE CARRIED OUT IN A LOOP. This requires that each calibration point, with the exception of one or both end points, be repeated, once for increasing temperature and once for decreasing temperature.

3-16. The first and last points on a calibration should be an easily repeated fixed point to which future work with the calibrated probe can be referred. The ice point is most convenient; once a calibration is made, future measurements are generally preceded and followed by a check of the fixed point to determine measurement uncertainty.

3-17. Typical calibrations might include the following:

Example 1	Example 2
Range: -80° to 120°C	Range: 0° to 40°
Interval: 40°	Interval: 10°
Order of Calibration:	Order of Calibration:
a. 0°C	a. 0°C
b. -40	b. 10
c. -80	c. 20
d. -40	d. 30
e. 0	e. 40
f. 40	f. 30
g. 80	g. 20
h. 120	h. 10
i. 80	i. 0
j. 40	
k. 0	

3-18. CALIBRATION PROCEDURE.

3-19. Actual details of calibration depend on the nature of the equipment available. Important considerations are:

a. Probes being calibrated and the reference probe to which they are compared must be equally coupled to the constant temperature reference environment. Stem conduction and heat transfer path resistance must be minimized.

b. Each sensor probe exhibits its own individual characteristic slope of actual versus indicated temperature which varies slightly as the applied temperature changes. Therefore, highest calibration accuracy demands that the slope for each probe be determined over the range of interest.

3-20. To simplify determination of the actual slope, an assumed slope of unity is first used as follows:

a. The scale factor trim switches are set to 8150 for a °C instrument or 2142 for a °F instrument.

b. The indicated temperature is divided by the reference temperature to obtain S (slope).

c. Scale factor switches are then set in accordance with the following formulae:

$$N \text{ for } ^\circ C = \frac{88150}{S} - 80000$$

$$N \text{ for } ^\circ F = \frac{132142}{S} - 130000$$

3-21. Setting the scale factor switches to 8150 establishes a time interval of exactly one second for integrating the signal that is a measure of temperature in °C. In a °F instrument, the setting of 2142 establishes an interval of 1.8 seconds. These are the intervals needed to indicate temperatures sensed by probes having unity slope. Departure of the slope from unity requires a compensatory change in the scale factor switch settings. This change alters the time over which the temperature measurement is integrated so the indicated temperature becomes equal to the actual temperature.

3-22. In addition to slope settings, it may be desirable to have a table of linearity offsets similar to that provided with the factory calibration. This requires that a smooth curve be fitted to the experimental data. The difference between this curve and the best straight line (of slope S) is the non-linearity.

3-23. The experimental uncertainty due to hysteresis generally requires a calculation of hysteresis at each repeated point in the calibration loop. Consider the case of such a repeat point, where the first measurement was at temperature T_1 and 2801A output was f_1, and the second measurement at T_2 gave output f_2. Now if T_1 is exactly equal to T_2, as in the case of a fixed point, then hysteresis (H) is correctly calculated by

$$H_{1-2} = f_2 - f_1$$

But if T_2 differs slightly from T_1, as it normally does in practice, then obviously this formula will not apply; the normal slope frequency difference corresponding to the temperature differential will have to be subtracted out, giving:

$$H_{1-2} = (f_2 - f_1) - (f_{T_2} - f_{T_1})$$

where f_{T_1} and f_{T_2} are the theoretical frequencies at T_1 and T_2, calculated from the known slope of the crystal. (This is the average slope listed on the factory calibration chart supplied with the probe, for example, 0.9884 kc/°C.)

3-24. PRACTICAL EXAMPLE OF SPECIAL CALIBRATION.

3-25. The following calibration was performed by HP for a customer who wished to use the Quartz Thermometer in calorimetry. It illustrates how, given special measurement conditions, accuracies higher than the all-purpose figures quoted in the specifications are obtainable with the Quartz Thermometer. It will be noted that the hysteresis uncertainty is smaller by an order of magnitude.

3-26. The calibration report read as follows:

1. Requirement

Two 2850A probes to be specially calibrated at 0, 20, 30, 40, 60°C. Special emphasis given to accurate determination of hysteresis effects over this range.

2. Description of Calibration

Reference temperatures for calibration were determined using a certified platinum resistance thermometer and a Mueller bridge.

Calibration was performed in constant temperature baths having typical stabilities of ±.005°C. Stability of the temperature environment actually imposed on the thermometers was further enhanced by mounting the Quartz Thermometer probes and the platinum thermometer in a copper block suspended in a can immersed in the bath. Helium was circulated around the copper block to improve the heat transfer characteristics of the system. Estimated uncertainty in measurements due to instability of the controlled temperature was no greater than ±.002°C.

The calibration was carried out in the following order of nominal temperatures:

a. 0°C.	f. 20°C.	j. 40°C.
b. 20	g. 30	k. 60
c. 0	h. 40	l. 40
d. 20	i. 30	m. 0
e. 30		

3. Description of Data and Data Reduction

Table 3-2 is a listing of the exact reference temperatures, actual probe output frequencies, and hysteresis effects. The reference temperature in °C is numerically equal to frequency in kHz, because the slope thumbwheel switches are set at 8150. Hysteresis effect (H) is the change in probe output frequency due to hysteresis, from the previous observation at a given temperature to the current one. For example, for the first two measurements at 20° with probe "A", H was computed as follows:

$$T_1 = f_{T_1} = 20.410 \qquad f_1 = 19.960$$
$$T_2 = f_{T_2} = 20.104 \qquad f_2 = 19.653$$
$$f_{T_2} - f_{T_2} = -.306 \qquad f_2 - f_1 = -.307$$

At this point there would appear to be a hysteresis effect of $(f_2 - f_1) - (f_{T_2} - f_{T_1}) = .001$ kHz.

BUT the slope of the frequency-temperature characteristic must be accounted for, as follows:

Slope $\frac{\Delta f}{\Delta T}$ = .987 kHz/°C (taken from probe standard calibration chart.)

For $\Delta T = -.306$°C, $\Delta f = 0.302$ kHz

Table 3-2. Indicated Frequencies and Hysteresis Errors for Calibration Example given in Text (See Paragraph 3-24)

EXACT TEMPERATURE (T) ±.002°C	PROBE "A"		PROBE "B"	
	f	H	f	H
0.000°C	-.197	-	-.175	-
20.410	19.960	-	19.993	-
0.000	-.195	+.002	-.173	+.002
20.104	19.653	-.005	19.689	+.002
30.241	29.665	-	29.707	-
19.921	19.472	+.001	19.506	+.001
30.152	29.577	+.000	29.615	-.004
40.066	39.366	-	39.409	-
30.352	29.775	-.000	29.813	-.000
39.389	38.702	+.003	38.747	+.006
59.843	58.888	-	58.941	-
40.167	39.466	-.004	39.508	-.007
0.000	-.198	-.003	-.167	+.006

Thus, if there were no hysteresis, the (f_2-f_1) above should be -.302; instead it is -.307. Therefore the hysteresis effect is -.005 kHz, which is equivalent to -(.005/.987)°C, essentially -.005°C.

Table 3-3 is derived from Table 3-2 and is used as an intermediate step in calculating the probe frequency-temperature slopes over restricted temperature ranges; these slopes are shown in Table 3-4.

In Table 3-3, "Exact Temperature Average" is simply the mean of exact temperatures for a given nominal temperature, as recorded in Table 3-2. "$f - f_T$" is the corresponding mean of error frequencies, computed as follows:

$$(f - f_T) = (f - f_0) - f_T$$

where f_0 is the average zero offset for the probe.

Table 3-3. Calculated Errors between Exact Temperatures and Indicated Frequencies in Calibration Example

EXACT TEMPERATURE AVERAGE	$f - f_T$ * PROBE "A"	$f - f_T$ * PROBE "B"
0.000°C	.000	.000
20.145	-.253	-.244
30.248	-.379	-.365
39.874	-.499	-.481
59.843	-.758	-.730

* These values normalized to account for average zero offset.

Table 3-4. Calculated Slope (in kHz/°C), Required Preset Switch Settings, and Maximum Hysteresis Error as Determined in Calibration Example

PROBE "A"			
RANGE	SLOPE	PRESET	MAX. HYSTERESIS
0 - 20	.98744	9271	±.002
20 - 30	.98753	9263	±.001
30 - 40	.98753	9263	±.002
40 - 60	.98703	9308	±.002

PROBE "B"			
RANGE	SLOPE	PRESET	MAX. HYSTERESIS
0 - 20	.98789	9230	±.001
20 - 30	.98802	9219	±.002
30 - 40	.98795	9225	±.003
40 - 60	.98753	9263	±.003

To illustrate: for a nominal temperature of 20°C, the temperature average is the mean of 20.410, 20.104 and 19.921, or 20.145°C. The actual probe frequencies at those temperatures are 19.960, 19.653 and 19.472, the mean of which is 19.695 kHz. The average zero offset for the probe is the mean of -.197, -.195 and -.198, or -.197 kHz. Therefore $(f - f_T)$ is equal to:

$$(19.695 + .197) - 20.145 = -.253$$

The use of $(f - f_T)$ to calculate slope is an arbitrary choice made for convenience; the plot of $(f - f_T)$ vs. T is the same as f vs. T with 1 kHz/°C subtracted out. Thus it follows that the actual slope of the frequency-temperature plot between two temperatures T_1 and T_2 is:

$$S_{1-2} = 1.0 + \left[\frac{(f-f_T)_2 - (f-f_T)_1}{T_2 - T_1}\right]$$

Table 3-4 gives the slope over each of the limited ranges for which hysteresis data were obtained. "Preset" gives the corresponding settings of the preset switches on the rear panel of the HP-2801A which compensate for slope. "Max. Hysteresis" is the largest uncertainty due to hysteresis that may be expected when working between the extremes of the given range. It is taken as half the maximum H observed in Table 3-2.

For example, over the range 20 to 30°C,

$$S_{1-2} = 1.0 + \left[\frac{-.379 + .253}{10.103}\right]$$

$$= .98753 \text{ kHz/°C}$$

The preset is given by

$$\text{PRESET} = \frac{88{,}150}{\text{SLOPE}} - 80{,}000$$

So, for the range 20 to 30°, we have 88,150/.98753 -80,000 = 9263.

Maximum hysteresis for the 20-30° span is .005°, so a mean value of .002° is listed in Table 3-4. In comparison, the hysteresis specification for the Quartz Thermometer over its full operating span is .05°C.

3-27. PRACTICAL ICE POINT REFERENCE.

3-28. A practical 0°C reference may be established by using a simple ice bath, consisting of an intimate mixture of shaved ice and water. A convenient form of ice bath illustrated in Figure 3-3. A large Dewar flask (preferably one quart or larger) is first filled with shaved or finely cracked clear ice, and enough water is added to fill all the spaces between the pieces of ice, but not enough to float the ice. Any potable water and ice are sufficiently pure for this purpose, and will provide a bath that is within a few hundredths of a degree of 0°C.

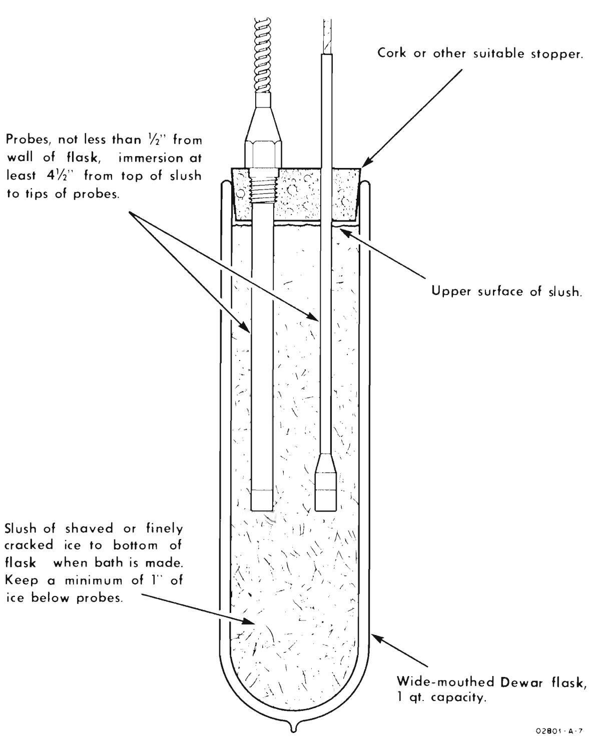


Figure 3-3. Practical Ice Bath for Calibrating Quartz Thermometers

3-29. Where the highest accuracy is required, both distilled water ice and distilled water should be used. Any materials in contact with the water-ice slush of the bath should, of course, be free from contaminants. When first prepared, the ice should extend to the bottom of the flask.

3-30. Each sensor probe is inserted through a hole in the cork of the flask. The tips of the probes should be at least 4-1/2 inches below the surface of the slush, and the probes should be at least 1/2 inch from the side of the flask.

3-31. Excess water should be poured off, and more ice should be added, as indicated above, at intervals sufficiently short that the bottoms of the probes are never surrounded by water alone. A safe practice is to keep a minimum of one inch of ice below the probes, because the temperature of the water below floating ice may be several degrees above the ice point. How often such renewal is required depends upon many factors, including the quality of the Dewar flask and the rate at which heat is conducted downward along the wires and probes.

3-32. PRACTICAL MEASUREMENT CONSIDERATIONS.

3-33. <u>THERMAL EFFECTS OF THE QUARTZ THERMOMETER PROBE.</u>

3-34. It is sometimes necessary to consider the rate of heat loss down the probe cable. For the probes with non-armoured cables, Models 2850A,D, E and F, this amounts to less than 0.001 calories per second, per degree C difference in temperature between the measurand and the surrounding air. The probes with armoured cables, Models 2850B and C, will create much higher heat loss rates and should not be used for small measurand volumes or in critical areas. They are intended for use in tanks and pipes and other industrial applications.

3-35. <u>HEAT TRANSFERENCE TO THE QUARTZ THERMOMETER PROBE.</u>

3-36. Response of the Quartz Thermometer probes is specified in relation to water moving at a certain speed. This specification is broad enough to apply to most situations in which the probe is placed in a liquid and there is some relative movement between the probe and the liquid, either as a result of natural flow or deliberate agitation. However, this is not true of gaseous measurands, and the Quartz Thermometer should be used for measuring gas temperatures only after the thermodynamics of heat transfer for a particular application are investigated.

3-37. Another corollary of heat transfer, not so obvious, is in measurement situations where the Quartz Thermometer probe is not in direct contact with the measurand, and there may actually be a high resistance heat path between the two. Examples are the triple point cell and the tin cell. Measurement accuracy can suffer because of heat leakage through the probe, such that the probe is, in effect, placed outside environment. The resistance between probe and measurand should be minimized by a close fitting sleeve or conductive liquid filler.

3-38. APPLICATIONS.

3-39. In the following list of applications no attempt is made to describe techniques employed in making the measurements. If additional information concerning any of these applications is desired, any HP field office will provide either individual suggestions or may be able to furnish published application notes. Application notes are published from time to time as the occasion demands.

General Temperature Monitor:

measurement of liquids and gases, and as part of data acquisition systems.

Laboratory Transfer Standard:

used to calibrate thermocouples, mercury thermometers, thermistors, temperature controllers, etc.

Calorimetry (accuracy ±0.0002°C):

measuring heats of combustion, heats of reaction, heats of solution, heats of fusion, and specific heat (Application Note 78-3).

Differential Temperature Measurements (T_1-T_2):

temperature gradients in baths and inlet vs. outlet temperature. For example:

1 - pump and turbine efficiency

2 - power output of liquid cooled high frequency transmitter

3 - heat rejection of automobile engines

4 - heat of respiration from plant tissues

5 - estimate of blood flow by heat transfer

Transition temperature in polymerization reaction.

Temperature gradient in atmospheric boundary layer over the sea.

Establishing thermal stability of a variety of materials.

Loss measurements in hydraulic machinery.

Density correction for mass energy transfer measurement.

Monitoring body temperatures of marine animals.

Oceanography:

sea temperatures at all depths for monitoring, calculating density and sound velocity measuring temperature gradients, forecasting weather and correcting other temperature sensitive transducers.

Other:

molecular weight and purity (through boiling point elevation and freezing point depression). (Request Application Note 78-2.)

3-40. USE AS A RATE COUNTER.

3-41. AC signals in the range of 2 Hz to 300 kHz at voltages of 0.5 to 10 volts rms can be applied to the BNC connector on the front panel of the Quartz Thermometer. When the RATE pushbutton is latched, any signal appearing at the input connector will affect the internal counting circuits for an interval of time determined by the setting of the RESOLUTION pushbuttons. Table 3-5 shows the resolution achieved for various time periods.

Table 3-5. Resolution

Pushbutton Latched	Reading* Resolution (CPS)	Full Scale Display (KC)	Sample Period (Second)
.01	10	0300.00	0.1
.001	1	300.000	1.0
.0001	0.1	(3)00.0000**	10.0

* ±1 digit ambiguity in least significant displayed digit for all sample periods.

** "Hundreds" digit not displayed when using 10 seconds sample period.

3-42. Measure unknown frequencies as follows:

a. Latch the RATE pushbutton.

b. Latch the RESOLUTION pushbutton providing required decimal point location.

c. Adjust the SENSITIVITY control clockwise until consistent results are observed in the display window. Adjust the DISPLAY INTERVAL control clockwise until successive measurements are occurring at the desired rate. Move this control fully clockwise to HOLD if successive readings are to be initiated manually. Press the RESET pushbutton each time a new measurement is to be made when the HOLD position is used.

SECTION IV
THEORY OF OPERATION

4-1. INTRODUCTION.

4-2. The very simplest way of viewing the Quartz Thermometer is as a beat frequency oscillator coupled to a frequency meter. The BFO generates a signal that is a measure of temperature (either absolute or comparative) and the frequency meter (rate counter) presents a digital display of the signal as measured during a precisely known interval of time.

4-3. Of course, there is more to it than this. Refinements are incorporated to assure higher accuracy and linearity, to extend the measurements to include the choice of °C or °F scales, and to indicate which of two temperatures is higher or, what amounts to the same thing, whether an indicated temperature is above or below zero. Moreover, since all the elements of an electronic counter are present, this function is also made available as an independent capability of the instrument.

4-4. To obtain an absolute temperature measurement, a radio-frequency signal generated by a temperature sensitive crystal oscillator is mixed with a similar radio-frequency signal generated by a very stable reference oscillator. The resulting beat frequency is then detected. This beat frequency varies between zero and about 250 kHz. The slope of the frequency/temperature curve is established as near as possible to 1000 Hz per °C. (This is equivalent to 555 Hz per °F but some other considerations are then involved which we will examine later.)

4-5. If the rate counter samples the beat frequency for exactly one second, then the indicated count will express temperature in millidegrees C. If the frequency of the variable oscillator is above the reference frequency, the indicated temperature will include a + sign; if it is below, the sign will be -. Determination of which sign will be attached to the numerical result is an automatic function of the instrument.

4-6. TEMPERATURE/FREQUENCY EQUIVALENT.

4-7. The Quartz Thermometer compares the frequency of an unknown temperature with the standard frequency for 0 °C or alternatively, for 0° F. (The reference frequencies for the two thermometric scales are slightly different for reasons that will be explained later.) In addition to making this comparison, it is also capable of comparing the frequencies of two variable temperatures. One of these temperatures is always subtracted from the other to obtain an indication of their difference. That is to say, one of these two variable frequencies (and it is always the same one) replaces the standard with which the other is compared. Again, the sign attached to the result might be either + or - depending on which temperature is higher.

4-8. RESOLUTION.

4-9. Although a sampling period of one second has been cited as an example, other sample periods either ten times as long or one tenth as long may also be used. The desired period is selected by latching an appropriate front panel pushbutton. It should be evident that increasing the length of time the counter is exposed to the beat frequency will result in a correspondingly larger total count. Obviously this does not represent a higher temperature but instead one that is resolved to a higher order of indication. It means, in effect, that the decimal point is shifted to provide one more significant figure to the right of the decimal point. In doing so, the leftmost figure, if it is in the hundreds column, must be dropped. Of course, the opposite shift in point location will occur when the shorter interval is selected.

4-10. °F MEASUREMENTS.

4-11. So far we have discussed the sample period in terms of decimal multiples of one second. One second is the nominal sampling interval related to the measurement of °C. When °F are to be measured, a sample interval is chosen that bears the same relation to one second as a °F bears to a °C. That is, the °F period is 1.8 times as long as the °C period. You can see why this is necessary if you remember that the 100°C span between water's freezing and boiling points corresponds to a span of 180°F (32° to 212°). Because the °F scale is more finely divided than the °C scale (by a factor of 1.8), 1.8 times as many counts must be accumulated to represent °F as to represent °C.

4-12. In addition to a finer division of the freezing to boiling span, the °F scale must exhibit a 32° offset from the °C scale. As the sensor probe frequency at water's freezing point remains unchanged, this change in beat frequency can only be brought about by changing the reference oscillator frequency. To accomplish this change, the crystal and crystal oven are changed to lower the reference frequency from 28.208 MHz to 28.190 MHz. The resulting beat frequency when the probe is exposed to freezing water temperatures is 17.78 kHz. When this is multiplied by the nominal 1.8 second sampling interval, the result is 32,000 cycles which is the indication for 32°F. This temperature, incidentally, is one of the most easily achieved, and accurately repeatable reference points for calibrating the Quartz Thermometer.

4-13. We have been referring to the oscillators as being temperature sensitive or temperature insensitive. You understand, of course, that we are actually speaking of the relative sensitivities of the oscillator frequency controlling elements: the quartz crystals. The remainder of the oscillator circuits are constructed on standard printed circuit cards that are usually installed in the instrument enclosure. There they are subject to the normal changes of ambient temperature but these affect the numerical temperature indication by less than .001°C per degree change in ambient temperature.

4-14. QUARTZ CRYSTALS AS TEMPERATURE SENSORS.

4-15. The angle from the crystalline axes at which a quartz crystal is cut has a great bearing on its temperature coefficient. By properly choosing the angle of cut, a crystal can be prepared to exhibit either a negative or a positive coefficient of temperature. Somewhere in between, a zero temperature coefficient is possible at a selected temperature. The performance of a zero coefficient crystal can be maintained by putting it in a temperature controlled oven, and that is what is done here to provide the stable reference frequency.

4-16. The temperature sensing crystal, on the other hand, should exhibit the most linear possible change of frequency with changing temperature. A special cut developed by HP is called the LC (linear coefficient) cut. It is used in preparing the sensor crystals. Although this cut produces the most linear possible temperature coefficient, the response curve is not a perfectly straight line over the entire range of temperature to which the crystal will be exposed. That is, a constant ratio of temperature to frequency is not maintained. The slope of the curve varies and it assumes a range of values represented by decimal fractions slightly smaller than the ideal of 1.0. However, at any given point on the curve, compensation can be applied by slightly changing the sampling period. This is done electronically by setting numerical thumbwheel switches in the instrument. The effect of this change in timing is to bring the slope of the curve at a preselected temperature up to, or perhaps above, the ideal of 1.0. Quite clearly this cannot straighten the curve but it can bring it into closer agreement with a straight line at more points if the best possible temperature of compensation is chosen. This all represents part of the calibration procedure which is discussed in another section of this book.

4-17. Another factor must be considered when the aim is to achieve the highest possible measurement accuracy. This factor is hysteresis in the quartz crystal. The effect of hysteresis is to cause the crystal to resonate at different frequencies for the same temperature depending on the span and direction from which that temperature is approached.

4-18. Because of hysteresis, the frequency versus temperature points will fall on a different line when plotted on a rising scale of temperature than when these points are plotted on a descending scale. The closed curve resulting from this plot is the hysteresis loop of the crystal. The width of the curve becomes smaller as the total excursions of temperature are made smaller. A precise determination of the width of the hysteresis loop can be obtained so that allowance can be made in interpreting the results of a measurement.

4-19. We have examined in broad terms, some of the capabilities and limitations of the Quartz Thermometer. In following paragraphs we shall inspect in greater detail how the principal building blocks of the Quartz Thermometer are related. Following that we shall discuss something of the individual circuits in these building blocks.

4-20. GENERAL PRINCIPLES.

4-21. We have said that the Quartz Thermometer comprises an electronic rate counter combined with a beat frequency oscillator. It is convenient to consider these two portions of the instrument separately. First we will examine the rate counter.

4-22. ELECTRONIC COUNTERS.

4-23. Electronic counters are, in general, binary counters. That is, they accumulate individual pulses sensed at the input by allowing some of their internal circuits to alternate between two stable conditions. These alternating conditions are a characteristic of symmetrical circuits wired so that one half the circuit is in a conducting state while the other half is in a non-conducting or cut-off state. These symmetrical arrangements of circuit elements are variously called flip-flops, binaries, bistable multivibrators, and other names as well. We will call them binaries.

4-24. Binary Counting Elements. The usefulness of binaries depends on the following behavior: successive input pulses cause the binary to assume alternate stable states. As a consequence of this behavior, two input pulses of a given polarity result in one output pulse of that polarity. Depending on your point of view this can mean either an accumulated count of two or an arithmetic division by two. Functionally the binary performs the same operation whether it is called counting or dividing. In the Quartz Thermometer, binaries are used both as counters and as dividers.

4-25. If a series of binaries are connected in a chain with the output of the first providing the input to the second -- and so on, at the end of the chain only one pulse will be produced as the consequence of a larger number of pulses applied to the input of the chain. How much larger this number of pulses will be depends on how many binaries are in the chain. Since each binary needs two input pulses for one output pulse, the number of input pulses needed to get one output pulse from a chain of n binaries is 2^n.

4-26. To count to 8, then, requires three binaries and to count to 16 requires four. To count to 10 requires more than three binaries so four must be used. When only 10 counts are required of four binaries, something must be done to keep them from counting past 10. This is called short counting and it is accomplished by wiring circuits into the chain so the binaries are forced to assume combinations of states that are not the usual direct result of chain counting. One such modified group of four binaries is called a decimal counting stage.

4-27. Decimal counting stages, or more simply just decimal counters, can be wired in chains so that the completion of a counting cycle in one stage directs a carry pulse to the stage representing the next higher decimal order. Six such stages can accumulate a count of 10^6 or one million.

4-28. Decoding the Contents of a Binary Counter. It is not possible merely to look at the binaries in a decimal counter and thus determine their respective states. However, if each binary were wired to an indicator lamp that disclosed whether a binary was "set" or "reset", you could decode in your mind the decimal meaning of any combination you observed. Although this method is sometimes used, it is not very convenient. It is not used in the Quartz Thermometer; instead some additional electronic parts are wired to the decimal counters to do the decoding for you. This assembly of parts is called, naturally enough, the decoder. Every combination of states of the four binaries that represents an individual decimal number is separately decoded to produce a single "true" output on a circuit unique to that decimal number. Every other decimal number circuit then exhibits a false output. Each decimal number circuit is connected to a corresponding numeric display structure that becomes visible when excited by an activating (true) signal. All ten numeric display structures are enclosed in a glass envelope and the whole assembly is called a Nixie tube.

4-29. Resetting to Zero. Some other circuits are added to the counter chains so that a single input pulse can reset all the binaries to what we call the zero state. (This pulse is not applied to the same input that is used for a counting pulse.) In the condition where all binaries are zeroed, the decoders (one for each decimal order) sense this state and consequently make active the circuits that excite the display of zeroes in the Nixie tubes.

4-30. After a reset to zero, successive pulses applied to the counting input will cause successive decimal numerals to become visible in the Nixie tubes. The indication can reach 999999 before returning to zero in natural sequence, or it can be returned to zero at any time by a reset pulse.

4-31. Binaries as Dividers. The main difference between a counter and a divider is that a divider does not require contents decoding. In a divider we are not concerned with observing the intermediate states of the various binaries; all we want is a final output condition signifying that some pre-established number of input pulses have been applied to the first binary in the chain. You can see that this is merely another aspect of counting. Nevertheless, it is not ordinarily called counting unless some of the intermediate results are decoded. You should know that binaries can be combined in dividers just as they are in counters so that division is accomplished in decimal multiples as well as in binary multiples. Both binary and decimal division are used in the Quartz Thermometer.

4-32. The Quartz Thermometer uses dividers in establishing a precise time base so that the interval over which temperature analog pulses are counted can by accurately fixed. This need arises because the beat frequency oscillator portion of the Thermometer generates pulses at a frequency that is analogous to temperature. Since frequency is a function of time, we need a good time base to attain accurate temperature readings.

4-33. The combination of a time base and a sequential counter such as we have described forms a rate counter. A rate counter is sometimes called a digital frequency meter.

4-34. TIME BASES.

4-35. A temperature indication in °C results from accumulating a count of the beat frequency pulses for nominally one second of time. (Later we will expand on this statement to show how minor alterations to this interval correct the temperature/frequency slope of the sensor probes.) To measure a one-second interval we need an accurate clock. Because we have a precise frequency standard in the reference oscillator, we can process its output signal to provide the needed clock. The reference oscillator frequency is successively divided in decimal and binary dividers until the required interval is obtained.

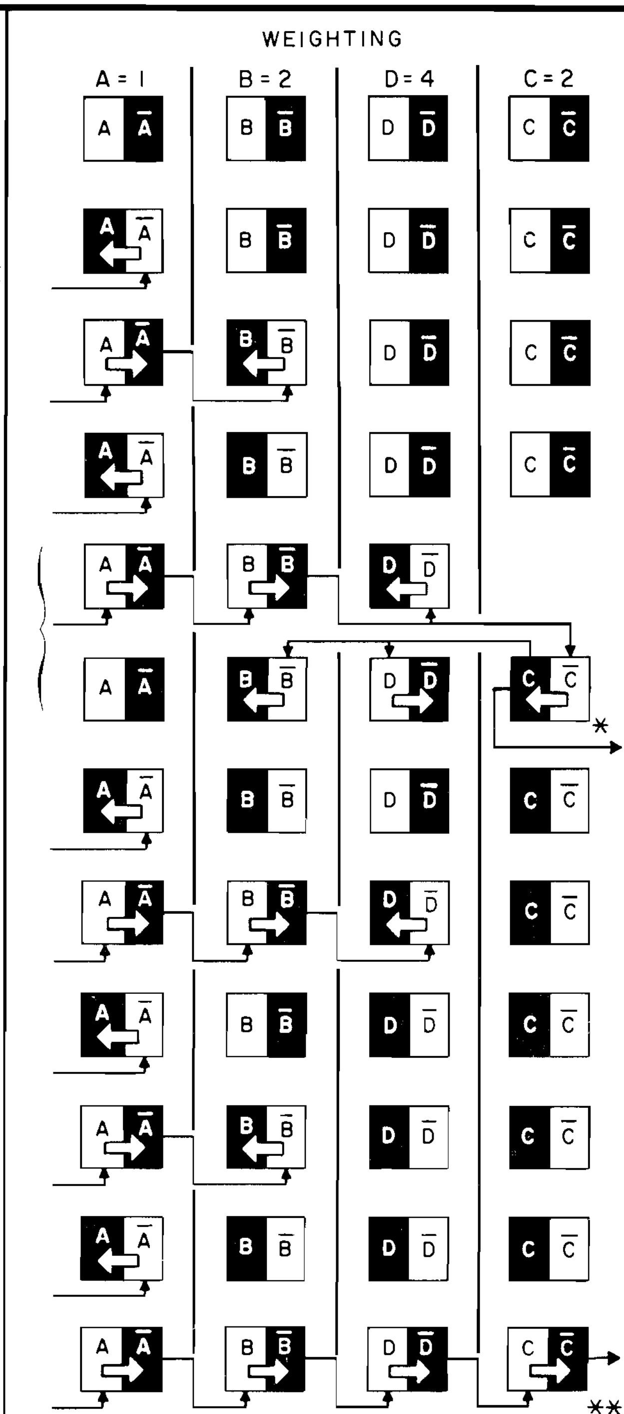
4-36. The fundamental frequency of the reference oscillator crystal for °C is 2.820800 MHz. A tuned frequency divider on the oscillator board (A20) furnishes a signal of half this frequency to the high speed divider (A23). Four cascaded binaries on A23 further divide the signal frequency by 16 to provide clock output frequency of 88,150 Hz. If we start counting (and accumulating) beat frequency pulses in the display counter at the same time we start accumulating clock pulses in a set of preset dividers, we will have counted both sets of pulses for exactly one second if we stop counting when 88,150 pulses have been accumulated in the dividers.

4-37. Although we have been speaking of accumulating clock pulses in the preset dividers, it is probably more descriptive to say that each clock pulse removes one unit of 88,150 units which are preset into the dividers before counting begins. When no more units remain in the dividers, the counting process stops and the display counter exhibits the temperature expressed as the analog of beat frequency.

4-38. Resolution is a Function of Time. Resolution in a temperature measurement is defined as the number of significant digits in the indication. When a one-second interval is used for accumulating the beat-frequency count, the resolution is to 0.001°C. An interval ten times as long, or ten seconds, will result in resolution of 0.0001°C. A one-tenth second interval produces a result having 0.01°C resolution. You must not interpret these figures to imply this order of accuracy in the measurement. Accuracy depends on other factors which we will examine elsewhere. Resolution is mentioned at this time so that we can extend our discussion of the preset decimal dividers.

4-39. Because time is measured by counting 88.15 kHz pulses from the clock, a ten second interval dictates that we count 881,500 pulses and a one-tenth

BINARY STATES (■ - CONDUCTION)



	4-LINE CODE A	B	D	C	DECIMAL VALUE COUNTER STAGE	DIVIDER STAGE
COUNTER RESET	0	0	0	0	0	3
1ST COUNTER INPUT PULSE	1	0	0	0	1	2
	0	1	0	0	2	1
DIVIDER RESET	1	1	0	0	3	0
4TH COUNTER PULSE & 1ST DIVIDER PULSE	0	1	0	1	4	9
	1	1	0	1	5	8
	0	0	1	1	6	7
	1	0	1	1	7	6
	0	1	1	1	8	5
	1	1	1	1	9	4
	0	0	0	0	0	3

02801-B-8

* BORROW PULSE IN DECIMAL DIVIDER
** CARRY PULSE IN DECIMAL COUNTER

Figure 4-1. BCD Combinations in Counters and Decimal Dividers second interval requires counting 8,815 pulses. Inserting an additional decade divider between the clock pulse source and the preset divider will lengthen the interval to ten seconds and removing one decade divider from the one-second chain will shorten the interval to one-tenth second. The front panel RESOLUTION pushbuttons connect the appropriate number of divider stages needed to accumulate clock pulses for the selected interval.

4-40. Time Base for °F. When °F are being measured, the frequency of the reference oscillator crystal is no longer 2.820800 MHz; it is instead 2.349185 MHz. Division of this frequency by 32 results in a number different than 88,150 Hz. Therefore, a different preset number must be set into the preset dividers. More than that, a different time interval is needed because the span of a °C is 1.8 times that of a °F.

Note

> If you noticed an apparent discrepancy in the frequency of the °F reference oscillator, earlier stated as being 28.19022 MHz, and the reference oscillator crystal frequency given here as 2.349185 MHz, the reason is that whereas the °C crystal frequency is multiplied by 10 to obtain the °C oscillator frequency, the °F crystal frequency is multiplied by 12 for the same purpose.

4-41. Three decimal place resolution of °F requires a time interval of 1.8 seconds and the other resolutions require decimal multiples of 1.8 seconds. The arithmetic shows that the preset number for 1.8 seconds must be 132,142. Insertion or removal of a decimal divider will lengthen or shorten the interval as required by the resolution selection.

4-42. DECIMAL COUNTERS AND PRESET DIVIDERS.

4-43. To understand how preset numbers are put into the dividers, we must first gain some insight into the operation of counters and dividers as numerical devices. Therefore, we now explore this subject.

4-44. Binary Coded Decimals (bcd). Figure 4-1 defines the successive states that four binaries assume in a bcd counter using 4 2' 2 1 bit weight. In this diagram, note that the column headed BINARY STATES lists the binaries in the order A B D C rather than the more usual A B C D. When binaries are listed this way, the code weight is sometimes described as 1 2 4 2. In both cases the sum of the true bit weights defines the decimal number. In fact, they are the same code merely expressed differently. The A B D C order is chosen simply because it is easier to show the routes taken by various intrastage pulses to achieve a short count of ten rather than the customary count of 16.

4-45. Counter Turnover. When the initial reset pulse is applied in parallel to the four bcd counter binaries, they assume states in which no true signals whatever are present at the unbarred (set) outputs of the binaries. That is to say, they are all in reset condition. This is decoded to exhibit a zero in the digital display. Successive pulses applied to the input of the decimal counter stage will step the counter through nine different conditions, each one decoded to exhibit the digits 1 through 9 in the digital display. The tenth pulse will turn the counter over to again exhibit a 0 in the display window and the transition from 9 to 0 causes a stepping pulse to be directed to the following counter stage.

4-46. Figure 4-2 is a simple block diagram illustrating the way in which input pulses change the states of the four binaries to produce a single output carry pulse after ten input pulses. Before any input pulses are applied, a single reset pulse makes the four binaries assume states defined as $\bar{A}\ \bar{B}\ \bar{D}\ \bar{C}$. This is shorthand notation that says the four binaries are reset. In other words, the reset transistors are in conduction and the set transistors are cut off. A bar over the binary designation letter indicates that that binary is reset. Another way of expressing this condition is to use a cipher in the position corresponding to a reset binary as: 0000, meaning all four binaries are reset. When a binary is set, the 0 is replaced by a 1. The

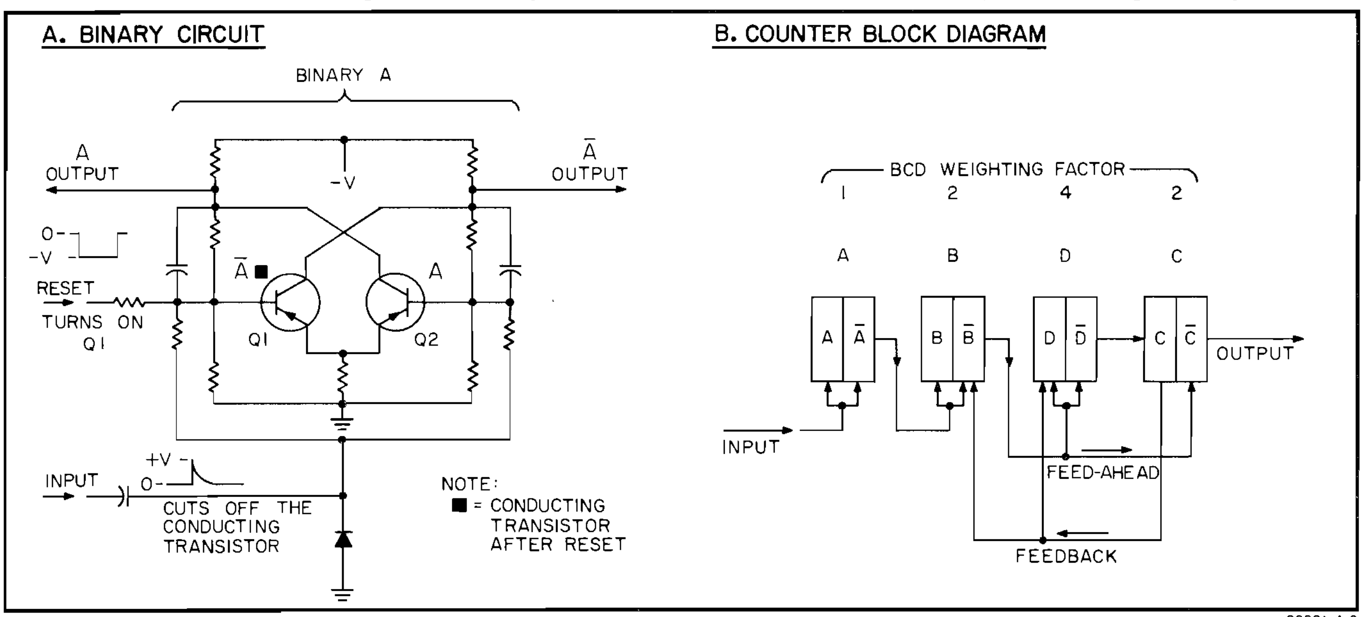


Figure 4-2. Basic Four-Binary Decimal Counter

sum of the binary weights assigned each position exhibiting a 1 is the decimal value of the binary expression.

4-47. Pulse Polarity. As a group of four binaries in a decimal counter responds to successive input pulses, the C binary will change from a reset state to a set state upon receipt of the fourth input pulse after initial reset. The C binary will remain set until after receipt of the ninth input pulse and at the tenth pulse, will go reset again. In doing so, a carry pulse is generated and directed to the next group of four binaries comprising the next higher decimal order. This pulse, of course, affects the second decimal counter as has been described for the first. Ten pulses later it, too, will generate a carry pulse. It is noteworthy that stepping pulses are positive going whereas reset pulses are negative going. Because of this polarity difference, stepping pulses act to turn off transistors that are in conduction and reset pulses act to turn on transistors that are not in conduction. Reset pulses are applied to only one side of a binary to make it assume reset state but stepping pulses are simultaneously applied to both sides of a binary. As stepping pulses act to turn off conducting transistors, they cannot affect those that are already off. Therefore, stepping pulses, successively applied, put the binary first in one state, then in the other. Positive going pulses occur at the collector of a PNP transistor when the transistor goes into conduction. When pulses are obtained from the reset side of a binary, they are positive going when the binary goes reset; they are negative going when the binary goes set. Only the positive going pulses affect the following binaries in the chain; negative going pulses are shunted to ground by the action of a diode.

4-48. Preset Dividers. What has been said thus far describes the effect of pulses directed to and through binaries connected as decimal counters. With some reservations this will also hold for the preset decimal dividers. Two principal differences between the counters and preset decimal dividers need our attention: dividers do not require decoding of states other than that one state defining home position or zero count, and secondly, although the progression of pulses and events is identical to that of counters, a different assignment of truth values makes dividers act as down-counters. That is, they count backwards toward zero. Because a different set of truth values applies to the preset dividers, the reset condition finds divider binaries exhibiting the following: $A\ B\ \overline{D}\ \overline{C}$. In words this says binaries A and B are set and binaries D and C are reset. This is the one decoded combination for preset dividers and it represents the state corresponding to decimal zero.

4-49. Divider Codes. The ten permissible combinations that define decimal numbers from 0 to 9 in the counters are used in the preset dividers to define these same decimal numbers but in a different order. A simple formula relates the decimal value of a combination in the divider to that same combination's decimal value in the counter. This formula can be used to assign a numerical value to the contents of a preset divider stage or it can be used to determine the combination corresponding to a given numerical value. In either case the common factor in the translation is the 1 2 4 2 code. This formula is stated in words as: The numerical value of the bits in a preset decimal divider is the ten's complement of three less than the 1 2 4 2 code exhibited. The inverse statement is: Three added to the ten's complement of the required number results in the 1 2 4 2 code that must appear in the divider binaries. For example, if the code exhibited is A B D C, which is decimal 9 in 1 2 4 2 code, then 9 - 3 = 6, and the ten's complement of 6 is 4. Four is the value represented by A B D C in a preset decimal divider. Four pulses will step the divider binaries to $A\ B\ \overline{D}\ \overline{C}$ which represents zero or home position in the divider. A second example: The preset divider is to hold a decimal 7. Complement 7 to obtain 3; add 3, resulting in decimal 6. Encode in 1 2 4 2 bcd to obtain $\overline{A}\ \overline{B}\ D\ C$. Seven pulses will step the divider binaries to decoded coincidence at $A\ B\ \overline{D}\ \overline{C}$.

4-50. Presetting. It is easy to see how the total accumulating in a counter increases from zero, but if zero is our goal and we are decrementing our register (divider), we must have found some way to put in a total from which we can regress. We can deliberately force the four binaries of a divider to assume any desired combination of set and reset states by simultaneously applying a turn-on signal to selected set or reset inputs of the individual binaries. This signal, like the initial reset signal, is negative going. It overrides the initial reset signal because it persists after the reset pulse has passed. This preset pulse is directed to appropriate binary inputs by means of a thumbwheel switch. The ten positions of this thumbwheel switch establish connections between the binaries and the preset pulse source. Each switch position directs the preset pulse to a different combination of set and reset inputs on the four binaries. Once the preset conditions have been established, the stepping pulses can start decrementing the count.

4-51. Down-Counting. Perhaps the easiest way to visualize what happens in a down-counting divider is to compare the decimal value columns in Figure 4-1. These two columns tabulate the decimal values represented by ten different binary combinations in the counter and the divider. The combination that represents a given decimal number in the counter is simply the 1 2 4 2 sum of the set binaries. The numbers in the dividers are related by the previously stated formula.

4-52. When a divider exhibits the combination that represents zero, the next input pulse must decrement the contents to show decimal 9. This is easy enough but it is not all that must occur at this transition. A "borrow" pulse must also be generated. The borrow pulse is directed to the next divider stage to make it decrement one step also. In fact, the borrow pulse must propagate down the entire length of the divider chain so that if all dividers were in the zero state, the first input pulse would put them all in the 9's state. This is analagous to a set of decimal counting wheels which, when turned backwards past all zeroes, next presents all nines.

4-53. The borrow pulse is obtained from the set side of the C binary and it appears when the first input pulse causes the reset $A\ B\ \overline{D}\ \overline{C}$ contents to change to

$\overline{A}$ B $\overline{D}$ C. We noted earlier that the change of states in the C binary occurs following count 3 and count 9 and that in the counter only the change at count 9 produces a carry pulse. The same combination that represents 3 in the counter, represents zero in the divider. The next step, representing 9 in the divider, must produce a carry (borrow) pulse. Therefore, the change in the state of binary C is taken as a positive going pulse from the set side instead of from the reset side as in the counter.

4-54. Thumbwheel Switches. Figure 4-3 shows how the thumbwheel switch is wired to direct preset pulses to the appropriate binary inputs. To cite only one example of how the number on the thumbwheel relates to the combination set into the divider, consider the following: In position 7, the four binaries are forced by the preset pulse to assume states inverted from those established by the reset pulse. Then the binaries contain $\overline{A}$ $\overline{B}$ D C. The number of combinations intervening between this combination and A B $\overline{D}$ $\overline{C}$, representing home position, is seven. In other words, the number 7 has been preset into the divider and seven pulses will be needed to take it out.

4-55. Low-Speed Divider. Composite diagram, Figure 7-1, shows all the preset dividers accepting the initial reset pulse on pins 1, 6, 10, and 12. We have shown that this puts the decimal dividers into a condition that corresponds to decimal 3 in 1 2 4 2 code. The low-speed divider (LSD) is not a decimal divider but is simply a 4-stage binary divider operating on the scale of 16. The binary weights assigned to a scale of 16 device are the conventional 1 2 4 8 series. No feed-forward or feed-back signals are entailed in scale-of-16 counting (dividing) so the order of the binaries is simply shown in Figure 7-9 as A B C D. The reset pulse puts the LSD into states that represent decimal 3 also, but this combination is decoded to signify that the LSD is in home position. In other words, that it is reset to zero. We do not decode any intermediate states of the LSD so the arbitrary assignment of this combination to represent zero is no handicap. It is done merely as a wiring convenience to be consistent with the decimal dividers. However, any number preset into the LSD must employ a combination of set and reset binaries that takes account of this 3-unit displacement. The preset numbers result from permanent wiring in the instrument and the wiring does take this into account.

4-56. The low-speed divider counts the most significant digit in the 88,150 total that must be removed from the preset dividers before coincidence of all dividers closes the display counter gate. Therefore, the LSD is preset to contain the combination eight states removed from coincidence. This combination is A B $\overline{C}$ D. Because the reset pulse has established A B $\overline{C}$ $\overline{D}$, the preset pulse must, therefore, force the D binary to go set and this is done by directing a set pulse to pin 2 of the low-speed divider.

4-57. You can see that since the D binary has a decimal weight of 8, presetting it has the effect of subtracting 8 from the total of 16 input pulses that would otherwise be needed before returning to decoded coincidence. (This is still conveniently looked on as down-counting.) Because there are no more significant digits to be affected, it is not necessary to generate a borrow pulse in the LSD so the only pertinent action of the LSD is to signify attainment of coincidence. After the LSD has stepped down to home position, there still remain 8,150 units in the four decimal dividers. These will be taken out by successive pulses until nothing but zeroes remain and at that time all the decoding diodes are at -12 volts and coincidence is indicated. (For °F the LSD counts the two most significant digits of the number 132,142 and therefore is preset to $\overline{A}$ B C $\overline{D}$, the combination that is 13 states removed from decoded coincidence. Refer to Paragraphs 4-40 and 4-41.)

4-58. GATES AND CONTROL CIRCUITS.

4-59. Preset Gates. Figure 7-1 shows that the preset pulses reach the preset dividers via two assemblies, A16 and A17, called preset gates. Schematic diagrams of these assemblies appear in Figures 7-12 through 7-15. Their purpose is twofold: to direct preset pulses to appropriate binary inputs when temperatures are being measured or to override the effect of thumbwheel switch setting when the instrument is operated as a rate counter. The preset pulse is not directed to the thumbwheel switch in rate counting but is, instead, directed to pin 15 of the preset gate assemblies. Diodes within the gate assemblies act as OR gates to permit the preset signal to derive from either the thumbwheel switches or the common line to pin 15. When the preset pulse is obtained from the common line, the preset dividers are forced to assume the condition corresponding to a thumbwheel setting of 8150 irrespective of the actual thumbwheel setting at that time. You will no doubt remember that the preset number 88,150 corresponds to a time interval of exactly one second. This interval, or a decimal multiple thereof, is needed for meaningful frequency measurements. Because the most significant digit, 8, of this number is preset into the low-speed-divider by permanent wiring in the preset gate, only the number 8150 need be set into the thumbwheel switches for a one-second interval. Other intervals may be needed to compensate for frequency/temperature slopes other than 1000 Hz/°C. For example, if the slope were 985 Hz/°C, we would need an interval longer than one second. This interval is defined as 1000/985 seconds. As 88,150 pulses represents one second, 88,150/0.985 is the number of pulses representing this longer interval. This number is 89,492. Again, only the 9492 portion need be entered into the thumbwheel switches. Section III of this manual expands on these ideas with a description of a practical example of special calibration.

4-60. Gate Control. Stepping pulses affecting both the decimal counter and the preset dividers must be controlled in their application. An assembly called the gate control, A10, permits or prohibits the pulses from reaching other circuits. The gate control simultaneously opens the gates that allow stepping pulses to increment the decimal counter and decrement the preset dividers. When the preset dividers attain coincidence, both sets of gates are closed and the display counter transfers its most recent count to the display assembly.

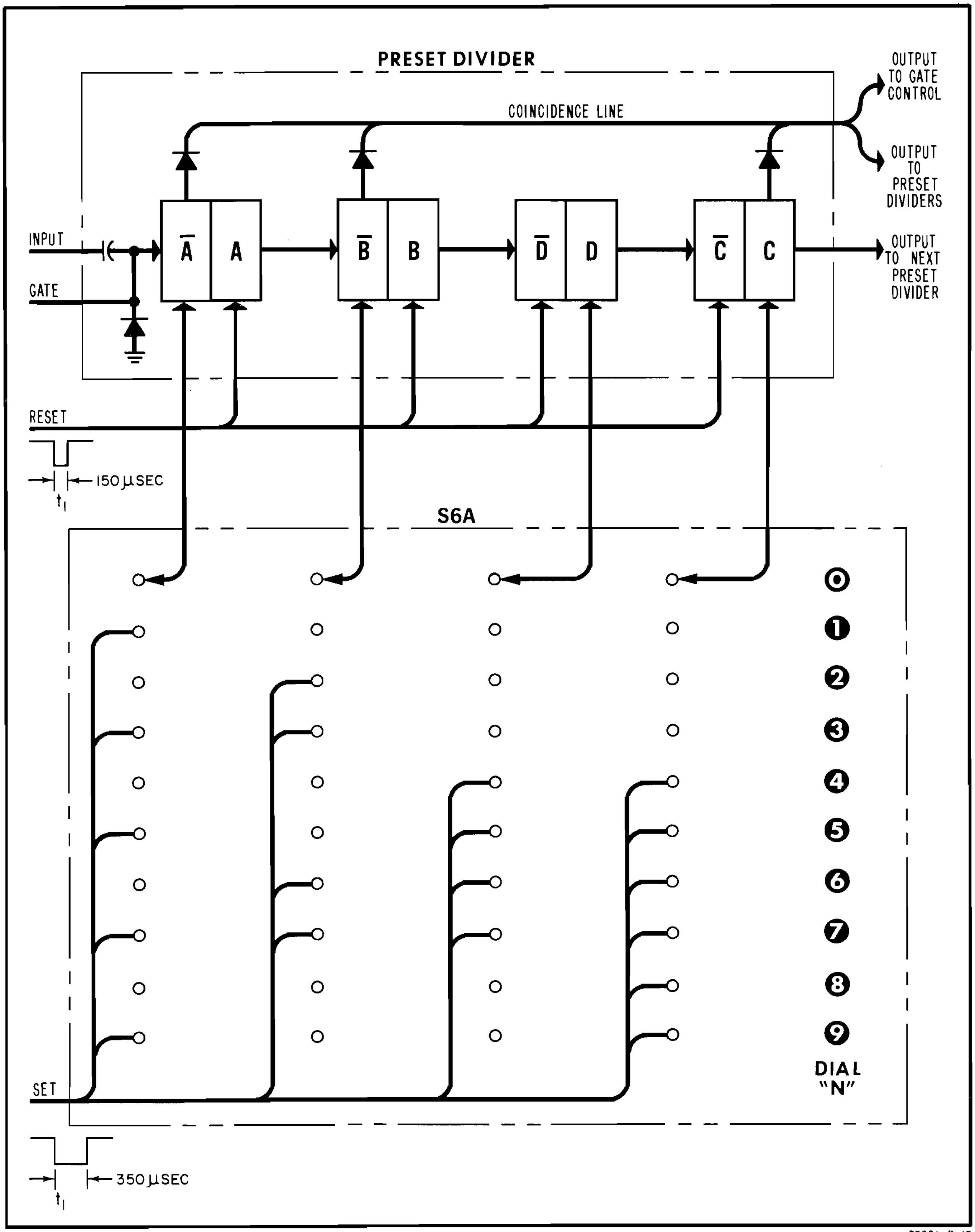


Figure 4-3. "N" Switch Logic -- Control of Preset Divider

4-61. Display Interval Control. The gate control does not initiate control signals on an arbitrary or random basis. It needs an initiating signal which originates elsewhere. This signal originates in the display interval control, assembly A11. This assembly contains an adjustable low-frequency pulse generator that resets and presets the counters and dividers at regular intervals. A front panel control permits adjustment of the interval from 0.2 to 5.0 second. While the reset and preset signals are being applied to the counters and dividers, an inhibit signal is directed to the gate control to prevent it from passing stepping pulses. The inhibit is removed after preset and the gate control opens the gates to stepping pulses. When coincidence in the dividers is sensed by the gate control, the gates are again closed.

4-62. Function and Resolution Selection. Assemblies A19 and A24, identified as the channel selector and the resolution selector, are nothing more than simple relay switching circuit assemblies that direct signals to various desired paths. The relay coils are transistor driven during remote operation. When operating in a local mode the transistors are biased off, and the switches on the front panel control the operation of these relays directly.

4-63. BEAT-FREQUENCY GENERATION.

The beat frequency that is a measure of temperature is the numerical difference between two parent frequencies. One of these parent frequencies must always be obtained from a sensor probe oscillator. Sometimes both of them are, as when making differential temperature measurements. When no frequency difference exists, the two signals are said to zero-beat; that is, no beat frequency is generated. As the indicated temperature is the analog of the beat frequency, zero beat must correspond to zero degrees. Assuming for now that only a single sensor probe is being used and consequently the stable reference oscillator is furnishing the second parent frequency, then the difference (beat) frequency will depend on the absolute frequency generated by the sensor probe oscillator. Whether the sensor probe frequency is above or below that of the reference oscillator depends on whether the temperature is above or below zero degrees. We want to know which, but unfortunately the beat frequency by itself does not contain information that enables us to tell whether it represents a temperature above or below zero. However, there is a process to which we can subject the parent frequencies that will give us this information. The following paragraphs explain how.

4-64. Determining the Higher of Two Parent Frequencies. First a little background: when two signals of the same frequency reach their crest amplitudes at the same time they are said to be in phase. If they maintain the same frequency, they remain in phase. If something is done to shift the relative phase of the two signals, one of them will reach its crest before the other.

4-65. A phase detector can tell which signal leads the other. Our object, then, is to obtain two identical beat frequencies separated in phase. This is simply done as follows: the two parent frequencies are mixed in a conventional way to obtain a beat frequency that does not exhibit any phase shift; at the same time one of the parent frequencies is passed through a phase shifting circuit that delays it by 90 electrical degrees and this delayed parent is mixed with the other undelayed parent to produce a beat frequency that is separated by 90 degrees from the conventionally obtained beat frequency. Whether this separation represents a leading or lagging angle depends on whether the delayed parent frequency is higher or lower than the undelayed parent. If the separation represents a leading angle, the phase detector says, "Frequency A is higher than frequency B." If the angle is lagging, the phase detector says, "Frequency A is lower than frequency B." Of course the phase detector does not say this in so many words; instead it causes either a + or a - sign to be attached to the displayed result.

4-66. A simple vector diagram helps to make clear how the phase detector knows which is which. Figure 4-4 shows two vectors, A and B, representing the two frequencies. Also shown is a vector representing the B frequency shifted by 90°. This vector is called B'. Both vectors A and B are rotating counterclockwise, the A vector at a radial velocity corresponding to the A frequency and both B vectors at a radial velocity corresponding to the B frequency. When there is a difference in frequency between A and B, one of the vectors is periodically overtaking the other. If the A frequency is higher, the A vector must be meeting the B' vector before it meets the B vector. On the other hand, if the A frequency is lower than the B frequency, the B vector will overtake the slower A vector before the B' vector does. Each of the two B vectors produces an individual beat frequency each time A and B cross. These two beat frequencies are individually

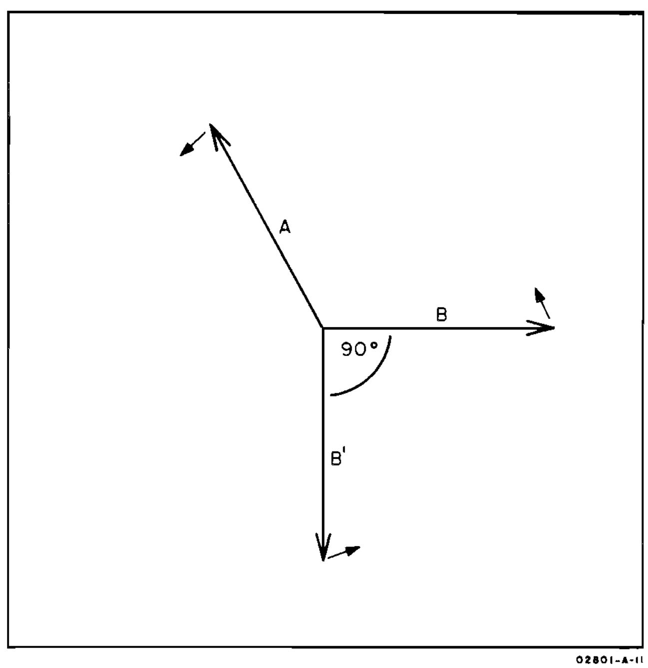


Figure 4-4. Beat Frequency Vectors

examined in the phase detector to determine which occurs first in time. Block diagram, Figure 4-5, shows how the two parent signals are mixed in two different ways and the resulting beat frequencies processed to trigger a binary to one state or the other. The two sides of the binary turn on respective lamp drivers that cause either the + or the - lamp to light.

4-67. Phase Detection. The phase-separated beat frequencies are first squared by amplifying and limiting one of them in assemblies A1 and A2 and the other in assembly A3 alone. Both signals are given equal treatment, the unshifted signal being processed in assembly A3 by circuits that are almost exact counterparts of the circuits in A1 and A2 that process the phase-shifted signal. But in addition to the squaring circuits, assembly A3 contains differentiating circuits that create spike pulses from the two sets of square waves. These spikes are superimposed upon the opposite square wave. In this way, each square wave acts as a pedestal on which the opposite's differentiated pulse is placed. In one case the pulse will rest upon the crest of one of the square waves and in the opposite case it will rest in the trough of the other square wave. The pulse riding the crest of the wave will continuously trigger the phase indicating binary to one state defining either a + or - polarity depending on whether the pulse is crest-borne on the leading or the lagging square wave. When the parent frequencies become relatively inverted, the triggering pulse rides the crest of the opposite square wave and the other side of the binary is triggered. The voltage level of the square waves is adjusted to be slightly below the triggering level of the binary. Therefore, only the upward thrusting spike triggers the binary.

4-68. We have introduced the subject of reference frequency generation in the foregoing paragraphs and mention has been made of the sensor probe frequency. The details of how these signals are generated, mixed, and detected will be treated in those paragraphs devoted to circuit description of the various printed circuit assemblies.

4-69. DETAILED CIRCUIT THEORY.

4-70. AMPLIFIER ASSEMBLY, A1.

4-71. Assembly A1 (Figure 7-2) amplifies either the beat frequency signal or, when the instrument is used as a rate counter, the unknown frequency signal before either of these signals are applied to the trigger circuits on assembly A2. High input impedance results from using two cascaded emitter followers before a common emitter amplifier with a voltage gain of about 8. Collector to base negative feedback in the common emitter amplifier, Q3, is furnished via R4 and C2. L1 is a filter in the ground return (0 volt) line. CR1 is a peak limiter that prevents the negative input voltage from exceeding -8 volts.

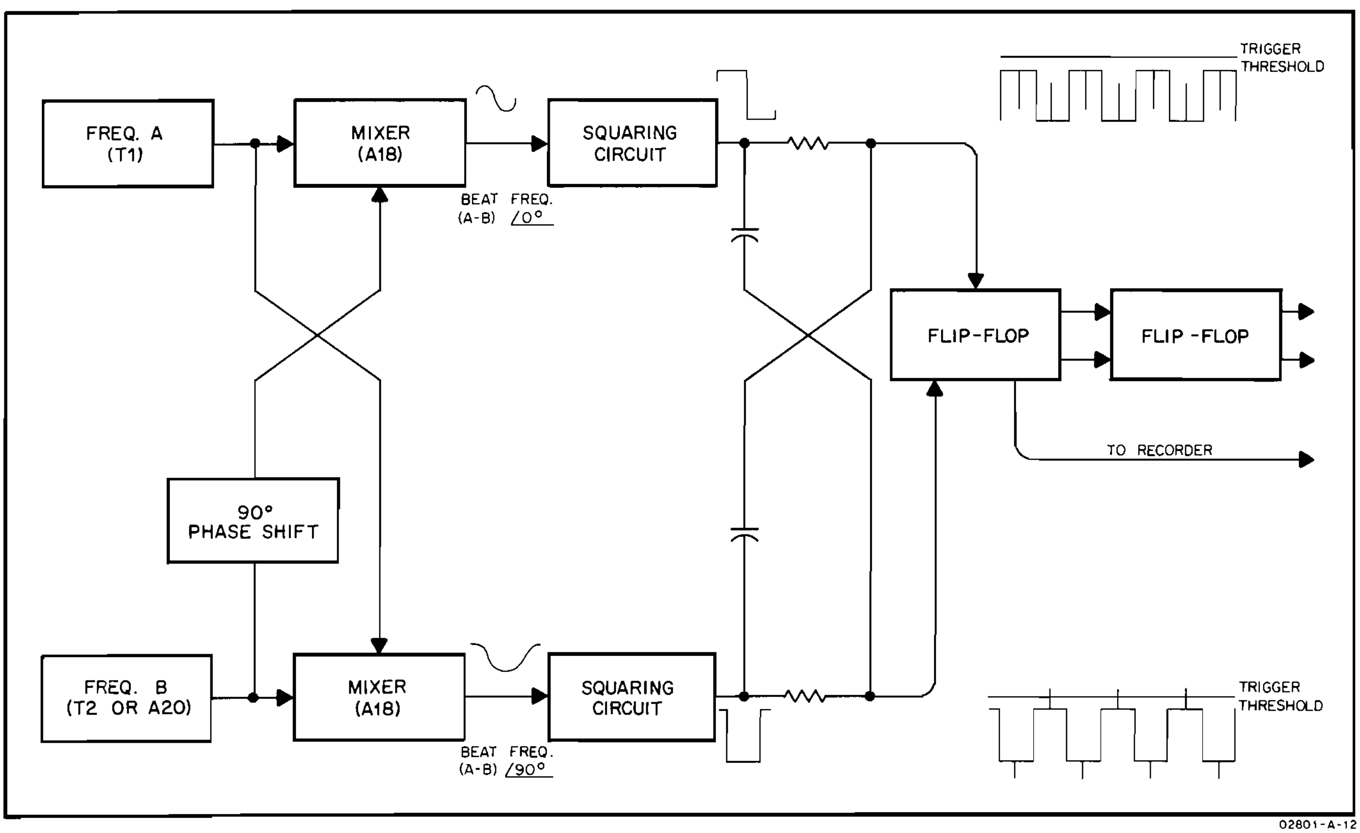


Figure 4-5. Polarity Sensor Block Diagram

4-72. SCHMITT TRIGGER ASSEMBLY, A2.

4-73. Assembly A2 (Figure 7-3) accepts the signal amplified in A1 and converts it to a square wave exhibiting fast rise and fall times. In addition to a regular two-transistor Schmitt trigger, A2 includes an amplifier, Q3, which inverts the trigger output before directing it to the input gate on the display counter A9. The direct trigger output obtained from the collector of Q2 is used in the polarity detector A3 where its phase sense is compared with another square wave signal obtained from another similar Schmitt trigger in assembly A3. Schmitt trigger action is as follows: Q1 is normally cut off because of static bias conditions at its base. A negative-going input signal can attain a level at which the static bias is slightly overcome and the transistor begins conducting. This need be no more than the most minute amount of conduction because, once started, regenerative action between Q1 and Q2 continues forcing Q1 into heavier conduction. When the input signal falls to that certain critical level again, the reverse action takes place and regeneration forces Q1 out of conduction very rapidly. A small difference in the input voltages at which conduction and cut-off takes place is called hysteresis. The squaring effect of the Schmitt trigger results from the rapid change of output voltage each time the input voltage crosses the critical point.

4-74. POLARITY DETECTOR, A3.

4-75. In actuality, assembly A3 (Figure 7-4) duplicates the functions of A1 and A2 with a 3-transistor amplifier and 2-transistor Schmitt trigger exactly as previously described. But more than that, A3 includes two flip-flops that generate + and - sign commands for use in lamp board A30. The flip-flop comprising Q8 and Q9 may be considered merely a gated lamp driver if you wish, as it is slaved to the action of flip-flop Q6/Q7 which is the real polarity sensor. It works this way: The bases of Q6 and Q7 are connected via coupling diodes CR3 and CR4, that allow only positive going pulses to be effective, to two identical differentiating and adding networks. The two individual Schmitt trigger outputs are 90° apart electrically and the differentiated pulse from one is added to the square wave output of the other in what might be described as symmetrical cross-coupling (R23, C10; R33, C15). This means that the positive-going differentiated pulse of one signal will ride the crest of the other undifferentiated square wave while at the same time the other positive-going differentiated pulse will appear in the trough of its opposite number. That pulse which rides the crest will continuously trigger into a cut off state the transistor to which it is connected. The other transistor in the flip-flop pair will, naturally, be in saturation. If the relative phase of the two Schmitt trigger output signals becomes inverted, then the crest-riding pulse will appear on the opposite transistor base, and the conduction conditions will reverse. As the relative phase of the two Schmitt trigger signals depends on which of two parent frequencies is higher, the polarity detector is able to determine and exhibit this information by furnishing power to an appropriate lamp on the A30 lamp board.

4-76. The gated feature of the lamp driver prevents polarity changes from being indicated until the numerical display is changed. If, for example, a temperature were falling and the crossover of zero occurred much before the next display interval pulse, the sign would change without a corresponding change of the numerals. This might be disconcerting to an operator. The way this works is: diodes CR5 and CR6 act as gates which are biased in accordance with the conduction states of Q6 and Q7. A transfer pulse enters at pin 3 when the display is to be changed; then the diode that is not biased into cut-off permits the transfer pulse to switch the states of Q8 and Q9.

4-77. DECIMAL COUNTER ASSEMBLIES, A4 - A9.

4-78. Principles of decimal counting have been treated in detail earlier in this discussion of operating theory. To recapitulate the salient points; stepping pulses are positive-going whereas reset pulses are negative-going. Carry pulses (positive going) are obtained from the reset side of binary C. The transition of binary C from set to reset takes place on receipt of the tenth stepping pulse after reset.

4-79. In assembly A9 only (Figure 7-5, or Figure 7-6 for the 2801A-M6), diode CR9 is used as the main input gate to enable or inhibit the passage of stepping pulses to binary A. The gate control voltage is furnished by gate control assembly A10.

4-80. Decoding of the ten possible states of the four binaries is done by an assembly of 18 light-sensitive resistors (LSR's) and eight neon-lamps that are lit in combinations of four-at-a-time. Each of the four binaries lights either one of two neon lamps to indicate whether it is in the set or reset state. Ten different patterns of light and dark neon lamps thus result. These ten patterns correspond to the ten decimal numerals 0 through 9. The eight neon lamps are disposed about a matrix of light sensitive resistors (LSR's) in a way that permits each lamp to excite a selected group of LSR's; light is excluded from all others by a light-tight enclosure surrounding the entire assembly. When dark, the LSR's exhibit a high resistance (in the megohm range) but when light excited, their resistance falls to about 7000 ohms. Each numeric electrode in the display tube is connected to a current source via a unique circuit path through three separately excited LSR's. Only when all three LSR's are light excited can current reach the numeric electrode causing it to glow. For each pattern of light and dark neon lamps, only one series connected group of three LSR's will be excited; at least one LSR in all the other groups will be dark. The relation of neon lamps and LSR's is shown in Figure 4-6.

4-81. The exciting lamps are wired in a circuit that exhibits memory of the last light/dark combination to which they were switched. Which is to say, even though the associated binaries switch states, the lamps remain as they were until a transfer pulse permits them to assume new states corresponding to the switched states of the binaries. Memory depends on two characteristics of neon lamps; lamps require a higher voltage to strike than to maintain conduction, and once established, the conduction path through the

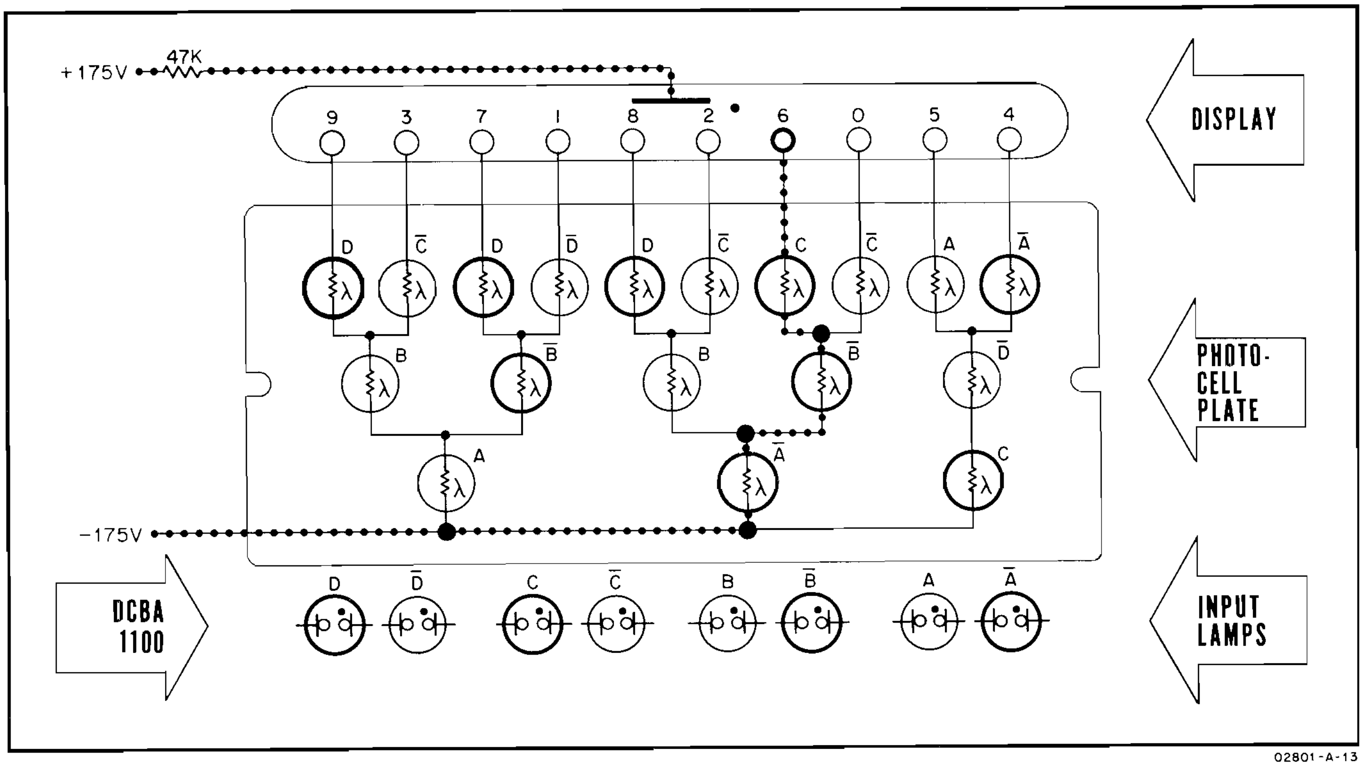


Figure 4-6. Decimal Decoder Matrix

ionized gas exhibits a constant voltage drop. As a consequence of these characteristics, when two lamps in parallel are connected with a significantly large series resistor between lamps and power source, the first lamp to strike will draw current through the resistor thereby lowering the voltage on the other lamp below its striking voltage. This is so because the voltage drop across the conducting neon lamp is fixed; it acts as a gaseous voltage regulator holding the terminals of the other lamp below striking voltage. The conditions just described are represented by Figure 4-7A wherein the forward biased diodes act to return the independent terminals of the two neon lamps to effectively the same voltage. The binaries cannot affect the lamps under these circumstances. (The small difference of 0.5 volts is not significant.) When the diodes are reverse biased the two neon lamps are disconnected from each other and then the terminal voltages of the binaries are effective in determining which lamp will receive striking voltage. The instant bias is reversed on the diodes, the common terminal of the two lamps rises to a voltage that is established by voltage divider action in the two resistors (390K and 56K) plus the fixed drop across the conducting lamp. If, for example, the conducting lamp were returned to a conducting transistor in the binary, then at the incidence of a transfer pulse the common point voltage would rise to only -68 volts. (See Figure 4-7C.) As the other neon lamp would, under the described conditions, be returned to a -30 volt point on the other transistor of the same binary, the difference of 38 volts would not be sufficient to fire the dark lamp. But if, on the other hand, the conducting lamp were returned to a non-conducting transistor as at B of Figure 4-7, then at the transfer pulse the common point voltage would rise to -93 volts and the dark lamp, being returned to -1 volt at the conducting transistor, would fire. The common point voltage would then instantly fall to -68 volts and, because the formerly ionized lamp is returned to -30 volts, it must go out; it cannot sustain ionization with only 38 volts. After 70 milliseconds, the transfer pulse expires and the diodes again become forward biased with the result that the voltage across both lamps becomes about 55 volts (with the 0.5 volt difference before mentioned).

4-82. GATE CONTROL, A10, AND DISPLAY INTERVAL CONTROL, A11.

4-83. Both the gate control assembly (Figure 7-7) and the display interval control assembly (Figure 7-8) work so closely together that it is convenient to treat them as functionally one element. To help keep things straight we'll attach the appropriate assembly designator to the parts reference designators wherever any question might arise.

4-84. The main job of the gate control (A10) is to enable or inhibit the main gates on the counter and the preset divider. The display interval control (A11) establishes the intervals at which successive measurements will be automatically initiated. In general, the gates are held open for an interval measured by the accumulation of a precisely predetermined number of clock pulses in the preset dividers. During this interval the counter is also accumulating a count the total of which is a measure of the unknown frequency. A clock pulse opens the gates, and another clock pulse closes them. In this way the interval is accurately established by the clock pulses and by no other control pulses that may also be used in the gate control logic.

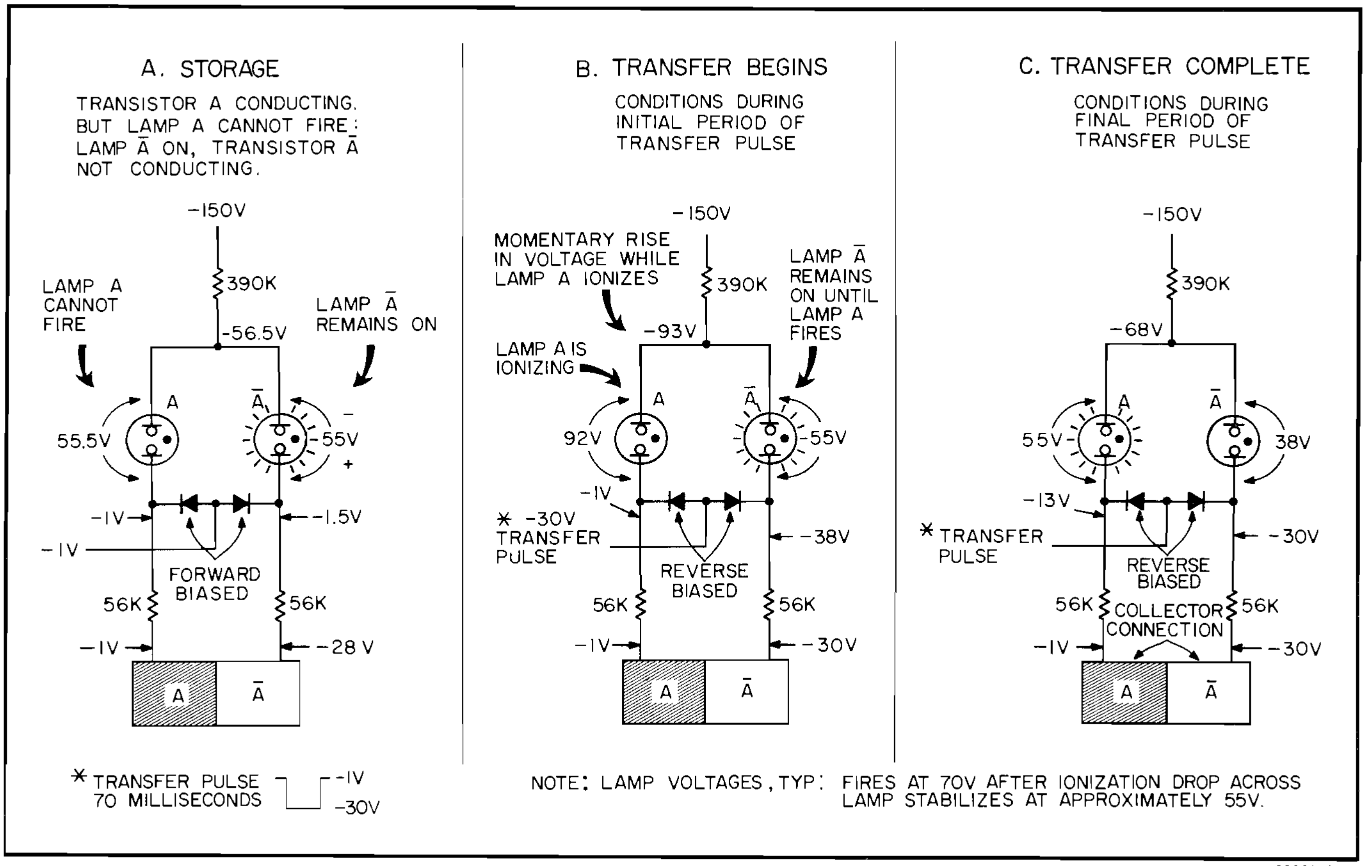


Figure 4-7. Lamp Control in Decimal Counter Assembly

As the gates are closed, a pulse is directed from A10 pin 14 to A11 pin 8. This pulse triggers the transfer multivibrator on A11 with the result that a 70 ms transfer pulse momentarily reverse biases the decoder diodes as has been explained in paragraphs describing A9. The transfer pulse also triggers the sample rate multivibrator on A11 into an active state. The time this one-shot MV remains active determines the interval between successive measurements. When the sample rate multivibrator recovers (returns to quiescence) it generates, through A11Q7 and A11Q8, the reset and preset pulses that are directed to the pulse counting assemblies. To assure that the counting assemblies have ample time in which to respond to these pulses, the inhibit signal, which is present while the sample rate multivibrator is active, is delayed in its removal by the action of A11CR9. This will be explained further a little later on. As soon as the inhibit signal is removed from pin 6 of A10, the next clock pulse on pin 11 of A10 can start a new measurement cycle.

4-85. Assembly A10 contains several transistor amplifiers and a binary memory element named the gate flip-flop. One amplifier consisting of Q3 and Q4 is not directly associated with the logic of the gate control assembly; it merely inverts the polarity of the timing square waves from the clock before they are transmitted to the preset dividers. This is called a phase-shift amplifier, not because of any unusual circuit characteristic, but simply because signal inversion (of a symmetrical waveform) is equivalent to a phase shift of 180 degrees. This means that the first clock pulse to reach the preset divider input binary will find the main gate firmly opened by the enabling pulse that reached it 180 degrees earlier.

4-86. The gate flip-flop alternates between two states one of which inhibits the main counter and divider input gates, and the other which enables these gates. A clock pulse (differentiated square wave) is always the cause of switching this flip-flop from one state to the other.

4-87. A10Q1 is the preset divider gate amplifier and A10Q2 is the display counter gate amplifier. Although Q1 is a common-emitter amplifier whereas Q2 is a common-base amplifier, their respective collectors furnish the same negative inhibiting voltage to the input gate diodes on the two pulse-counting assemblies (A9 and the selected preset divider) whenever A10Q5 is conducting.

4-88. Clock pulses entering A10 at pin 11 cannot turn off A10Q5 as long as an inhibiting bias is applied to A10CR1. CR1 is held reverse biased by negative voltage reaching its anode via R13, R26, and R27. When A10Q9 goes into conduction in response to removal of the inhibit signal (until now present at pin 6), the reverse bias on CR1 is removed and the next clock pulse will reach the base of Q5 turning it off. Q6 will then be in conduction. Some time later, another clock pulse will be allowed to reach the base of Q6 turning it off. This stop pulse must pass through CR2 which is presently being reverse biased by Q7 in conduction. When all preset divider binaries have been stepped down to coincidence, the base of Q7 becomes sufficiently negative to cause cut-off. This removes the back bias on CR2 and the next clock pulse turns off Q6. Of course, when Q6 turns off, Q5 is again turned on and the main gates are once more disabled so stepping pulses can no longer affect either the preset divider or the display counter.

4-89. Q8 is simply an amplifier used to sense conduction (or lack thereof) in Q6 so a front panel neon indicator lamp will glow during the gate enabled time. Neon lamp V1 is effectively a voltage level shifter that permits low-voltage transistor Q8 to control the 175 volt firing voltage to the external indicator lamp. The second neon lamp, DS1, is an excitation source that helps assure reliable firing of V1 by furnishing it with ambient light.

4-90. Because the shortest sample gate time of 100 ms would allow the indicator lamp to be lit almost too briefly to be seen, the duration of the transfer pulse interval is added to the lamp "on" time. Diodes CR5 and CR6 comprise an OR gate for the two signals that keep Q8 cut off for gate time plus transfer time.

4-91. Figure 4-8 shows the waveforms generated by the Display Interval Control and Gate Control Assemblies.

4-92. The main timing element on the display interval control assembly is a one-shot multivibrator that is triggered to its active state by the transfer multivibrator. This last named MV is a one-shot that remains active for 70 milliseconds after being triggered by a stop pulse from A10. The length of time the sample rate multivibrator remains in its active state is determined by the setting of the front panel DISPLAY INTERVAL control knob. As soon as it recovers to quiescence, the sample rate MV removes the inhibit signal from A10Q9 thus permitting a new sequence of measurement activity to start. One extreme position of the DISPLAY INTERVAL control knob puts the timing circuit out of operation so the sample rate MV remains in its active state indefinitely. This position is called HOLD. The last made measurement is thereby displayed until some later operator action removes the hold condition.

4-93. In addition to the two one-shot MV's, the display interval control assembly includes four transistor amplifiers. Transistors Q7 and Q8 are called reset and preset amplifiers because they furnish the pulses that accomplish these functions in the pulse counting assemblies. The size of the coupling capacitors in the base circuits of Q7 and Q8 determines the duration of these two pulses. The preset pulse lasts 350 microseconds whereas the reset pulse lasts only 150 microseconds. The longer duration of the preset pulse permits it to override the effect of the reset pulse in the preset divider assemblies.

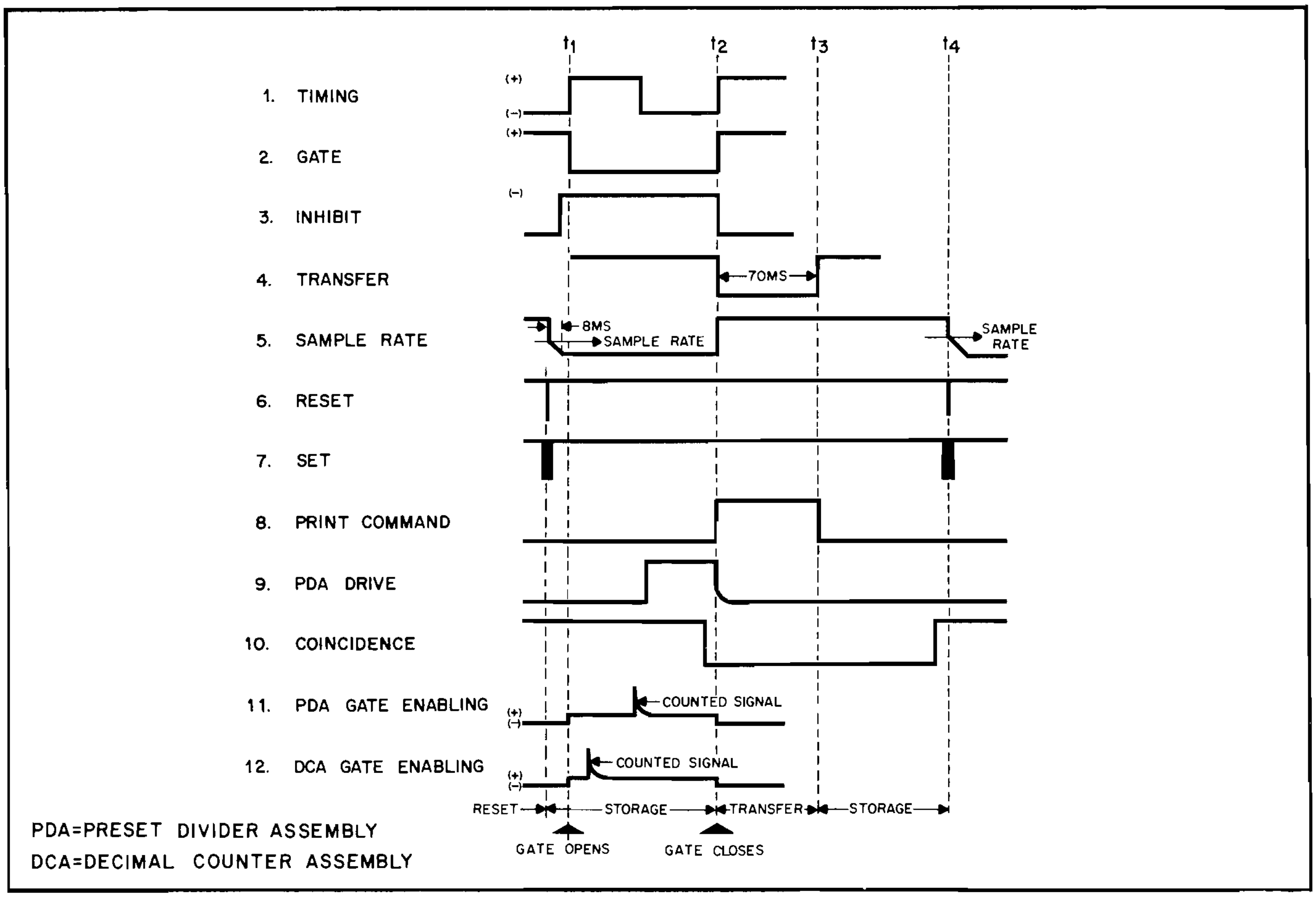


Figure 4-8. Gate Control and Display Interval Control Waveforms

4-94. Recovery amplifier, Q6, furnishes a positive going signal to Q7 and Q8 by going into conduction as the sample rate MV returns to quiescence. Recovery of the sample rate MV also puts a negative voltage on the anode of delay diode CR9. As the reset and preset pulses will have been generated in Q7 and Q8 before CR9 begins to conduct at about -15 volts, the inhibit signal is not removed from A10 until after the counting assemblies have been prepared (by reset and preset) for a new counting cycle.

4-95. Q2 of the transfer MV is the conducting transistor when the transfer MV is quiescent. An incoming transfer pulse, occurring as the gate flip-flop on A10 inhibits the main gates in the pulse counting assemblies, turns off Q2 by making its base momentarily positive. The accumulated count in the display counter is thus transferred from the binaries through the decoding circuits into the numerical display. Q3 amplifies the transfer pulse to drive the multiple diode transfer gates.

4-96. LOW SPEED DIVIDER, A12.

4-97. This divider (Figure 7-9), because it is the last one in the chain of preset dividers, counts the most significant digit of incoming clock pulses. A12 is not a decimal divider; it is instead, a scale of 16 divider that is always preset to count down to home position with fewer than 16 pulses. (This is not, however, related in any way to short counting as is required internally for decimal counters and dividers.) Home position is defined by A B $\overline{C}$ $\overline{D}$ just as it is in the decimal dividers. Unlike the decimal dividers, however, every one of the four binaries must be examined by the decoding diodes to determine when the low speed divider is at home. Unless all four binaries are in the states defining home position, one of the decoding diodes will pull the coincidence line down to ground. Coincidence, you will remember, is indicated by -12 volts on the coincidence line.

4-98. Diodes CR4, CR5, CR7, and CR8, shunt negative-going pulses to ground so only positive-going pulses are effective in switching the states of each following binary. Although diode CR4 could be controlled by a forward bias applied at pin 8, this is not done on the low speed divider; it is done only on the input decimal divider chosen for appropriate resolution.

4-99. PRESET DIVIDER ASSEMBLIES, A13, A14, A25, A26, AND A27.

4-100. Divider principles have been discussed in some detail in earlier paragraphs. As in the decimal counters, stepping pulses are positive-going whereas both reset and preset pulses are negative-going. Preset pulses override reset pulses because they last longer and remain present after the reset pulse has expired. At turnover (when the divider stage has completed a decimal cycle) a borrow pulse is generated in the C binary as it goes set. This borrow pulse is directed to the next divider in the chain where it acts to remove one decimal count from the existing divider contents. These preset dividers (Figure 7-10) are down-counters. That is, each pulse applied to an input removes one count from the existing contents.

4-101. Because clock pulses will be applied to a selected one of three different dividers according to the time interval required, three different divider main gates must be controlled. These gates in each case are represented by diode CR4 which is either forward or reverse biased by control voltage appearing at pin 8 of the selected assembly. Control voltage is only applied to the main gate of the input divider assembly selected for appropriate resolution.

4-102. Home position in the divider has been defined as A B $\overline{D}$ $\overline{C}$. In the 9 other combinations of the four binaries, no conditions will arise wherin A, B, and C will simultaneously have coincident values as in home position. For that reason only these three binaries in each decimal divider assembly need be examined by the diode coincidence gates to determine that the divider is at home. Binary D represents a "don't care" situation in decoding home position.

4-103. FREQUENCY MULTIPLIER, A15.

4-104. Assembly A15 (Figure 7-11), the frequency multiplier, consists of three tuned amplifier stages. Each stage is biased to operate non-linearly to generate a signal containing stage through a double tuned coupling transformer that selects the desired harmonic. Multiplication in successive stages is by factors of two, five, and two in the °C instrument and by three, four, and two in the °F instrument.

4-105. PRESET BOARDS, A16 AND A17.

4-106. The preset boards (Figures 7-12 through 7-15) are simply wired interconnecting printed circuit boards. Their sole function is to establish the required circuit paths needed to preset the binaries in the preset divider according to the scale of measurement, either °C or °F. When rate measurements are being made, a path is established through wired in diodes that bypass the thumbwheel switches. Under these conditions, the thumbwheel switch settings are ineffective and the preset number in the dividers is established to count one second intervals (or decimal multiples thereof).

4-107. The difference between the A and B versions of these two boards is in the cross-connecting of preset pulse circuits and the preset dividers. These circuit differences establish a different preset number in each case for °C or °F.

4-108. MIXER.

4-109. The schematic diagram of this assembly (Figure 7-16) discloses that the mixer is essentially two nearly identical amplifiers each one handling one of two input signals. Each amplifier has two separate emitter-follower output stages. The output signals of Q5 and Q6 are mixed to appear as a difference signal at terminal 6-F. The output signal of Q2, however, is shifted in phase by 90° in C9, L2, and C10. Where it is mixed with the signal from Q3, the difference signal at terminal 10-L is the same as that at terminal 6-F except that there is 90° separation in phase.

4-110. Except for the inclusion of the phase shifter, the two halves of the mixer are identical. They are shown as mirror images to point up their similarity.

4-111. Because sensor probe T1 is provided with operating current through its signal cable, R1, L5, and C21 comprise a filter to keep radio-frequency from reaching the +14 volt power supply terminal at pin 5. This is also the function of capacitors C2, C4, C6, C17, and C20.

4-112. Probe T2 also requires operating current to be furnished through its cable. A similar filter, mounted on the instrument chassis, is inserted into the power supply circuit by action of relay K2 on the channel selector assembly, A19.

4-113. The combination of L1, R3, and CR1 (and their counterparts on the other half of the mixer) forms a limiter which prevents the signal level on the bases of the emitter followers from exceeding a limit set by the dc voltage drop developed across R3 in the collector current supply circuit. This voltage drop back biases CR1 which clips the signal waveform if its peak rises to the bias level. However, because L1 and its distributed capacitance constitute a tuned circuit, the clipping action of the diode does not square off the tops of the signal waveform; the tuned circuit keeps it round on top though at reduced amplitude.

4-114. <u>CHANNEL SELECTOR, A19.</u>

4-115. The channel selector (Figure 7-17) consists of three relays and associated transistor gates that permit the three relays to be remotely controlled. The main purpose of this assembly is to direct the sensor probe and reference oscillator output signals to appropriate input circuits on the mixer, A18, so that either probe frequency can be compared to the reference standard or the two probe frequencies can be compared with each other. A secondary purpose is to selectively connect calibrating resistors to the reference oscillator to adjust its frequency over a limited range.

4-116. The three relay coils are commonly connected at one end and this connection is returned to -35 volts through pins 15 and S. When the opposite end of any relay coil is grounded, that relay will operate. Local operating mode grounds the relay coils through contacts on the three front-panel latching pushbutton switches (T1, T2, and T1-T2) that select the chosen combination of signals. When the REMOTE pushbutton is latched, ground is removed from the three pushbuttons so they may no longer energize the relay coils. Instead, because -35 volts is then applied via pin 8 to the bases of the three transistor gates, grounding any of the three emitters will cause operating current to flow in the corresponding relay coil. The emitters are selectively grounded at the remote control location.

4-117. <u>REFERENCE OSCILLATOR, A20.</u>

4-118. Transistor Q1 on the reference oscillator assembly (Figure 7-18) operates with a temperature controlled quartz crystal in a separate crystal oven to generate a stable reference frequency. The output of the oscillator is amplified in Q2 for use in a following tuned frequency divider and a full-wave voltage doubler rectifier that furnishes AGC (automatic gain control) voltage to the oscillator stage.

4-119. Viewing the quartz crystal as a series resonant circuit of high Q, capacitors C4 and C16 are seen to be effectively connected across the resonant element. They form a capacitive voltage divider by means of which a portion of the voltage developed across the crystal can be applied to the emitter of Q1 to maintain oscillation. As the base of Q1 is effectively at ground for signal voltage, Q1 may be considered a grounded base amplifier operating at the resonant frequency. Although the base is grounded for signal voltage, the dc bias conditions at the base are established by the level of voltage fed back from the AGC voltage doubler. The polarity of this control voltage is such as to limit the signal voltage amplitude at the collector of Q2.

4-120. Transistor Q2 is a straightforward untuned amplifier that is entirely conventional. Both input and output are capacitively coupled and the dc bias conditions are established by resistors in the base and emitter circuits. Signal voltage is developed across a load resistor in the collector circuit.

4-121. The AGC voltage doubler is in no way unusual. CR1, CR2, C10, and C11 are connected as a regular full-wave voltage doubler rectifier which receives the signal output of Q2. The dc voltage developed is added to a portion of the -35 volt power supply voltage and the combined result used to bias the base of Q1. As the signal voltage tends to rise, the bias voltage increases in a way to lower the gain of the oscillator transistor thus keeping the output level nearly constant.

4-122. The resonant frequency of the quartz crystal can be altered slightly to zero beat at the range of ice-point frequencies found in production sensor crystals. This is done by changing the voltage applied to varicap CR2 (chassis mounted on the parent instrument). This voltage is adjusted through the action of R7, R8, R9, and R26 which are selectively connected by the channel selector as various modes of operation are established by pressing the front panel pushbuttons.

4-123. The combination of C12, L2, and CR3 forms a resonant circuit at the oscillator frequency. CR3 is a voltage variable capacitor which is biased by voltage developed across R12 so that it never goes into conduction. Its capacity decreases as the voltage across it rises. During the first of two successive cycles of input signal, the voltage is low and the capacitor can take a charge from the voltage developed across L2. During the second cycle the voltage continues to rise and the capacity decreases so charge must leave the capacitor. At about the time the second cycle has reached its positive peak, the capacity is at its minimum and the reversal of the signal voltage direction causes the capacity to start increasing again. As this means the capacitor can start taking a charge again, the voltage continues to fall in what can be likened to regenerative action. The fall of voltage is rapid until the reversal at the bottom of the wave and then the voltage again rises toward a peak that occurs two cycles later. This action results in frequency division by two. The divided signal is amplified in Q3 which is a conventional linear amplifier.

4-124. HIGH SPEED DIVIDER, A23.

4-125. Little need be said about the high speed divider (Figure 7-19). It consists of four cascaded binaries so it operates as a scale-of-16 device. No decoding or resetting is used but in other respects this divider is like others previously described. That is, it responds to positive-going input pulses. Sixteen input pulses result in one output pulse. Its purpose is to furnish clock pulses to the preset dividers after passing through the gate control assembly.

4-126. RESOLUTION SELECTOR, A24.

4-127. As a piece of hardware the resolution selector (Figure 7-20, or Figure 7-21 for the 2801A-M6) is very similar to the channel selector A19. Its function, however, is to direct clock pulses into a selected stage of the preset decimal divider. Depending on which stage receives the incoming clock pulses, the time interval may be either a unit value or one ten times as long or one-tenth as long. The same sort of transistor gates are used to extend resolution selection to a remote location. The front panel resolution selector switches are deprived of ground when the REMOTE pushbutton is latched. Indicator lamps are individually associated with each relay to show which relay is operated and consequently what resolution has been selected. These three indicator lamps represent decimal points in the displayed number.

4-128. POWER SUPPLY, A28.

4-129. Operating voltages for the entire Quartz Thermometer are obtained from circuits on assembly A28. This assembly includes two bridge rectifiers and a reference voltage regulator. (See Figure 7-22.)

4-130. The two bridge rectifiers are conventional. They operate from separate grounded center-tapped secondaries on the power transformer. In effect, each bridge constitutes two separate full-wave center-tapped rectifiers exhibiting opposite polarity outputs. Consequently both negative and positive voltages with respect to ground can be obtained.

4-131. The two 175 volt outputs appear as unregulated + and - voltages at pins 14 and 3. Additionally, the -175 volts is used to supply collector current to A28Q1 via load resistor R2. The amount of collector current, and therefore the voltage at pin 2, is established by the relative base-emitter voltage on A28Q1. As the emitter of Q1 is at a fixed voltage below ground as set by the reference diode CR9, voltage changes at the base of A28Q1 will be reflected as voltage changes at pin 2. The level of base voltage is established by voltage divider R6, R7, and R8, and the amount of voltage appearing at pin 15. This voltage is normally set to be -35 volts and it results from dropping the voltage available at pin 7 through the chassis-mounted series pass transistor Q2. (See Figure 7-1.) The base of Q2 is directly coupled to the emitter of chassis-mounted Q1. Therefore, they may be considered as acting as a single transistor with increased current sensitivity. The base of chassis-mounted Q1 is connected to the collector of A28Q1. This establishes a negative feedback relationship between the input at the base of A28Q1 and the emitter of Q2. Any tendency of the voltage at pin 15 to become more negative will result in greater conduction in A28Q1 with the consequence that the base of chassis-mounted Q1 goes more positive. This causes Q2 to increase its resistance thus offsetting any tendency of its emitter voltage to move more negative. Because R7 is adjustable, the exact value of base voltage needed to set pin 15 to -35 volts can be obtained.

4-132. Positive 14 volts is obtained from the emitter of chassis-mounted Q3 which, with R21, drops the voltage obtained from the positive section of the low voltage bridge. After 60 cycle filtering, the unregulated dc output voltage is used to establish a pre-regulated reference voltage across CR5 for use by CR1. In this way CR1 reference voltage applied to the base of Q3 can be made exceptionally stable. As the base of Q3 is fixed by CR1, the emitter of Q3 will also remain well fixed because of emitter follower behavior.

4-133. HP-2830A SENSOR OSCILLATOR.

4-134. The sensor oscillator, which is contained in an individual die-cast aluminum housing, consists of an LC oscillator that is frequency controlled by the sensor probe crystal, followed by a one-stage broadly tuned RF amplifier. (See Figure 7-23.)

4-135. Capacitor C9, in series with the sensor crystal, permits adjustment of the resonant frequency over a range sufficient to provide zero beat between crystals having frequencies matched to within 100 cps. It is accessible through an adjusting hole in the oscillator case.

4-136. Capacitor C3 tunes the collector-connected feedback transformer to resonance. This capacitor does not ordinarily require adjustment. Therefore it is accessible only by opening the sensor oscillator case.

4-137. Operating current for the sensor oscillator is furnished through the coaxial cable that carries the output signal.

SECTION V
MAINTENANCE

5-1. PERFORMANCE CHECK.

5-2. A routine performance check can be accomplished on the Quartz Thermometer without the need for any additional instruments or equipment. Merely turn on instrument power when both probes and sensor oscillators are connected, and observe the ambient temperature indication. Follow the procedure given in Section III of this manual for setting up and operating the instrument. If the ambient temperature indication falls in the range of 20 to 30°C, and the differential temperature is in the range of 1°C or thereabouts, it can be presumed that the instrument is capable of performing correctly. If calibration procedures cannot be accomplished, some of the analysis procedures given in following paragraphs may help to determine the area in which the trouble lies.

5-3. TROUBLE ANALYSIS.

5-4. Trouble such as complete failure of the instrument to light up, points toward power failure. Check fuses, power source, and interconnecting power cable before opening the instrument case for further analysis. When the symptoms are not clear-cut, it is helpful to measure the various voltages that are indicated on the composite drawing. Although the +14 volt supply is regulated, it is not adjustable and production tolerance permits it to vary from its nominal value by about 15%. The -35 volt supply is adjustable and R7 on A28 should be set so the voltage measured at F2 is -35 ±1.5 volts. If the 175 volt supplies fail, the glow lamps will not light even though the instrument may work in all other respects. The 175 volts supplies should not show deviation greater than ±10 volts.

5-5. As a general procedure, trouble analysis is much easier if parts or module substitution can be effected. The 2801A Quartz Thermometer contains some duplicate modules which can be switched around to help isolate the cause of a malfunction.

5-6. <u>EXCHANGING MODULES.</u>

5-7. Although probes and sensor oscillators are normally used in mated combinations, for testing purposes there is no reason for not switching probes between the two sensor oscillators. More than that, the sensor oscillators need not be kept in their assigned front panel drawers if switching them will help to locate trouble. For example, if both probes work with one sensor oscillator but not with the other, the next step should be to exchange oscillator locations in the parent instrument. The results of this exchange will indicate whether the fault lies in the sensor oscillator rather than in the internal circuits of the parent instrument. To mention just one possibility, if the trouble is related to an oscillator location, perhaps the circuit providing operating voltage to the sensor oscillator is not complete. Reference to the composite diagram (Figure 7-1) will help determine successive steps needed to isolate a fault of this nature.

5-8. Other modules duplicated in the Quartz Thermometer are the Preset dividers and the display counters. A little later we will offer some suggestions as to how switching these modules can be helpful in locating a fault.

5-9. First, though, we will discuss a fault that would prove most vexing if no opening wedge could be devised to analyze it. This is failure of the gate control to open the counter and divider gates so pulses can accumulate. The two assemblies directly concerned with gate control are A10 and A11. However, faults in other areas of the instrument can also cause failure of the gate enable function. One fault that comes to mind is absence of clock pulses which are needed to step the preset dividers to coincidence. Without coincidence from the preset dividers, the gate control board is disabled. The next paragraphs give a procedure to find out why there are no gating pulses.

5-10. <u>GATE PULSE FAILURE.</u>

CAUTION

No circuit boards should be removed or replaced without first removing power from the instrument. Failure to heed this caution could result in damage to the circuits.

5-11. Disconnect power from the instrument; then remove the top and bottom covers. Remove circuit boards A10 and A11. Install both sensor oscillators and connect both probes. Latch the T_1-T_2 pushbutton, apply power, and observe a running count accumulating in the display counter. What is seen is the beat frequency pulses accumulating without the time limit normally imposed by preset divider coincidence acting through gate control board A10.

5-12. The beat frequency will be quite low and pulses slow to accumulate if the two probes are producing nearly the same frequency. Warm one of the probes with your hand to increase the frequency difference. In that way you can be sure a count is being generated and accumulated.

5-13. Now if either the T_1 or T_2 pushbutton is pressed, the beat frequency should increase because the difference between the probe frequency and the reference oscillator frequency is normally much greater than the difference between two probe frequencies. However, if the reference oscillator is not working, the numbers in the display counter will remain unchanged except for a possible random movement of the least significant digit. In this case, there is the possibility that the tuned frequency divider on

A20 needs adjustment. Instructions for doing this are given in paragraph 5-35.

5-14. When the reference oscillator is found to be working, the possibility arises that the high speed divider, A23, is at fault. A square wave of 88,150 Hz and about 1.2 volts p-p can be expected at pin 13 of A23. (In M1 instruments it will be 73,412 Hz.) Without the use of other instruments, you can determine if pulses are present by connecting a .01 capacitor (nominal value) between A1-1 and A23-13. This connection puts the output of the high speed divider directly into the amplifier that furnishes an input to the least significant digit (LSD) counter in the counter assembly. If clock pulses are present, they will cause a running count to accumulate in the display counter when the RATE pushbutton is latched.

5-15. Having ruled out absence of clock pulses as the cause of gating pulse failure, we must now direct out attention to assemblies A10 and A11. Do this:

a. Turn off instrument power.

b. Insert A10 in the XA10 receptacle being careful not to put it into the XA11 receptacle inadvertently.

c. Unlatch all RESOLUTION pushbuttons by partially pressing one of the unlatched ones just far enough to release the lock.

d. Turn on instrument power and observe a running count accumulating in the display counter; this can continue indefinitely.

e. Press the .01 pushbutton; the gate indicator lamp on the front panel should go out and the count should stop almost instantly.

f. Unlatch the .01 pushbutton and momentarily turn power off and again turn it back on; the gate indicator lamp should glow and a running count should again be visible.

g. Press the .001 pushbutton and see the count stop and the gate lamp go out after about a second or two of delay.

h. Repeat step f, then press the .0001 pushbutton and see that the delay before stopping the count increases to about 10 to 15 seconds.

5-16. What this has demonstrated is that the A10 board is working as it should and cannot be blamed for gate pulse failure. An examination of the A11 functions is next called for; proceed as follows:

a. Turn off instrument power.

b. Remove board A10 and replace board A11. Be sure A11 is not inadvertently installed in the XA10 receptacle.

c. Turn on instrument power, press and hold the RESET pushbutton, and observe a running count accumulate in the display counter.

d. Release the RESET pushbutton momentarily and then press and hold it again. Observe the running count resume, starting from zero.

5-17. This test shows that ground applied to pin 5 of A11 is forcing the transfer multivibrator to go set and so remain when the -35 volts normally biasing Q2 through R5 is pulled to ground through CR5. When the transfer multivibrator is held set, the display transfer gates are enabled so the continuously occurring running count becomes visible. If the running count is seen to start from zero each time the RESET pushbutton is pressed, this shows that a reset pulse is being generated in Q7.

5-18. Successful completion of all the foregoing tests will have ruled out just about everything but the sample rate multivibrator as the cause of gate pulse failure. Further analysis at the pc board level will require test equipment; preferably an oscilloscope such as the HP 175, but at least a VTVM like the HP 412A.

5-19. COUNTER AND DIVIDER PERFORMANCE EVALUATION.

5-20. When the counter and divider gates are being properly enabled, the counting functions can be evaluated by using a procedure that applies clock pulses to the counter input and the divider input simultaneously. Under these conditions, each pulse that affects the preset divider is also recorded as one count in the display counter. When the preset divider has been stepped to coincidence, the display counter will show how many pulses this has required. A gross check of the entire capacity of the preset divider is made by preventing any preset number from being entered into the divider after both the counter and divider have been reset. Then, when the clock pulses are gated through to the respective inputs, coincidence in the dividers will not occur until 16 times some power of ten pulses have been applied. The power of ten will correspond to the number of decimal divider stages connected in the chain. This is a function of the RESOLUTION pushbutton selected. Preset pulses to the dividers are interrupted by partially pressing the RATE pushbutton so the circuit between A11-6 and the thumbwheel switches is broken. The RATE pushbutton cannot be latched when this test is performed because then the preset pulse from A11-6 would be applied to the hard wired preset gates which put 88,150 into the dividers.

5-21. If the .01 pushbutton is latched for this test, the display counter should exhibit 0160.00. Pressing the .001 pushbutton will shift the numbers and decimal point one place to the left, and pressing the .0001 pushbutton will shift everything one more place to the left. This time the leftmost digit will be dropped and the digit 6 will occupy the MSD location. The display will then appear as: 60.0000. Any of the numbers cited as representative displays can vary by one count in the least significant digit position; thus the last cited example might appear as 59.9999. This is not an abnormal indication.

5-22. Because resolution of .01 does not require using dividers A25 and A26, these two assemblies can be substituted in positions XA13, XA14, or XA27 to replace any divider suspected of improper performance. In the same way, the display counter in the MSD location could be used to replace any other equivalent numeric assembly occupying less significant positions.

5-23. Because lack of coincidence in the dividers represents an inhibiting condition, it is possible to completely remove a divider assembly and thereby eliminate its inhibiting effect. When this is done, however, the borrow pulses normally propagated through each divider (except the low-speed-divider) will be interrupted. For that reason, when trying to eliminate the possibility that one of the dividers is not lifting the inhibit signal when coincidence is attained, remove them one at a time starting with the low-speed-divider and progressing sequentially through the chain. Removing the low-speed-divider will make decimal divider A13 represent the most significant digit in the count. Removing A13 passes the MSD function to A14 and so forth.

5-24. EVALUATING SCALE FACTOR FUNCTION.

5-25. When the RATE pushbutton is unlatched, the preset dividers receive preset pulses directed through the scale factor thumbwheel switches. The setting of the switches determines the number that will be preset. As the preset number will be indicated in the counter display when clock pulses are applied to both counter and divider inputs via the .01 capacitor between A1-1 and A23-13 (refer to Paragraph 5-14), the thumbwheel setting can be verified by examining the counter display. Ordinarily the displayed number will be one count less than the number set into the four thumbwheel switches. However, the display may be equivalent to the switch setting or it may fluctuate by one count. For example, a setting of all zeros in the four thumbwheels might display the number 799999 in the .0001 resolution mode. On the other hand, it could show 800000. Either indication would be acceptable. Of course, with resolution setting of .01, the changes resulting from thumbwheel movements could be observed more rapidly because the gate time is short and the display changes more frequently.

5-26. As soon as the RATE pushbutton becomes latched, the thumbwheel settings are bypassed by the hard-wired gate settings. In a °C instrument the hard wiring puts in the number 88150 or in a °F instrument, the number 73412. Assuming gates, dividers, and counters are working correctly, these are the numbers you will observe in the display counter when the RATE pushbutton is latched while the clock pulses are directed to the counter input gate.

5-27. Even though clock pulses are being generated by high-speed-divider A23, the input signal to A23 may not have the waveform required for flawless operation. Oscilloscopic examination of this waveform is the only way in which it can be adjusted to optimum. Adjustment is made to the tuned frequency divider on A20. The procedure is outlined in paragraph 5-35. When the waveform is sufficiently distorted, the clock pulses will cease entirely but a lesser distortion might have no effect other than to cause erratic polarity indications. When trouble appears in the polarity indication function, check the waveform at A20-2 before doing anything else. Another symptom of improper adjustment in the tuned divider is a temperature indication that remains reasonably steady but is obviously wrong. When both probes produce similar erroneous indications, the cause is probably erratic division of the signal to A23 as the result of an improperly shaped input signal.

5-28. Complete failure of the RF portion of the instrument should lead toward investigating A15, A18, or A19. We assume the reference oscillator is working all right if clock pulses are reliably produced. In all likelihood, failure in the mixer, A18, will not affect both sections of the twin-like mixer circuit, so removing board A3 and jumpering A18-6 to A18-10 might get a signal through if trouble occurred in Q2, Q3, Q5, or Q6. Signal tracing would then be used to find out which of these transistors was at fault.

5-29. Signal tracing, again, is the only way to locate trouble in multiplier A15. Adjustment of the several stages, described in paragraph 5-37, must be accurately made to attain the correct output frequency. But once having been made, a slight touch-up adjustment should be sufficient to peak the output signal. An RF VTVM could be used here if the frequency of the output signal were known to be correct.

5-30. We have mentioned a possible cause of improper polarity indication as arising in the reference oscillator. The mixer, too, can cause trouble in this function unless C10 is in proper adjustment. This capacitor determines the amount of phase shift between two beat signals that are in other respects identical. Oscilloscopic comparison of the two beat signals can be made if trouble is suspected in this area but adjustment of the phase shift is normally made by following another procedure that is outlined in paragraph 5-39. Under some conditions it might be helpful to check out the amplifier and Schmitt trigger on board A3 by removing board A2 and putting a jumper between TP2 on A3 and pin 4 of A2. This will apply the mixer output signal directly to the counter circuit via a different route. The counter should then indicate the same as it does when operated via A1 and A2.

5-31. The channel and resolution selectors, A19 and A24, seldom exhibit trouble in the relays which are sealed. However, the transistor and diode circuits on these boards should be checked out if any operating difficulty is encountered.

5-32. ADJUSTMENTS.

5-33. Although the Quartz Thermometer can be performance checked without the use of other instruments, adjustments which require removal of top or bottom covers must not be attempted unless adequate test equipment is at hand. Of the several dc operating voltages used in the Quartz Thermometer, only the -35 volt supply is adjustable. A service-type voltohmmeter is satisfactory for adjusting this voltage and for measuring the other dc voltages all of which are permitted fairly wide tolerance. Table 5-1 lists

Table 5-1. Operating Voltages

VOLTAGE	WHERE MEASURED	REGULATION	LIMITS	MAX RIPPLE
	From chassis to:		(volts dc)	(Millivolt rms)
+ 175	XA28-14	unregulated	± 10	not stated
- 175	XA28-3	unregulated	± 10	not stated
+ 14	XA3-4	0.5 volts	± 2	3
- 35	XA28-15	0.5 volts	± 2	25
- 9.5	XA28-13	not stated	not stated	not stated
- 17.5	XA28-12	not stated	not stated	not stated

the voltages and their limits. High-frequency waveforms and their levels are critical; they can only be observed by using an oscilloscope such as the HP 175A or its equivalent. Unless you have an instrument of this quality, do not attempt to adjust the tuned frequency divider on board A20, or the Schmitt trigger and polarity detector on boards A2 and A3. If an accurate calibration of the RATE function is required, a frequency standard of 100 kHz with an accuracy of one part per million should be used. Input signals below .5v rms will not give consistent results in rate measurements.

5-34. It should seldom be necessary to adjust any of the internal circuits except after parts replacement. However, an orderly procedure for adjusting each adjustable circuit is given here; the user to select those he needs. The first step should always be, of course, to adjust the operating voltage to -35 ±2 volts by setting R7 on A28. This voltage is measured at F2. (See Figure 7-1.)

5-35. ADJUSTMENT OF A20, REFERENCE OSCILLATOR.

5-36. The fundamental frequency at which the reference oscillator works is established by a quartz crystal contained in a separate temperature controlling oven. Although the exact frequency of the crystal is adjustable over a small range, this adjustment is not part of the reference oscillator adjustment. The only adjustment on the reference oscillator board is that which tunes the two-to-one frequency divider. Proceed as follows:

a. Connect scope probe to XA20-2 and adjust L2 and C12 on A20 until the principal waveform observed is 1.41 MHz (this will be 1.174 MHz on °F instruments) and a maximum amplitude greater than 7v p-p is obtained.

b. As L2 is adjusted in both directions, the frequency will double and the amplitude will halve at the extreme points of adjustment. Over a portion of the range between the extreme points a glitch will appear (see Fig. 5-1). The final setting of L2 should be approximately centered between the two extremes at a point where the waveform is as smooth as possible (no glitch).

Note

The final adjustment point should not be near either extreme as ambient temperature change can cause a shift outside the operating range.

5-37. ADJUSTMENT OF A15, MULTIPLIER.

5-38. Although the same multiplier board is used for both °C and °F instruments, the tuning of its various stages is done differently to achieve multiplication of 20 and 24 respectively. On the assumption that the fundamental input frequency is correct, we are interested in examining frequency ratios as the signal progresses through the multiplier. For this reason it is convenient to adjust the scope to present an easily counted number of cycles of the input frequency as measured at A15. Then the number of cycles counted at the output of each successive stage is a small integral number multiple of the number of input cycles input to that stage. Do this:

a. Remove A15 and reinstall it using an extender board. Connect the 10:1 scope probe to A15-14 and adjust the scope controls to display an integral number of cycles occupying the full width of the graticule.

b. Move the probe to the base of Q2 and adjust L1 and L2 to produce twice the number of cycles (three times in °F instruments).

c. Re-adjust the scope for a smaller number of cycles in the full width graticule and move the probe

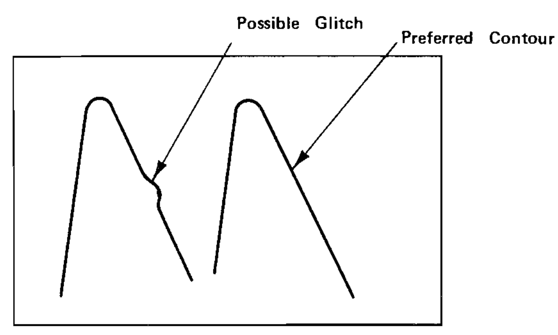


Figure 5-1. Tuned Frequency Divider Output Waveform

to the base of Q3. Adjust L3 and L4 to produce five times the number of cycles (four times in °F instruments).

d. Re-adjust the scope for a smaller number of cycles; move the probe to A15-2; adjust L5 and L6 to produce twice the number of cycles seen previously. Repeat the adjustment of L1, L2, L3, and L4 to obtain maximum amplitude of the output signal. This signal should be greater than 6 v p-p.

5-39. ADJUSTMENT OF POLARITY SENSOR.

5-40. Correct adjustment of the polarity sensing function entails use of adjustable elements on boards A2, 3, and 18. Because the action of Schmitt trigger A2 is related to the precision with which polarity indications will be given, this trigger is adjusted to achieve optimum performance in this function. The adjustment that is necessary for good polarity sensing is also adequate for rate counting.

5-41. To be sure the polarity sensing function works over a wide range of temperatures, the polarity sensor is adjusted while one probe is inserted in an ice bath and the other probe is in an oven capable of providing and maintaining 240±5°C. (Do not exceed the maximum temperature rating.) The ice bath is prepared as described in paragraph 3-27. If an oven is not available, one probe may be inserted in boiling water although the reliability of rate measurements above 100 kHz may then be limited. This is so because the performance of the Schmitt trigger in the counting function can not be assured unless polarity adjustments are made at higher frequency.

5-42. Waveforms are observed by capacitively coupling both Schmitt trigger outputs into the scope probe simultaneously. Enough coupling results from merely clipping the test prod to the insulated space between TP1 and TP2 on board A3. Press T_1-T_2 pushbutton then carry on as follows:

a. Using the scope controls, set point A of the observed waveform to the leftmost line of the graticule; then adjust the SWEEP VERNIER control to put point E on the 8th line of the graticule. See Figure 5-2.

b. Adjust R9 on A2 to set point C at line 4.

c. Adjust C10 on A18 to set point B at line 2.

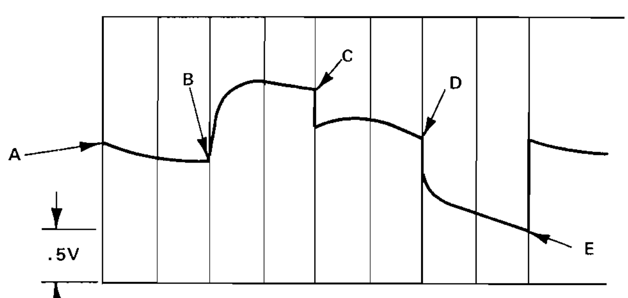


Figure 5-2. Polarity Sensor Waveforms

d. Adjust R13 on A3 to set point D on line 6.

e. Repeat steps b, c, and d until all waveform points are within one millimeter of the designated lines.

5-43. 2830A SENSOR OSCILLATOR ADJUSTMENT (Type 711).

5-44. An ice-point calibration is described in Section III. The procedure given there includes adjustments to C9 in the sensor oscillator. Capacitor C9 is accessible through a hole in the oscillator case cover. The sensor oscillator circuit also includes another adjustable capacitor, C3. This capacitor can only be adjusted by opening the sensor oscillator case. Normally the range of adjustment over which C3 can be set is quite small. It is important that C3 be first adjusted to its maximum capacity by aligning the orange dot over the arrow as shown in Figure 5-3. In this position the oscillator will probably be disabled. Clockwise rotation of C3 will cause the oscillator to suddenly start oscillating. To be sure C3 is properly set for the highest frequency required of the sensor oscillator, the associated probe must be exposed to a temperature of 245 ±5°C. Complete adjustment on the sensor oscillator is made as follows:

a. Install the 2830A oscillator with its probe connected, in the parent instrument. Connect either the oscilloscope probe or an HP 411A RF VTVM to J4 (or J5) on the rear panel.

b. Put the probe into the high temperature chamber, press T_1 (or T_2) to provide operating power to the oscillator.

c. Set C3 to maximum capacity as described before; then rotate clockwise until oscillation is perceived. Continue turning the adjusting shaft of C3 until maximum amplitude has been passed very slightly. A perceptible but not very significant decrease in amplitude is all that is required.

d. Determine that oscillation continues for all positions of C9 as it is rotated through 360 degrees. The minimum signal level observed during this procedure should not fall below 150mv RMS.

e. Immerse the probe in a properly prepared ice-bath and adjust C9 to obtain an indication of 000.000 ±1 when the .001 pushbutton is pressed. Alternatively, C9 can be adjusted so that the differential temperature

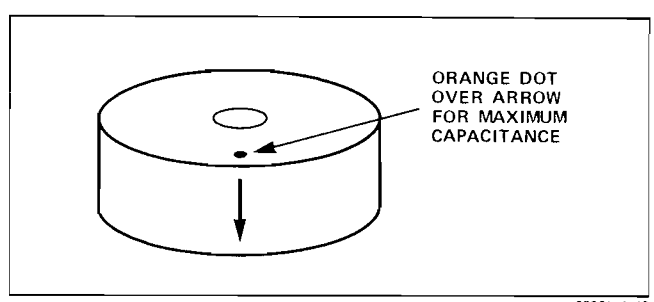


Figure 5-3. Sensor Oscillator Capacitor C3

indication between the instrument's two probes is 000.000 ±1. In this case, the T_1-T_2 mode switch must be pressed before adjustment is made. Both probes, of course, must be in the ice-bath.

5-45. 2830A SENSOR OSCILLATOR ADJUSTMENT (Earlier than type 711).

5-46. Earlier sensor oscillators are not provided with access holes in their top covers. For this reason, the cover must be removed when C9 is in need of adjustment. Care should be taken to avoid adjusting C3 by mistake. However, if C3 needs adjustment, the procedure merely requires C3 to be set to a point where oscillation is obtained reliably each time the instrument is turned on while the probe is at ambient temperature. Observation of the readout as the probe is exposed to the full range of temperature is then used to be sure the correct setting of C3 has been obtained. Additional adjustment will be needed if oscillation is not obtained over full range. Zero-beat with either the other sensor oscillator or, alternatively, with the reference oscillator, is accomplished by adjusting C9 as described for later model oscillators. Measurements are made at J4 or J5 as appropriate.

5-47. ADJUSTMENT OF RATE FUNCTION.

5-48. In instruments designed primarily as counters, the Schmitt trigger in the input path is adjusted for best symmetry of the resultant square wave. The Quartz Thermometer, however, uses the Schmitt trigger mainly for polarity sensing and only secondarily to provide pulses to the counting circuits. For this reason the Schmitt triggers are not adjusted to obtain optimum counter performance. Do not, therefore, make changes to the Schmitt trigger adjustments when making adjustments to the rate measuring circuits.

5-49. A front-panel sensitivity control is furnished so that signals having amplitudes of 0.5 to 10 v rms can be applied to the rate counting input. If the signal input falls below the minimum, reliable results cannot be expected. If inconsistent results are obtained when adequate signal level is present, the input frequency may be higher than that for which trigger adjustments were made in the temperature measuring mode. That is, the probe was not exposed to the highest permissible temperature during trigger adjustments. (Refer to paragraph 5-41.)

5-50. Rate measurements are made by opening the gate to the digital counter for a precisely defined interval of time. The duration of this interval is determined by the incidence of a fixed number of clock pulses in the preset dividers. As this number does not change, calibration is accomplished by changing the rate of clock pulses. When the RATE pushbutton is latched, R9 on the calibration board (5060-5831) is connected to the reference oscillator crystal tuning varicap CR2. Changing the setting of R9 alters the voltage applied to the varicap and thus changes the frequency of the reference oscillator crystal by a small amount. By this means, the clock interval may be adjusted to the precision required. Make the adjustment as follows:

a. Apply a 100 kHz signal from a standard having an accuracy of at least one part per million to the input connector on the front panel.

b. Adjust the sensitivity control to obtain consistent successive readout of the applied frequency.

c. Adjust R9 until the readout is equal to the known applied frequency ± one count when the .001 pushbutton is latched.

5-51. SUMMARY OF ADJUSTMENTS.

5-52. The following paragraphs describe a procedure for checking the adjustment of the internal reference oscillator A20, multiplier A15, and polarity sensor A3, and for checking the recorder output and remote program circuits. Verify the operating voltages given in Table 5-1 before altering circuit adjustments.

5-53. Internal Reference Oscillator.

a. Set the 2801A controls for operation as follows:

(1) T_1 (or T_2) Mode

(2) .01 Resolution

(3) Sample rate to repeat conveniently.

b. Using an oscilloscope, check the signal at pin 2 of XA20. The amplitude should be greater than 7 volts p-p; each complete cycle occurs in approximately 0.7 μ sec. (See Figure 5-1.) If adjustment is needed, refer to paragraph 5-35.

5-54. Multiplier.

a. Set the 2801A controls the same as in paragraph 5-53. The probe selected for use should be at ambient temperature.

b. Using an oscilloscope, check the signal at XA15, pin 2. The amplitude should be greater than 0.6 volts p-p; frequency, about 28 MHz. If adjustment is needed, refer to paragraph 5-37.

5-55. Polarity Sensor.

a. Using either a container of boiling water or an oven at 245 ±5°C, raise the temperature of one of the probes. (Do not exceed the maximum temperature rating of the probe.)

b. Set the 2801A controls for operation as follows:

(1) T_1-T_2 Mode

(2) .01 Resolution

(3) Sample rate to repeat conveniently.

c. Clip the probe of an oscilloscope to the A3 polarity detector board between the two test points. This probe should be air-coupled; not directly connected to the circuitry.

d. Adjust the scope's sweep vernier and horizontal centering as necessary. One complete cycle should coincide with the scope graticule as shown in Figure 5-2. Amplitude should be adjusted for a convenient display. If the observed waveform is significantly different than that in Figure 5-2, perform the adjustment procedure given in paragraph 5-39.

5-56. Digital Recorder Output.

a. Connect an HP 562A Digital Recorder, or equivalent, to the rear-panel RECORDER connector (J7).

b. Change the Thermometer's mode, resolution, and function, noting that the Recorder's printed record is correct.

5-57. Remote Programming.

a. Connect the HP 562A Recorder as in paragraph 5-56.

b. On the 2801A, press the REMOTE pushbutton.

c. Program the Thermometer by connecting pins of the PROGRAM connector (J6) to ground. Note that the Recorder's printed record is correct, as tabulated at the right:

On Remote Program Connector J6

Grounding Pin results in	Printed Record of Program Function:
w	T_1 Mode
p	T_2 Mode
e	T_1 - T_2 Mode
CC	.01 Resolution
AA	.001 Resolution
EE	.0001 Resolution
c	Reset
HH	Common

5-58. PIN CONNECTIONS.

5-59. Pin assignments for connectors J6 and J7 are listed in Tables 5-2 and 5-3.

Table 5-2. Pin Connections for Connector J6

Pin	Function	Internal Destination
B, F, L, R, V, Z, d, j	Spare	
u	- 35V Output	S3-D N.O.
y	+ 14V Output	S3-D N.O.
CC	.01 Remote Resolution Selection	A24-J
AA	.001 Remote Resolution Selection	A24-6
EE	.0001 Remote Resolution Selection	A24-D
HH	Ground	
D, J, N, T, X, b, f, m, s	Spare	
w	T_1 Remote Mode Selection	A19-C
p	T_2 Remote Mode Selection	A19-10
e	T_1 - T_2 Remote Mode Selection	A19-12
A, E, K, P, U, Y, h, n, t, x, BB	Spare	
c	Remote Reset	A11-5
r	Used with HP Sensor Oscillator Scanners to permit scanned Sensors to be zero-adjusted individually.	CR104
M	Used with HP Sensor Oscillator Scanners to permit scanned Sensors to be zero-adjusted individually.	Junction of CR6, R23
S	Used with HP Sensor Oscillator Scanners to permit scanned Sensors to be zero-adjusted individually.	A19-3
C, H, W, a, k, z	Spare	
v	Negative reference - 17.5V	A28-12
FF	Positive reference - 9.5V	A28-13
DD	Scan Advance	J7-49

Table 5-3. Pin Connections for Connector J7

Pin	Function		Internal Destination
1	1	10^0 digit	A9-6
2	2		A9-9
26	2'		A9-13
27	4		A9-14
3	1	10^1 digit	A8-6
4	2		A8-9
28	2'		A8-13
29	4		A8-14
5	1	10^2 digit	A7-6
6	2		A7-9
30	2'		A7-13
31	4		A7-14
7	1	10^3 digit	A6-6
8	2		A6-9
32	2'		A6-13
33	4		A6-14
9	1	10^4 digit	A5-6
10	2		A5-9
34	2'		A5-13
35	4		A5-14
11	1	10^5 digit	A4-6
12	2		A4-9
36	2'		A4-13
37	4		A4-14

Pin	Function		Internal Destination
13	1	Mode:	A19-E
14	2	bcd 1 = T_1	A19-D
38	2'	bcd 2 = T_2 bcd 3 = T_1-T_2	R44
39	4	bcd 5 = Rate*	R41
15	1	Polarity:	A3-8
16	2	bcd 1 = +degrees	A3-7
40	2'	bcd 2 = -degrees	R40
41	4		R43
17	1	Resolution	A24-L
18	2	bcd 2 = .01	A24-N
42	2'	bcd 3 = .001	A24-k
43	4	bcd 4 = .0001	R42
22	Print Inhibit		A11-9
23	Print Command		A3-6 via CR4
24	Negative reference -17.5V		A28-12
25	Positive reference -9.5V		A28-13
49	Scan Advance		J6-DD
50	Ground		
19, 20, 21, 44, 45, 46, 47, 48	Spare		
	*bcd 7 = Rate in 2801A-M6		

5-60. The following table provides information on connections between the Quartz Thermometer and a Model R86-562A/R Digital Recorder and on the assignment of connectors P101 through P109 to column boards 1 through 9.

2801A QUARTZ THERMOMETER		DIGITAL RECORDER (R86-562A/AR)		
J7 PINS	FUNCTION	J101 PINS	CONNECTOR ASSY.	COLUMN BOARD
17, 18, 42, 43	RESOLUTION	17, 18, 42, 43	P109-6, 5, 4, 3(9BLK)	1
1, 2, 26, 27	DATA 10^0	1, 2, 26, 27	P101-6, 5, 4, 3(1BLK)	2
3, 4, 28, 29	DATA 10^1	3, 4, 28, 29	P102-6, 5, 4, 3(2BLK)	3
5, 6, 30, 31	DATA 10^2	5, 6, 30, 31	P103-6, 5, 4, 3(3BLK)	4
7, 8, 32, 33	DATA 10^3	7, 8, 32, 33	P104-6, 5, 4, 3(4BLK)	5
9, 10, 34, 35	DATA 10^4	9, 10, 34, 35	P105-6, 5, 4, 3(5BLK)	6
11, 12, 36, 37	DATA 10^5	11, 12, 36, 37	P106-6, 5, 4, 3(6BLK)	7
15, 16, 40, 41	SIGN	15, 16, 40, 41	P108-6, 5, 4, 3(8BLK)	8
13, 14, 38, 39	MODE	13, 14, 38, 39	P107-6, 5, 4, 3(7BLK)	9

NOTE: The blue connector carrying control signals and reference voltages marked A (P201) must be installed on the uppermost connector of the control board. The blue connector marked B (P202) must be installed on the lowest, the unwired, connector of the control board.

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION

6-2. This section contains information for ordering replacement parts. Table 6-1 lists parts in alphanumerical order of their reference designations and provides the following information on each part:

a. Description of the part (see list of abbreviations below).

b. HP stock number.

c. Typical manufacturer of the part in a five-digit code: see list of manufacturers at the back of this section.

d. Manufacturer's part number.

6-3. ORDERING INFORMATION

6-4. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office (see the list at the rear of this manual for addresses). Identify parts by their Hewlett-Packard stock numbers.

6-5. To obtain a part that is not listed, include:

a. Instrument model number.

b. Instrument serial number

c. Description of the part.

d. Function and location of the part.

REFERENCE DESIGNATORS

A	=	assembly
B	=	motor
BT	=	battery
C	=	capacitor
CP	=	coupler
CR	=	diode
DL	=	delay line
DS	=	device signaling (lamp)
E	=	misc electronic part
F	=	fuse
FL	=	filter
IC	=	integrated circuit
J	=	jack
K	=	relay
L	=	inductor
LS	=	loud speaker
M	=	meter
MK	=	microphone
MP	=	mechanical part
P	=	plug
Q	=	transistor
R	=	resistor
RT	=	thermistor
S	=	switch
T	=	transformer
TB	=	terminal board
TP	=	test point
V	=	vacuum, tube, neon bulb, photocell, etc.
VR	=	voltage regulator
W	=	cable
X	=	socket
Y	=	crystal
Z	=	tuned cavity, network

ABBREVIATIONS

A	=	amperes
AFC	=	automatic frequency control
AMPL	=	amplifier
BFO	=	beat frequency oscillator
BE CU	=	beryllium copper
BH	=	binder head
BP	=	bandpass
BRS	=	brass
BWO	=	backward wave oscillator
CCW	=	counter-clockwise
CER	=	ceramic
CMO	=	cabinet mount only
COEF	=	coefficient
COM	=	common
COMP	=	composition
COMPL	=	complete
CONN	=	connector
CP	=	cadmium plate
CRT	=	cathode-ray tube
CW	=	clockwise
DEPC	=	deposited carbon
DR	=	drive
ELECT	=	electrolytic
ENCAP	=	encapsulated
EXT	=	external
F	=	farads
FH	=	flat head
FIL H	=	fillister head
FXD	=	fixed
G	=	giga (10^9)
GE	=	germanium
GL	=	glass
GRD	=	ground(ed)
H	=	henries
HDW	=	hardware
HEX	=	hexagonal
HG	=	mercury
HR	=	hour(s)
HZ	=	hertz
IF	=	intermediate freq
IMPG	=	impregnated
INCD	=	incandescent
INCL	=	include(s)
INS	=	insulation(ed)
INT	=	internal
K	=	kilo = 1000
LH	=	left hand
LIN	=	linear taper
LK WASH	=	lock washer
LOG	=	logarithmic taper
LPF	=	low pass filter
M	=	milli = 10^{-3}
MEG	=	meg = 10^6
MET FLM	=	metal film
MET OX	=	metallic oxide
MFR	=	manufacturer
MHZ	=	mega hertz
MINAT	=	miniature
MOM	=	momentary
MTG	=	mounting
MY	=	"mylar"
N	=	nano (10^{-9})
N/C	=	normally closed
NE	=	neon
NI PL	=	nickel plate
N/O	=	normally open
NPO	=	negative positive zero (zero temperature coefficient)
NPN	=	negative-positive-negative
NRFR	=	not recommended for field replacement
NSR	=	not separately replaceable
OBD	=	order by description
OH	=	oval head
OX	=	oxide
P	=	peak
PC	=	printed circuit
PF	=	picofarads = 10^{-12} farads
PH BRZ	=	phosphor bronze
PHL	=	Phillips
PIV	=	peak inverse voltage
PNP	=	positive-negative-positive
P/O	=	part of
POLY	=	polystyrene
PORC	=	porcelain
POS	=	position(s)
POT	=	potentiometer
PP	=	peak-to-peak
PT	=	point
PWV	=	peak working voltage
RECT	=	rectifier
RF	=	radio frequency
RH	=	round head or right hand
RMO	=	rack mount only
RMS	=	root-mean square
RWV	=	reverse working voltage
S-B	=	slow-blow
SCR	=	screw
SE	=	selenium
SECT	=	section(s)
SEMICON	=	semiconductor
SI	=	silicon
SIL	=	silver
SL	=	slide
SPG	=	spring
SPL	=	special
SST	=	stainless steel
SR	=	split ring
STL	=	steel
TA	=	tantalum
TD	=	time delay
TGL	=	toggle
THD	=	thread
TI	=	titanium
TOL	=	tolerance
TRIM	=	trimmer
TWT	=	traveling wave tube
U	=	micro = 10^{-6}
VAR	=	variable
VDCW	=	dc working volts
W/	=	with
W	=	watts
WIV	=	working inverse voltage
WW	=	wirewound
W/O	=	without

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Table 6-1. Replaceable Parts

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	HP 2801A QUARTZ THERMOMETER					
A1	AF Amplifier	5060-5004	04404		1	0
A2	Schmitt Trigger	5060-5028	04404		1	0
A3	Polarity Detector	5060-3825	04404		1	0
A4-9	Decimal Counter	5060-5123	04404		6	0
A10	Gate Control	5060-5094	04404		1	0
A11	Sample Rate	5060-5095	04404		1	0
A12	Low Speed Divider	5060-5024	04404		1	0
A13, 14, 25-27	Preset Divider	5060-5096	04404		5	0
A15	Multiplier	5060-5043	04404		1	0
A16A	Preset Gate	5060-5051	04404		1	0
A17A	Preset Gate	5060-5052	04404		1	0
A18	Mixer	5060-5833	04404		1	0
A19	Channel Select	5060-5027	04404		1	0
A20	Time Base	5060-3826	04404		1	0
A23	High-Speed Divider	5060-5023	04404		1	0
A24	Resolution	5060-5038	04404		1	0
A28	Power Supply	5060-5022	04404		1	0
A29A	Lamp	5060-3834	04404		1	0
A30	Polarity Lamp	5060-5041	04404		1	0
A31	Reference Adjust	5060-5831	04404		1	0
B1	Fan, 60 cycle	3140-0030	28480		1	0
	Blade for B1	3160-0035	28480		1	0
C1	C: fxd, cer, 2 × .01 μf, 20%, 250v	0150-0119	56289	36C219A	1	1
C2	C: fxd, al-elect, 700 μf, -10+75%, 75v	0180-1720	56289	39D Sect DFP hdwr.	1	1
C3, 4	C: fxd, al-elect, 20 μf, -10+100%, 200v	0180-0107	56289	D34154	2	1
C5	C: fxd, al-elect, 500 μf, -10+100%, 75v	0180-0047	56289	D32443	1	1
C6, 8, 9	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	3	1
C7	C: fxd, my, 1 μf, 10%, 600v	0170-0073	09134	1041	1	1
C11	C: fxd, cer, .02 μf, -20+80%, 600v	0150-0024	71590	DD03	1	1
C13	C: var, cer, 8 to 50 pf	0130-0017	28480		1	1
CR1	Diode: avalanche	1902-0055	28480		1	1
CR2	C: voltage var, 100 pf, 20%, 20v	0122-0006	01281	1N4815	1	1
CR3	Diode: Si	1901-0025	28480		1	1
CR4	Diode: switching, Si, 50v	1901-0081	28480		1	1
CR5	Diode: avalanche, 30v, 20%, 1 w	1902-0782	28480		1	1
CR102	Diode: Ge, 60v	1910-0016	28480		1	1
DS1	Lamp: indicator, clear	1450-0042	03797	1BG36980 Spec No. 6 red dot	1	0
DS2-4	Lamp: glow, frosted, T-2 bulb	2140-0028	24455	NE2E4	3	3
F1	Fuse: 2a, 250v	2110-0002	28480		1	5
F2	Fuse: 1a, 250v	2110-0001	28480		1	5
J1, 2, 4, 5	Conn: RF, female	1250-0757	95712	401311	4	1
J3	Conn: RF, recept, BNC	1250-0118	28480		1	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	ⓗ STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	Main Chassis (Cont'd.)					
J6	Conn: insert, 50 pin	1251-0338	95238	2550SS	1	1
J7	Conn: insert, 50 pin	1251-0087	02660	57-40500-375	1	1
J8	Conn: power, 3 pin, male	1251-0148	28480		1	1
L1	Inductor: choke, fxd, RF, 12 μh	9100-0371	99800	1537-721	1	1
L2	Inductor: coil, fxd, RF, 10 μh	9100-2265	82142	09-4446-4K	1	1
Q1	Transistor: Ge, PNP	1850-0070	01295	2N1373	1	1
Q2	Transistor: Ge, PNP	1850-0098	28480		1	1
Q3	Transistor: Si, NPN	1854-0039	02735	2N3053	1	1
R1	R: fxd, comp, 220Ω, 5%, 1/2 w	0686-2215	01121	EB2215	1	1
R3, 27	R: fxd, comp, 2.2K, 5%, 1 w	0689-2225	28480		2	1
R4	R: fxd, comp, 4.7K, 5%, 1/2 w	0686-4725	01121	EB4725	1	1
R5	R: fxd, comp, 270K, 5%, 1/2 w	0686-2745	01121	EB 2745	1	1
R6 (S1A/B)	R: var, comp, 250K, 20%, 1/4 w	2100-0318	28480		1	0
R11	R: fxd, comp, 470K, 5%, 1/4 w	0683-4745	01121	CB4745	1	1
R12, 16	R: fxd, comp, 47K, 5%, 1/2 w	0686-4735	01121	EB4735	2	1
R13	R: fxd, metox, 10K, 2%, 1/4 w	0757-0948	19701	MF07C	1	2
R14	R: fxd, comp, 10K, 5%, 1/4 w	0683-1035	01121	CB1035	1	1
R15	R: fxd, metox, 39K, 2%, 1/4 w	0757-0962	19701	MF07C	1	1
R17, 40, 41 42, 43, 44	R: fxd, comp, 100K, 5%, 1/4 w	0683-1045	01121	CB1045	6	1
R18	R: var, 3M, 20%, 2w	2100-0046	28480		1	0
R21	R: fxd, comp, 1K, 5%, 2 w	0692-1025	01121	HB1025	1	1
R28	R: fxd, comp, 2.2K, 5%, 1/4 w	0683-2225	01121	CB2225	1	1
R29	R: fxd, cflm, 10K, 1%, 1/2 w	0727-0891	28480		1	1
S1 A/B (part of R6)	Switch: off-on	NSN			0	0
S2	Switch: slide, DPDT	3101-0033	79727	6501C	1	1
S3	Switch: pushbutton	3101-0707	04404		1	1
S4	Switch: pushbutton	3101-0706	04404		1	1
S5-8	Switch: thumbwheel, BCD, preset	3100-1404	04404		4	1
T1	Transformer	9100-1205	28480		1	1
Y1	Crystal and Oven: high, reference,	5080-5899	04404		1	1
	low, reference	5080-5898	04404		2	1
XA1, 2	Conn: pc, 12 pin	1251-0198	28480		1	1
XA3-15, 18, 20-23, 25-28	Conn: pc, 15 pin	1251-0135	95354	SD615UR	22	2
XA16, 17, 19, 24	Conn: pc, 30 pin	1251-0159	28480		4	1
XF1, 2	Fuseholder	1400-0084	75915	342014	2	0
XY1	Socket: octal	1200-0178	04404		1	0
	Miscellaneous					
	Decal, pushbutton (S3, 4) 11/set	5080-2896	04404		1 set	
	Knob, S1A/B	0370-0084	14493		2	
	Pushbutton (S3, (5 ea); S4 (4 ea.)	0370-0162	28480		9	
	Seal, "O" Ring (2830A)	0905-0087			2	2
	Heat Dissipator, Nut	1205-0025		1101A-1	4	1
	Heat Dissipator, Body	1205-0026		1101A-1	4	1
	Tool, Adjusting	5080-6608			1	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A1 AF AMPLIFIER	5060-5004				
C1	C: fxd, al-elect, 40 μf, -10+75%, 50v	0180-0050	56289	30D406G050DD2-DS	1	1
C2	C: fxd, al-elect, 100 μf, -10+75%, 12v	0180-0039	56289	30D107G012CC2-DSM	1	1
C3	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	28480		1	1
C4	C: fxd, al-elect, 500 μf, -10+75%, 3v	0180-0063	56289	30D507G003DF2-DSM	1	1
C5	C: fxd, mica, 1000 pf, 5%, 300v	0140-0152	72136	DM16F102J	1	1
CR1	Diode: avalanche, Si	1902-0050	28480		1	1
L1	Inductor: coil, fxd, RF, 35 μh	9140-0027	99848		1	1
Q1	Transistor: Si, NPN	1854-0003	28480		1	1
Q2, 3	Transistor: Ge, PNP	1850-0037	02735	2N274	2	1
R1	R: fxd, comp, 1K, 5%, 1/2 w	0686-1025	01121	EB1025	1	1
R2	R: fxd, comp, 68K, 5%, 1/4 w	0683-6835	01121	CB6835	1	1
R3	R: fxd, comp, 180K, 5%, 1/4 w	0683-1845	01121	CB1845	1	1
R4	R: fxd, comp, 150K, 5%, 1/4 w	0683-1545	01121	CB1545	1	1
R5	R: fxd, comp, 33K, 5%, 1/4 w	0683-3335	01121	CB3335	1	1
R6	R: fxd, comp, 22K, 5%, 1/4 w	0683-2235	01121	CB2235	1	1
R7	R: fxd, comp, 2.7K, 5%, 1/4 w	0683-2725	01121	CB2725	1	1
R8	R: fxd, comp, 39K, 5%, 1/4 w	0683-3935	01121	CB3935	1	1
R9	R: fxd, comp, 47K, 5%, 1/4 w	0683-4735	01121	CB4735	1	1
R10	R: fxd, comp, 6.2K, 5%, 1/2 w	0686-6225	01121	EB6225	1	1
R11	R: fxd, comp, 680Ω, 5%, 1/4 w	0683-6815	01121	CB6815	1	1
R12	R: fxd, comp, 150Ω, 5%, 1/4 w	0683-1515	01121	CB1515	1	1
R13	R: fxd, comp, 18K, 5%, 1/4 w	0683-1835	01121	CB1835	1	1
	A2 SCHMITT TRIGGER	5060-5028				
C1	C: fxd, al-elect, 50 μf, -10+75%, 25v	0180-0058	56289	30D506G025CC2-DSM	1	1
C2	C: fxd, mica, 240 pf, 5%, 300v	0140-0199	28480		1	1
C3	C: fxd, mica, 33 pf, 5%, 300v	0160-2150	28480		1	1
C4, 5	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	2	1
CR1	Diode: switching, Ge, 60 piv, 5 ma	1910-0016	28480		1	1
CR2	Diode: Si	1901-0025	28480		1	1
Q1-3	Transistor: Si, PNP	1853-0009	28480		3	1
R1	R: fxd, metox, 18K, 2%, 1/4 w	0757-0954	19701	MF072	1	1
R2	R: fxd, comp, 2.7K, 5%, 1 w	0689-2725	01121	GB2725	1	1
R3, 8	R: fxd, comp, 1.8K, 5%, 1 w	0689-1825	01121	GB1825	2	1
R4	R: fxd, metox, 270Ω, 2%, 1/4 w	0757-0910	19701	MF07C	1	1
R5	R: fxd, metox, 8.2K, 2%, 1/4 w	0757-0946	19701	MF07C	1	1
R6	R: fxd, comp, 27Ω, 5%, 1/4 w	0683-2705	01121	CB2705	1	1
R7, 13	R: fxd, metox, 22K, 2%, 1/4 w	0757-0956	19701	MF07C	2	1
R9	R: var, comp, 1K, 20%, 1/4 w	2100-1533	28480		1	0
R10	R: fxd, metox, 1.2K, 2%, 1/4 w	0757-0926	19701	MF07C	1	1
R11	R: fxd, comp, 47Ω, 5%, 1/4 w	0683-4705	01121	CB4705	1	1
R12	R: fxd, metox, 2.2K, 2%, 1/4 w	0757-0932	19701	MF07C	1	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A3 POLARITY DETECTOR	5060-3825				
C1	C: fxd, al-elect, 40 μf, -15+75%, 50v	0180-0050	56289	30D406G050DD2-DS	1	1
C2	C: fxd, al-elect, 50 μf, -10+75%, 25v	0180-0058	56289	30D506G025 CC2-DSM	1	1
C3, 10, 15	C: fxd, mica, 33 pf, 5%, 300v	0160-2150	72136	RDM15E330J3C	3	1
C4	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	1	1
C5	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	72136	RDM15F201J3C	1	1
C6	C: fxd, al-elect, 100 μf, -10+75%, 12v	0180-0039	56289	30D107G102CC2-DSM	1	1
C7	C: fxd, al-elect, 500 μf, -10+75%, 3v	0180-0063	56289	30D507G003DF2-DSM	1	1
C8, 11, 14	C: fxd, mica, 1000 pf, 5%, 300v	0140-0152	72136	DM16F102J	3	1
C9	C: fxd, mica, 240 pf, 5%, 300v	0140-0199	72136	RDM15F241J3C	1	1
C12, 13, 18, 19	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	72136	RDM15F111J3C	4	2
C16, 17, 20	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	3	1
CR1	Diode: avalanche, 8.66v, 5%, 400 mw	1902-0050	28480		1	1
CR2	Diode: switching, Ge, 60 piv, 5 ma	1910-0016	28480		1	1
CR3, 4	Diode: switching, Si, 50v	1901-0081	28480		2	1
CR5, 6	Diode: avalanche, 10v, 5%, 400 mw	1902-0025	28480		2	1
L1	Inductor: RF, 35 μh, 10%	0140-0027	99848	1035-15-350	1	1
Q1	Transistor: Si, NPN	1854-0003	28480		1	1
Q2-9	Transistor: Si, PNP	1853-0009	28480		8	1
R1	R: fxd, comp, 180K, 5%, 1/4 w	0683-1845	01121	CB1845	1	1
R2, 48	R: fxd, metox, 22K, 2%, 1/4 w	0757-0956	19701	MF07C	2	1
R3	R: fxd, metox, 6.2K, 2%, 1/4 w	0757-0943	19701	MF07C	1	1
R4	R: fxd, metox, 1K, 2%, 1/4 w	0757-0924	19701	MF07C	1	1
R5, 47	R: fxd, metox, 18K, 2%, 1/4 w	0757-0954	19701	MF07C	2	1
R6	R: fxd, comp, 2.7K, 5%, 1 w	0689-2725	19701	GB2725	1	1
R7	R: fxd, comp, 1.8K, 5%, 1 w	0689-1825	01121	GB1825	1	1
R8	R: fxd, metox, 68K, 2%, 1/4 w	0757-0968	01121	MF07C	1	1
R9	R: fxd, metox, 150K, 2%, 1/4 w	0757-0976	19701	MF07C	1	1
R10	R: fxd, metox, 39K, 2%, 1/4 w	0757-0962	19701	MF07C	1	1
R11, 30, 32, 42-45	R: fxd, metox, 47K, 2%, 1/4 w	0757-0964	19701	MF07C	7	3
R12	R: fxd, metox, 300Ω, 2%, 1/4 w	0757-0911	19701	MF07C	1	1
R13	R: var, 1K	2100-1533	19701		1	1
R14	R: fxd, metox, 8.2K, 2%, 1/4 w	0757-0946	19701	MF07C	1	1
R15	R: fxd, metox, 1.2K, 2%, 1/4 w	0757-0926	19701	MF07C	1	1
R16	R: fxd, comp, 27Ω, 5%, 1/4 w	0683-2705	19701	CB2705	1	1
R17	R: fxd, comp, 47Ω, 5%, 1/4 w	0683-4705	19701	CB4705	1	1
R18	R: fxd, metox, 2.7K, 2%, 1/4 w	0757-0934	19701	MF07C	1	1
R19	R: fxd, metox, 680Ω, 2%, 1/4 w	0757-0920	19701	MF07C	1	1
R21	R: fxd, metox, 150Ω, 2%, 1/4 w	0757-0904	19701	MF07C	1	1
R22	R: fxd, metox, 33K, 2%, 1/4 w	0757-0960	19701	MF07C	1	1
R23, 33, 34, 41	R: fxd, metox, 3.9K, 2%, 1/4 w	0757-0938		MF07C	4	2
R24, 27	R: fxd, metox, 2.2K, 2%, 1/4 w	0757-0932	19701	MF07C	2	1

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Table 6-1. Replaceable Parts (Cont'd)

CIRCUIT REFERENCE	DESCRIPTION	ⓗⓟ STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A3 (Cont'd.)					
R25	R: fxd, metox, 1.5K, 2%, 1/4 w	0757-0928	19701	MF07C	1	1
R28,29	R: fxd, metox, 5.1K, 2%, 1/4 w	0757-0941	19701	MF07C	2	1
R31	R: fxd, metox, 270Ω, 2%, 1/4 w	0757-0910	19701	MF07C	1	1
R37,38	R: fxd, metox, 2.4K, 2%, 1/4 w	0757-0933	19701	MF07C	2	1
R39,40,49,	R: fxd, metox, 24K, 2%, 1/4 w	0757-0957	19701	MF07C	4	2
	A4-9 NEW DECIMAL COUNTER	02801-60010			1	
C1	C: fxd, 39 pf, 300v	0140-0190			1	
C2	C: fxd, 22 pf, 500v	0140-0145			1	
C3,4,12	C: fxd, 82 pf, 300v	0140-0193			3	
C5	C: fxd, 47 pf, 500v	0140-0204			1	
C6,9	C: fxd, 180 pf, 300v	0140-0197			2	
C7,11	C: fxd, 91 pf, 300v	0160-2203			2	
C8	C: fxd, 68 pf, 300v	0140-0192			1	
C10	C: fxd, 140 pf, 300v	0140-0217			1	
C13,15	C: fxd, 160 pf, 300v	0160-2206			2	
C14	C: fxd, 130 pf, 300v	0140-0195			1	
CR1,CR2-8	Diode: Si	1901-0025			8	
CR9, CR10-18	Diode: Ger, 60 wiv	1910-0016			10	
DS1A,1B, 2A,2B,3A, 3B,4A,4B	Lamp: Glow	2140-0044			8	
R1	R: fxd, 47K, 5%, .5 w	0686-4735			1	
R2	R: network	0845-0001			1	
R6,7,8,9	R: fxd, 390K, 5%, .250 w	0683-3945			4	
R10,13,15, 28,38,41, 51,54	R: fxd, 7.5K, 5%, .5 w	0686-7525			8	
R11,12,26, 27,39,40, 52,53	R: fxd, 56K, 5%, .250 w	0683-5635			8	
R14,15,18, 22,23,29, 30,34,42, 43,47,55, 56,60	R: fxd, 47K, 5%, .250 w	0683-4735			14	
R16,19,31, 32,35,45, 48,58,61	R: fxd, 3.9K, 5%, .250 w	0683-3925			9	
R17,33,46, 59	R: fxd, 180Ω, .250 w	0683-1815			4	
R20,37,50 64	R: fxd, 100K, 5%, .250 w	0683-1045			4	
R21,24	R: fxd, 3K, 5%, .250 w	0683-3025			2	
R36,44	R: fxd, 8.2K, 5%, .250 w	0683-8225			2	
R49,57,62	R: fxd, 10K, 5%, .250 w	0683-1035			3	
R63	R: fxd, 68K, 5%, .250 w	0683-6835			1	
R65	R: fxd, .2K, 5%, .250 w	0683-2025			1	
	A4-9 Miscellaneous					
	BD Blank	05212-2016			1	
	Block: photoconductor	5040-1425			1	
	Cov: column	5212A-83C			1	
	Gasket: felt	0905-0051			1	
	Gasket: photoconductor	0905-0043			1	
	Readout: inline	5040-4569			1	
	Shld: photoplate	05212-0011			1	
	Tube: readout	1970-0009			1	
	Xstr: selected	5080-0060			8	
	Plate: photoconductor	1990-0009			1	

Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	ⓗ STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A10 GATE CONTROL	5060-5094				
C1, 2	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	72136	RDM15F111J3C	2	1
C3	C: fxd, mica, 270 pf, 5%, 300v	0140-0210	72136	RDM15F271J3C	1	1
C4, 5	C: fxd, mica, 390 pf, 5%, 300v	0140-0200	72136	RDM15F391J3C	2	1
C6, 7	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	2	1
C8	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	04062	RDM15F201J3C	1	1
CR1-3	Diode: switching, Ge, 100 ma at 0.85v	1910-0016	28480		3	3
CR4	Diode: avalanche, Si	1902-0132	28480		1	1
CR5-8	Diode: Si	1901-0025	28480		4	1
DS1	Lamp: glow, Ne	2140-0022	24446	NE-2E	1	1
Q1	Transistor: Si, NPN	1854-0015	28480		1	1
Q2	Transistor: Si, NPN	1854-0003	28480		1	1
Q3-6	Transistor: Ge, PNP, SPL 2N404	1850-0062	28480		4	1
Q7	Transistor: Ge, NPN	1851-0017	01295	2N1304	1	1
Q8, 9	Transistor: Ge, PNP	1850-0040	94154	2N383	2	1
R1	R: fxd, comp, 5.6K, 5%, 1/2 w	0686-5625	01121	EB5625	1	1
R2	R: fxd, metox, 1.5K, 5%, 1 w	0761-0015	28480		1	1
R3	R: fxd, comp, 4.7K, 5%, 1/2 w	0686-4725	01121	EB4725	1	1
R4, 18	R: fxd, metox, 2.2K, 5%, 1 w	0761-0005	28480		1	1
R5, 9, 10	R: fxd, comp, 22K, 5%, 1/4 w	0683-2235	01121	CB2235	3	1
R6	R: fxd, comp, 3.3K, 5%, 1/4 w	0683-3325	01121	CB3325	1	1
R7	R: fxd, comp, 3.9K, 5%, 1/2 w	0686-3925	01121	EB3925	1	1
R8, 20	R: fxd, comp, 27K, 5%, 1/4 w	0683-2735	01121	CB2735	2	1
R11, 12, 23	R: fxd, comp, 4.7K, 5%, 1/4 w	0683-4725	01121	CB4725	3	1
R13	R: fxd, comp, 18K, 5%, 1/4 w	0683-1835	01121	CB1835	1	1
R14, 16, 17	R: fxd, comp, 47K, 5%, 1/4 w	0683-4735	01121	CB4735	3	1
R15, 21, 22, 25	R: fxd, comp, 33K, 5%, 1/4 w	0683-3335	01121	CB3335	4	2
R19	R: fxd, comp, 27Ω, 5%, 1/4 w	0683-2705	01121	CB2705	1	1
R24	R: fxd, comp, 6.8K, 5%, 1/2 w	0686-6825	01121	EB6825	1	1
R26	R: fxd, comp, 24K, 5%, 1/4 w	0683-2435	01121	CB2435	1	1
R27	R: fxd, comp, 10K, 5%, 1/4 w	0683-1035	01121	CB1035	1	1
R28	R: fxd, comp, 2.2K, 5%, 1/4 w	0683-2225	01121	CB2225	1	1
R29	R: fxd, comp, 100K, 5%, 1/4 w	0683-1045	28480	CB1045	1	1
R30	R: fxd, comp, 270K, 5%, 1/4 w	0683-2745	28480	CB2745	1	1
R31	R: fxd, comp, 330K, 5%, 1/4 w	0683-3345	28480	CB3345	1	1
V1	Lamp: glow, Ne	2140-0022	24446	NE-2E	1	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A11 SAMPLE RATE	5060-5095				
C1	C: fxd, mica, 470 pf, 5%, 300v	0140-0149	04062	DM15F471J	1	1
C2	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	1	1
C3	C: fxd, Ta-elect, 6.8 μf, 10%, 35v	0180-0116	28480	150D685X9035B2-DYS	1	1
C4, 5	C: fxd, mica, 390 pf, 5%, 300v	0140-0200	28480	RDM15F391J3C	2	1
C6, 10	C: fxd, my, 0.056 μf, 10%, 200v	0160-0165	28480	192P56392-PTS	2	1
C7	C: fxd, cer, 5000 pf, -20+80%, 500v	0150-0014	04222	DI-4	1	1
C8	C: fxd, mica, 1000 pf, 5%, 300v	0140-0152	72136	DM16F102J	1	1
C9	C: fxd, al-elect, 50 μf, -10+75%, 25v	0180-0058	56289	30D506G025CC2-DSM	1	1
C11	C: fxd, my, 0.1 μf, 10%, 200v	0160-0168	56289	192P10492-PTS	1	1
C12	C: fxd, al-elect, 20 μf, -10+75%, 50v	0180-0049	56289	30D206G050CC2-DSM	1	1
C13	C: fxd, my, 0.0033 μf, 10%, 200v	0160-0155	56289	192P33292-PTS	1	1
CR1, 2, 12, 13	Diode: Si	1901-0025	28480		4	4
CR3-8, 10, 11	Diode: switching, Ge, 100 ma at 0.85v	1910-0016	28480		8	8
CR9	Diode: breakdown	1902-0164	28480		1	1
Q1, 3, 6	Transistor: Ge, PNP	1850-0040	28480		3	1
Q2, 4, 5	Transistor: Ge, PNP, SPL 2N404	1850-0062	28480		3	1
Q7, 8	Transistor: Ge, NPN	1851-0024	01295	2N388A	2	1
R1, 3, 7, 14	R: fxd, comp, 3.3K, 5%, 1/4 w	0683-3325	01121	CB3325	4	2
R2, 8, 13	R: fxd, comp, 5.6K, 5%, 1/2 w	0686-5625	01121	EB5625	3	1
R4, 10	R: fxd, comp, 10K, 5%, 1/4 w	0683-1035	01121	CB1035	2	1
R5	R: fxd, comp, 6.8K, 5%, 1/2 w	0686-6825	01121	EB6825	1	1
R6	R: fxd, comp, 47K, 5%, 1/4 w	0683-4735	01121	CB4735	1	1
R9	R: fxd, comp, 220K, 5%, 1/4 w	0683-2245	01121	CB2245	1	1
R11, 19	R: fxd, comp, 27K, 5%, 1/4 w	0683-2735	01121	CB2735	2	1
R12	R: fxd, comp, 100K, 5%, 1/4 w	0683-1045	01121	CB1045	1	1
R15	R: fxd, comp, 15K, 5%, 1/4 w	0683-1535	01121	CB1535	1	1
R16	R: fxd, comp, 24K, 5%, 1/4 w	0683-2435	01121	CB2435	1	1
R17	R: fxd, comp, 390Ω, 5%, 1/4 w	0683-3915	01121	CB3915	1	1
R18, 21, 25, 26	R: fxd, comp, 2.2K, 5%, 1/4 w	0683-2225	01121	CB2225	4	2
R20	R: fxd, comp, 2.7K, 5%, 1/4 w	0683-2725	01121	CB2725	1	1
R22, 27	R: fxd, comp, 1.2K, 5%, 1/4 w	0683-1225	01121	CB1225	2	1
R23, 28	R: fxd, comp, 1K, 5%, 1/2 w	0686-1025	01121	EB1025	2	1
R29	R: fxd, comp, 68K, 5%, 1/4 w	0683-6835	01121	CB6835	1	1
R30	R: fxd, comp, 5.6K, 5%, 1/4 w	0683-5625	01121	CB5625	1	1
	A12 LOW SPEED DIVIDER	5060-5024				
C1	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	1	1
C2, 11	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	72136	RDM15F391J3C	2	1
C3, 4, 8-10	C: fxd, mica, 130 pf, 5%, 300v	0140-0195	72136	DM15F131J	5	2
C5-7	C: fxd, mica, 150 pf, 5%, 300v	0140-0196	72136	RDM15F151J3C	3	1
C12, 13	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	72136	RDM15F201J3C	2	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A12 (Cont'd.)					
CR1-3, 6 CR4, 5, 7, 8	Diode: switching, Ge, 60v	1910-0016	28480		8	2
Q1-8	Transistor: Ge, PNP, SPL 2N404	1850-0062	28480		8	1
R1	R: fxd, metox, 390Ω, 2%, 1/4 w	0757-0914	19701	MF07C	1	1
R2, 12, 13, 23, 25, 35, 36, 46	R: fxd, metox, 22K, 2%, 1/4 w	0757-0956	19701	MF07C	8	3
R3, 9, 14, 20, 26, 32, 37, 43	R: fxd, metox, 6.8K, 2%, 1/4 w	0757-0944	19701	MF07C	8	3
R4, 10, 15, 21, 27, 33, 38, 44	R: fxd, metox, 47K, 2%, 1/4 w	0757-0964	19701	MF07C	8	3
R5, 11, 16, 22, 28, 34, 39, 45	R: fxd, metox, 10K, 2%, 1/4 w	0757-0948	19701	MF07C	8	3
R6, 8, 17, 19, 29, 31, 40, 42	R: fxd, metox, 3.9K, 2%, 1/4 w	0757-0938	19701	MF07C	8	3
R7, 18, 30, 41	R: fxd, metox, 200Ω, 2%, 1/4 w	0757-0907	19701	MF07C	4	2
	A13, 14, 25-27 PRESET DIVIDER	5060-5096				
C1	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	1	1
C2, 11	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	72136	RDM15F391J3C	2	1
C3, 4, 9, 10	C: fxd, mica, 130 pf, 5%, 300v	0140-0195	72136	DM15F131J	4	2
C5-7	C: fxd, mica, 150 pf, 5%, 300v	0140-0196	72136	RDM15F151J3C	3	1
C8	C: fxd, mica, 240 pf, 5%, 300v	0140-0199	72136	RDM15F241J3C	1	1
C12, 13	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	72136	RDM15F201J3C	2	1
C14	C: fxd, mica, 390 pf, 5%, 300v	0140-0200	72136	RDM15F391J3C	1	1
CR1-8	Diode: switching, Ge	1910-0016	28480		8	2
Q1-8	Transistor: Ge, PNP, SPL 2N404	1850-0062	28480		8	1
R1	R: fxd, comp, 390Ω, 5%, 1/4 w	0683-3915	01121	CB3915	1	1
R2, 12, 13, 23, 25, 35, 36, 46	R: fxd, comp, 22K, 5%, 1/4 w	0683-2235	01121	CB2235	8	3
R3, 9, 14, 20, 26, 32, 37, 43	R: fxd, comp, 6.8K, 5%, 1/4 w	0683-6825	01121	CB6825	8	3
R4, 10, 15, 21, 27, 33, 38, 44	R: fxd, comp, 47K, 5%, 1/4 w	0683-4735	01121	CB4735	8	3
R5, 11, 22, 28, 39, 45	R: fxd, comp, 10K, 5%, 1/4 w	0683-1035	01121	CB1035	6	2
R6, 8, 17, 19, 29, 31, 40, 42	R: fxd, comp, 3.9K, 5%, 1/4 w	0683-3925	01121	CB3925	8	3
R7, 18, 30, 41	R: fxd, comp, 200Ω, 5%, 1/4 w	0683-2015	01121	CB2015	4	2
R16, 34	R: fxd, comp, 8.2K, 5%, 1/4 w	0683-8225	01121	CB8225	2	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A13, 14, 25-27 (Cont'd.)					
R24	R: fxd, comp, 68K, 5%, 1/4 w	0683-6835	01121	CB6835	1	1
	A15 MULTIPLIER	5060-5043				
C1, 3, 4, 10, 15	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	5	2
C2	C: fxd, mica, 470 pf, 5%, 300v	0160-2940	72136	RDM15F471J3C	1	1
C5	C: fxd, mica, 240 pf, 5%, 300v	0140-0199	72136	RDM15F241J3C	1	1
C6, 12, 17	C: fxd, my, 0.015 μf, 10%, 300v	0160-0194	72136	RDM15F111J3C	3	1
C8	C: fxd, mica, 390 pf, 5%, 300v	0140-0200	72136	RDM15F391J3C	1	1
C9, 14	C: fxd, my, 0.001 μf, 10%, 200v	0160-0153	28480		2	1
C11, 19	C: fxd, mica, 56 pf, 5%, 300v	0140-0191	72136	DM15E560J 300v	2	1
C13	C: fxd, mica, 62 pf, 5%, 300v	0140-0205	72136	RDM15E620J3C	1	1
C16	C: fxd, mica, 39 pf, 5%, 300v	0140-0190	72136	RDM15E390J3C	1	1
C18	C: fxd, mica, 5 pf, 10%, 500v	0140-0209	72136	RDM15C050K5C	1	1
C20	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	72136	RDM15F201J3C	1	1
L1, 2	Inductor: coil, var, 8.3-18.7 μh	5080-4077	04404		2	1
L3, 4	Inductor: coil, var	5080-4078	04404		2	1
L5, 6	Inductor: coil, var	5080-4079	04404		2	1
Q1-3	Transistor: Ge, PNP, 2N2048	1850-0091	19701	2N2048	2	1
R1	R: fxd, metox, 10K, 2%, 1/4 w	0757-0948	28480	MF07C	1	1
R3	R: fxd, metox, 1.8K, 2%, 1/4 w	0757-0930	19701	MF07C	1	1
R4	R: fxd, metox, 16K, 2%, 1/4 w	0757-0953	19701	MF07C	1	1
R5	R: fxd, metox, 5.1K, 2%, 1/4 w	0757-0941	01121	MF07C	1	1
R6, 9, 10, 13, 15	R: fxd, metox, 2.2K, 2%, 1/4 w	0757-0932	01121	MF07C	5	2
R7, 16	R: fxd, metox, 470Ω, 2%, 1/4 w	0757-0916	19701	MF07C	2	1
R8	R: fxd, metox, 11K, 2%, 1/4 w	0757-0949	19701	MF07C	1	1
R11, 17	R: fxd, metox, 100Ω, 2%, 1/4 w	0757-0900	19701	MF07C	2	1
R12	R: fxd, metox, 9.1K, 2%, 1/4 w	0757-0947	19701	MF07C	1	1
R14	R: fxd, metox, 680Ω, 2%, 1/4 w	0757-0920	19701	MF07C	1	1
	A16 PRESET GATE °C	5060-5051				
CR1-12	Diode: switching, Si, 50v	1901-0081	28480		12	1
	A18 MIXER	5060-5833				
C1, 18	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	28480		2	1
C2-4, 6, 7, 15-17, 19, 20	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	10	3
C5, 14	C: fxd, Ta-elect, 50 μf, -15+20%, 10v	0180-0081	10411	MTA-50-10	1	1
C8, 11	C: fxd, cer, 1500 pf, -20+100%, 500v	0150-0077	72982	801-000-X5UO-152Z	2	1
C9	C: fxd, mica, 22 pf, 5%, 500v	0140-0145	72136	DM15C220J	1	1
C10	C: var, cer, 9-35 pf	0121-0105	28480		1	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A18 (Cont'd.)					
C12, 13	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	28480		2	1
CR1, 4	Diode: switching, Si, 50v	1901-0081	28480		2	1
CR2, 3	Diode: Ge	1910-0023	73293	1N270	2	1
L1, 3	Inductor: coil, assy	5080-4024	04404		2	1
L2, 4	Inductor: coil, 2.2 μh	9140-0142	28480		1	1
L5	Inductor: choke, 22 μh, fxd, coil	9140-0181	78526	1A2201M	1	1
Q1-6	Transistor: Si	1854-0019	28480	MF07C	6	1
R1	R: fxd, metox, 68Ω, 2%, 1/4 w	0757-0896	19701	MF07C	1	1
R2, 10	R: fxd, metox, 24K, 2%, 1/4 w	0757-0957	19701	MF07C	2	1
R3, 9, 26, 28	R: fxd, metox, 100Ω, 2%, 1/4 w	0757-0900	19701	MF07C	4	2
R4, 8	R: fxd, metox, 22K, 2%, 1/4 w	0757-0956	19701	MF07C	2	1
R5, 7	R: fxd, metox, 220Ω, 2%, 1/4 w	0757-0908	19701	MF07C	2	1
R6, 20	R: fxd, metox, 2.2K, 2%, 1/4 w	0757-0932	19701	MF07C	2	1
R11, 25	R: fxd, metox, 6.8K, 2%, 1/4 w	0757-0944	19701	MF07C	2	1
R12, 23	R: fxd, comp, 22Ω, 5%, 1/4 w	0683-2205	01121	CB2205	2	1
R13, 24	R: fxd, metox, 1.5K, 2%, 1/4 w	0757-0928	19701	MF07C	2	1
R14, 22	R: fxd, metox, 10K, 2%, 1/4 w	0757-0948	19701	MF07C	2	1
R15, 21, 27, 29	R: fxd, metox, 1K, 2%, 1/4 w	0757-0924	19701	MF07C	4	2
R16, 18	R: fxd, metox, 470Ω, 2%, 1/4 w	0757-0916	19701	MF07C	2	1
R17, 19	R: fxd, metox, 4.7K, 2%, 1/4 w	0757-0940	19701	MF07C	2	1
	A19 CHANNEL SELECT	5060-5027				
C1	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	1	1
CR1-10	Diode: switching, Si, 50v	1901-0081	28480		10	1
K1-3	Relay: reed, 4PST	0490-0130	04404		3	1
Q1-3	Transistor: Ge, PNP	1850-0113	01295	2N1997	3	1
R1, 2	R: fxd, metox, 100K, 2%, 1/4 w	0757-0972	19701	MF07C	2	1
R3, 7, 11	R: fxd, comp, 270K, 5%, 1/4 w	0683-2745	01121	CB2745	3	1
R4, 8, 12	R: fxd, metox, 27K, 2%, 1/4 w	0757-0958	19701	MF07C	3	1
R5, 9, 13	R: fxd, metox, 15K, 2%, 1/4 w	0757-0952	19701	MF07C	3	1
R6	R: fxd, metox, 68Ω, 2%, 1/4 w	0757-0896	19701	MF07C	1	1
R15	R: fxd, metox, 221Ω, 2%, 1/4 w	0757-0805	19701	MF7C-T-0	1	1
	A20 TIME BASE	5060-3826				
C1	C: fxd, mica, 5600 pf, 1%, 300v	0140-0183	72136	RDM20F562F3C	1	1
C2	C: fxd, al-elect, 20 μf, -10+75%, 50v	0180-0049	28480		1	1
C3, 6-11	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121	56289	5C50B1	7	3
C4	C: fxd, mica, 1000 pf, 5%, 300v	0140-0152	72136	DM16F102J	1	1
C5, 15	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	2	1
C12	C: var, cer, 9-35 pf	0121-0105	28480		1	1
C13	C: fxd, mica, 680 pf, 5%, 300v	0140-0208	72136	DM15F681J	1	1
C14	C: fxd, mica, 82 pf, 5%, 500v	0140-0137	14655	22A5Q82	1	1

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A20 (Cont'd.)					
C16	C: fxd, mica, 3000 pf, 1%, 100v	0140-0172	72136	RDM19F302F1S	1	1
C17	C: fxd, factory selected	OBD	04404		1	1
CR1, 2	Diode: Ge, 60 piv, 5 ma	1910-0016	28480		2	2
CR3	C: voltage var, 100 pf, 20%, 20v	0122-0006	01281	1N4815	1	1
L2	Coil: var	5080-4080	04404		1	1
Q1-3	Transistor: Si, PNP	1853-0009	28480		3	1
R1, 5	R: fxd, metox, 2.7K, 2%, 1/4 w	0757-0934	19701	MF07C	2	1
R2	R: fxd, metox, 27K, 2%, 1/4 w	0757-0958	19701	MF07C	1	1
R3	R: fxd, metox, 3.3K, 2%, 1/4 w	0757-0936	19701	MF07C	1	1
R4, 13	R: fxd, metox, 3.9K, 2%, 1/4 w	0757-0938	19701	MF07C	2	1
R6	R: fxd, metox, 820Ω, 2%, 1/4 w	0757-0922	19701	MF07C	1	1
R7, 15, 17	R: fxd, metox, 1.2K, 2±, 1/4 w	0757-0926	19701	MF07C	3	1
R9	R: fxd, metox, 24K, 2%, 1/4 w	0757-0957	19701	MF07C	1	1
R10	R: fxd, metox, 6.8K, 2%, 1/4 w	0757-0944	19701	MF07C	1	1
R11	R: fxd, metox, 2.2K, 2%, 1/4 w	0757-0932	19701	MF07C	1	1
R12, 14	R: fxd, metox, 18K, 2%, 1/4 w	0757-0954	19701	MF07C	2	1
R16	R: fxd, metox, 4.3K, 2%, 1/4 w	0757-0939	19701	MF07C	1	1
R18	R: fxd, metox, 5.1K, 2%, 1/4 w	0757-0941	19701	MF07C	1	1
R19	R: fxd, metox, 4.7K, 2%, 1/4 w	0757-0940	19701	MF07C	1	1
	A23 HIGH SPEED DIVIDER	5060-5023				
C2	C: fxd, mica, 100 pf, 2%, 300v	0140-0176	72136	RDM15F101G3C	1	1
C3	C: fxd, cer, 0.01 μf, -20+80%, 100v	0150-0093	91418	TA	1	1
C4, 6	C: fxd, mica, 56 pf, 5%, 300v	0140-0191	72136	DM15E560J 300v	2	1
C5	C: fxd, cer, 2000 pf, 20%, 500v	0150-0122	72982	801000Y5S 202M	1	1
C7	C: fxd, mica, 30 pf, 5%, 300v	0160-0181	14655	RDM15E300J3S	1	1
C8, 10	C: fxd, mica, 68 pf, 5%, 300v	0140-0192	28480	RDM15E680J3C	2	1
C11, 12, 14	C: fxd, mica, 82 pf, 5%, 500v	0140-0137	14655	22A5Q82	3	1
C13	C: fxd, mica, 130 pf, 5%, 300v	0140-0195	28480	RDM15F131J3C	1	1
C16, 17	C: fxd, mica, 200 pf, 5%, 300v	0140-0198	28480	RDM15F201J3C	2	1
CR1-3, 5-8	Diode: switching, Si, 30v	1901-0040	28480		7	1
CR10, 11	Diode: switching, Ge	1910-0016	28480		2	1
Q1-6	Transistor: Si, PNP	1853-0009	28480		6	1
Q7, 8	Transistor: Ge, PNP, SPL2N404	1850-0062	28480		2	1
R2	R: fxd, comp, 100Ω, 5%, 1 w	0689-1015	01121	GB1015	1	1
R3, 11, 14, 23	R: fxd, metox, 1.8K, 5%, 1/2 w	0758-0043	16299	C5	4	2
R4, 12, 15, 24, 42, 49	R: fxd, metox, 10K, 2%, 1/4 w	0757-0948	19701	MF07C	6	2
R5, 13, 16, 25	R: fxd, metox, 3.3K, 2%, 1/4 w	0757-0936	19701	MF07C	4	2
R7, 9, 18, 21	R: fxd, metox, 62Ω, 2%, 1/4 w	0757-0895	19701	MF07C	4	2

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A23 (Cont'd.)					
R8, 19, 31	R: fxd, metox, 110Ω, 2%, 1/4 w	0757-0901	19701	MF07C	3	1
R20, 32, 45	R: fxd, metox, 1K, 2%, 1/4 w	0757-0924	19701	MF07C	3	1
R26, 35	R: fxd, metox, 2.7K, 5%, 1/2 w	0758-0004	16299*	C5	2	1
R27, 36	R: fxd, metox, 12K, 2%, 1/4 w	0757-0950	19701	MF07C	2	1
R28, 37	R: fxd, metox, 2.7K, 2%, 1/4 w	0757-0934	19701	MF07C	2	1
R30, 33	R: fxd, comp, 47Ω, 5%, 1/4 w	0683-4705	01121	CB4705	2	1
R40, 47	R: fxd, metox, 6.8K, 5%, 1/2 w	0758-0009	19299	C5	2	1
R41, 48	R: fxd, metox, 47K, 2%, 1/4 w	0757-0964	19701	MF07C	2	1
R44	R: fxd, metox, 200Ω, 2%, 1/4 w	0757-0907	19701	MF07C	1	1
	A24 RESOLUTION	5060-5038				
CR5-11	Diode: switching, Si, 50v	1901-0081	28480		7	1
K1-3	Relay: reed, 4PST	0490-0130	04404		3	1
Q1-3	Transistor: Ge, PNP	1850-0113	01295	2N1997	3	1
R3, 8, 12	R: fxd, metox, 27K, 2%, 1/4 w	0757-0958	19701	MF07C	3	1
R5, 10	R: fxd, comp, 100K, 5%, 1/4 w	0683-1045	01121	CB1045	2	1
R4, 9, 13	R: fxd, comp, 270K, 5%, 1/4 w	0683-2745	01121	CB2745	3	1
R6, 11, 15	R: fxd, metox, 15K, 2%, 1/4 w	0757-0952	19701	MF07C	3	1
R7	R: fxd, metox, 221Ω, 1/2 w	0757-0805	19701	MF7C T-0	1	1
R16	R: fxd, metox, 68K, 2%, 1/4 w	0757-0968	19701	MF07C	1	1
	A28 POWER SUPPLY	5060-5022				
C1	C: fxd, my, 0.022 μf, 20%, 200v	0170-0024	56289	192P22302	1	1
C2, 3	C: fxd, al-elect, 40 μf, -10+75%, 50v	0180-0050	56289	30D406G050DD2-DS	2	1
CR1-8	Diode: rect, Si	1901-0028	28480		8	1
CR9	Diode: avalanche, 7.15v, 5%	1902-0074	28480		1	1
Q1	Transistor: Ge, PNP, SPL 2N404	1850-0062	28480		1	1
R1	R: fxd, comp, 3.6K, 5%, 1 w	0689-3625	01121	GB3625	1	1
R2	R: fxd, metox, 120K, 2%, 1/4 w	0757-0974	19701	MF07C	1	1
R3	R: fxd, metox, 12K, 2%, 1/4 w	0757-0950	19701	MF07C	1	1
R4	R: fxd, metox, 1K, 2%, 1/4 w	0757-0924	19701	MF07C	1	1
R5	R: fxd, ww, 0.47Ω, 10%, 2 w	0813-0019	28480		1	1
R6	R: fxd, comp, 2.2K, 5%, 1 w	0689-2225	28480		1	1
R7	R: var, comp, 250Ω, 20%, 1/3 w	2100-0128	28480		1	0
R8	R: fxd, metox, 470Ω, 2%, 1/4 w	0757-0916	19701	MF07C	1	1
R9	R: fxd, metox, 3.3K, 2%, 1/4 w	0757-0936	19701	MF07C	1	1
R10	R: fxd, metox, 1.5K, 2%, 1/4 w	0757-0928	19701	MF07C	1	1
R11	R: fxd, metox, 1.8K, 2%, 1/4 w	0757-0930	19701	MF07C	1	1
R12, 13	R: fxd, comp, 47Ω, 5%, 1/4 w	0683-4705	01121	CB4705	2	1

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*Not on Mfr. Code List: 16299. Corning Glass Works, Raleigh, North Carolina

Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	A29 LAMP	5060-3834				
DS1-5	Lamp: incd. 0.04a, 28v	2140-0037	24455	2187D	5	4
R1	R: fxd, comp, 470Ω, 5%, 1 w	0689-4715	01121	GB4715	1	1
	A30 POLARITY LAMP	5060-5041				
DS2, 3, 5, 6	Lamp: incd, 0.04a, 28v	2140-0037	24455	2187D	4	4
	A31 REFERENCE ADJUST ASSY.	5060-5831				
CR6	Diode: avalanche, 14.7v, 10%, 400mw	1902-0055	28480		1	1
CR101, 103, 104	Diode: Si	1901-0025	28480		3	1
K101	Relay: 2 form C, coil 1825Ω, 26.5v	0490-0091	71482	FRP9001-G10	1	1
R7-9, 26	R: var, ww, 10K, 10%, 1 w	2100-0451	28480		4	0
R10	R: fxd, metox, 12.1K, 2%, 1/4 w	0727-0783	19701	MF7C	1	1
R20, 22	R: fxd, metox, 100K, 2%, 1/4 w	0757-0972	19701	MF07C	2	1
R23	R: fxd, comp, 2.2K, 5%, 1/4 w	0683-2225	01121	CB2225	1	1
R24, 25	R: fxd, metox, 10K, 5%, 1/4 w	0757-0948	19701	MF07C	1	1
R101	R: fxd, comp, 820Ω, 5%, 1/4 w	0683-8215	01121	CB8215	1	1
	HP 2801A-M1					
	Ref Std 2801A except as follows:					
	Delete: Y1; A15-17					
	Add:					
A15	Multiplier (Ref Std A15 listing)	5060-6268	04404		1	0
A16	Preset Gate (Ref Std A16 listing except as follows: Delete: CR11, 12)	5060-5054	04404		1	0
A17	Preset Gate	5060-5752	04404		1	0
A17CR1, 2	Diode: switching, Si, 50v	1901-0081	28480		2	1
Y1	Crystal and oven: high, reference	5060-5735	04404		1	1
	low, reference	5060-5734	04404		1	1
	HP 2801A-M6					
	Ref Std 2801A except as follows:					
	Delete: A4-9, 24					
	Add:					
A4-9	Decade +8421	5060-5617	04404		6	0
A24B	Resolution +8421	5060-5174	04404		1	0

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Table 6-1. Replaceable Parts (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	M6 A4-9 Decade Counter Assembly +8421	5060-5617				
C1, 3, 5, 6, 8, 9	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	72136	RDM15F111J3C	6	2
C2	C: fxd, mica, 140 pf, 2%, 300v	0140-0217	28480		1	1
C4	C: fxd, mica, 180 pf, 5%, 300v	0140-0197	72136	RDM15F181J3C	1	1
C7	C: fxd, mica, 130 pf, 5%, 300v	0140-0195	72136	RDM15F131J3C	1	1
C10	C: fxd, mica, 150 pf, 5%, 300v	0140-0196	72136	RDM15F151J3C	1	1
C11, 12	C: fxd, mica, 200 pf, 5%, 300v	0140-0198		RDM15F201J3C	2	1
C13	C: fxd, cer, 0.1 μf, -20+80%, 50v	0150-0121		5C50B1	1	1
CR1-8	Diode: Si	1901-0025	28480		8	1
CR9-14	Diode: switching, Ge, 100 ma at .85v	1910-0016	28480		6	1
DS1A/B, 2A/B, 3A/B, 4A/B	Lamp: glow, Ne	2140-0044	24446	NE-2E	8	3
L1	Inductor: coil, fxd, 3.6 mh, 5%	9140-0161	28480		1	1
Q1-8	Transistor: Ge, PNP, SPL, 2N404	1850-0062	28480		8	1
R1	R: fxd, comp, 47K, 5%, 1/2 w	0686-4735	28480	EB4735	1	1
R2	Z: network, fxd, cflm, 270K, 20%, 1/4 w	0845-0001	28480		1 set	1 set
R6-9	R: fxd, comp, 390K, 5%, 1/4 w	0683-3945	01121	CB3945	4	2
R10-17	R: fxd, comp, 56K, 5%, 1/4 w	0683-5635	01121	CB5635	8	3
R18, 26, 30, 37, 41, 48, 52, 59	R: fxd, comp, 7.5K, 5%, 1/2 w	0686-7525	01121	EB7525	8	3
R19, 27, 31, 38, 42, 49, 53, 60, 64	R: fxd, comp, 43K, 5%, 1/4 w	0683-4335	01121	CB4335	9	3
R20, 28, 29, 39, 40, 50, 51, 61	R: fxd, comp, 10K, 5%, 1/4 w	0683-1035	01121	CB1035	8	3
R21, 32, 43, 54	R: fxd, comp, 47K, 5%, 1/4 w	0683-4735	01121	CB4735	4	2
R22, 25, 33, 36, 44, 47, 55, 58	R: fxd, comp, 3.9K, 5%, 1/4 w	0683-3925	01121	CB3925	8	3
R23, 34, 45, 56	R: fxd, comp, 180Ω, 5%, 1/4 w	0683-1815	01121	CB1815	4	2
R24, 35, 46, 57	R: fxd, comp, 100K, 5%, 1/4 w	0683-1045	01121	CB1045	4	2
R62	R: fxd, comp, 7.5K, 5%, 1/4 w	0683-7525	01121	CB7525	1	1
R63	R: fxd, comp, 4.7K, 5%, 1/4 w	0683-4725	01121	CB4725	1	1
V1	Tube: electron, spec. purpose	1970-0009	28480		1	1
	A24B - Resolution Board +8421	5060-5174				
CR3-11	Diode: switching, Si, 50v	1901-0081	28480		9	1
K1-3	Relay: reed	0490-0130	28480		3	1
Q1-3	Transistor: Ge, PNP	1850-0113	01295	2N1997	3	1
R2	R: fxd, metox, 100K, 2%, 1/4 w	0757-0972	19701	MF07C	1	1
R3, 8, 12	R: fxd, metox, 27K, 2%, 1/4 w	0757-0958	19701	MF07C	3	1

M0183

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	M6 A24B (Cont'd.)					
R4, 9, 13	R: fxd, comp, 270K, 5%, 1/4 w	0683-2745	01121	CB2745	3	1
R5, 10	R: fxd, comp, 100K, 5%, 1/4 w	0683-1045	01121	CB1045	2	1
R6, 11, 15	R: fxd, metox, 15K, 2%, 1/4 w	0757-0952	19701	MF07C	3	1
R7	R: fxd, metox, 221Ω, 2%, 1/4 w	0757-0805	19701	MF7C T-0	1	1
R16	R: fxd, metox, 68K, 2%, 1/4 w	0757-0968	19701	MF07C	1	1

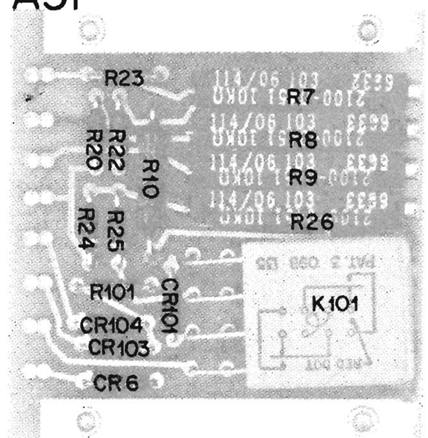
M0183

SECTION VII
CIRCUIT DIAGRAMS

7-1. INTRODUCTION.

7-2. This section contains the circuit diagrams necessary for maintenance of the Models 2801A, 2801A-M1, and 2801A-M6. A composite diagram, schematic diagrams, and part-location photographs are included. The composite diagram (Figure 7-1) shows the connections between all circuit boards and the chassis-mounted parts. The location photographs show the physical location of each part on each circuit board, and they accompany the appropriate schematic diagram. The location photograph for circuit board 5060-5831 is shown on page 7-2, and the schematic of the board is included in the composite diagram, Figure 7-1.

A31


R23
R7
R8
R9
R26
R22
R20
R10
R24
R25
R101
CR101
CR104
CR103
CR6
K101

ART 0932

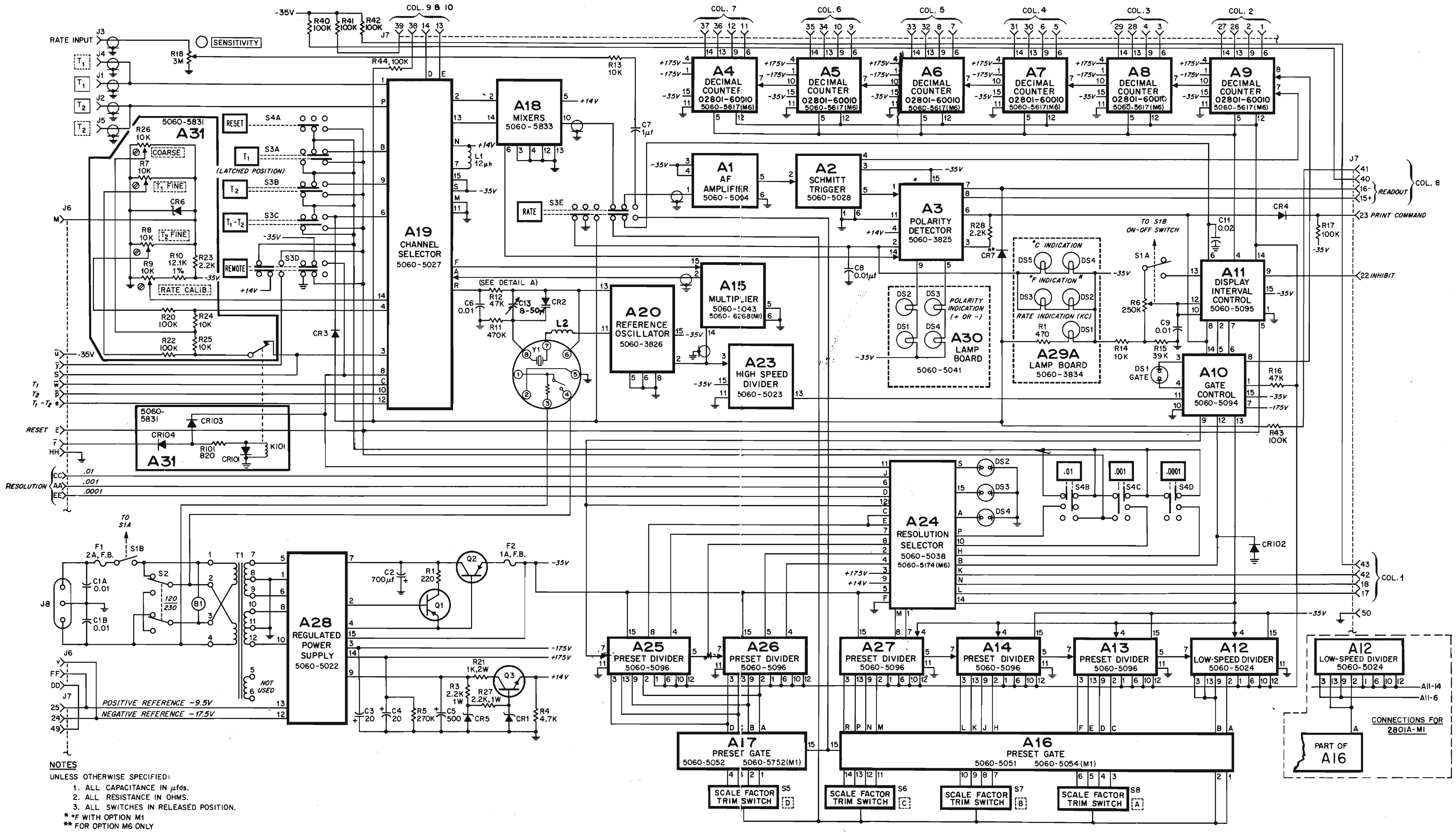
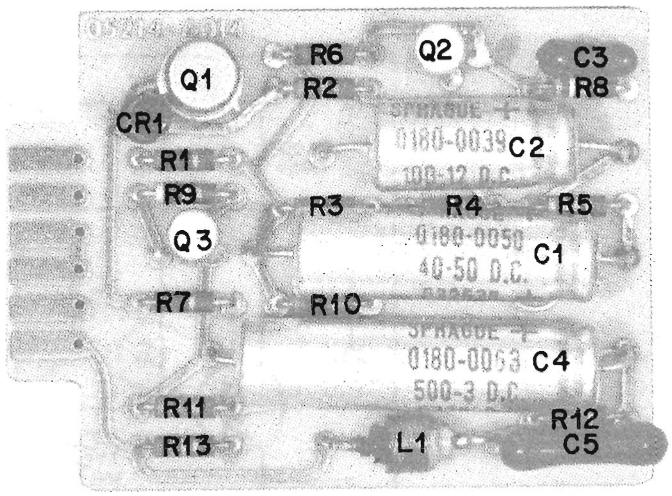
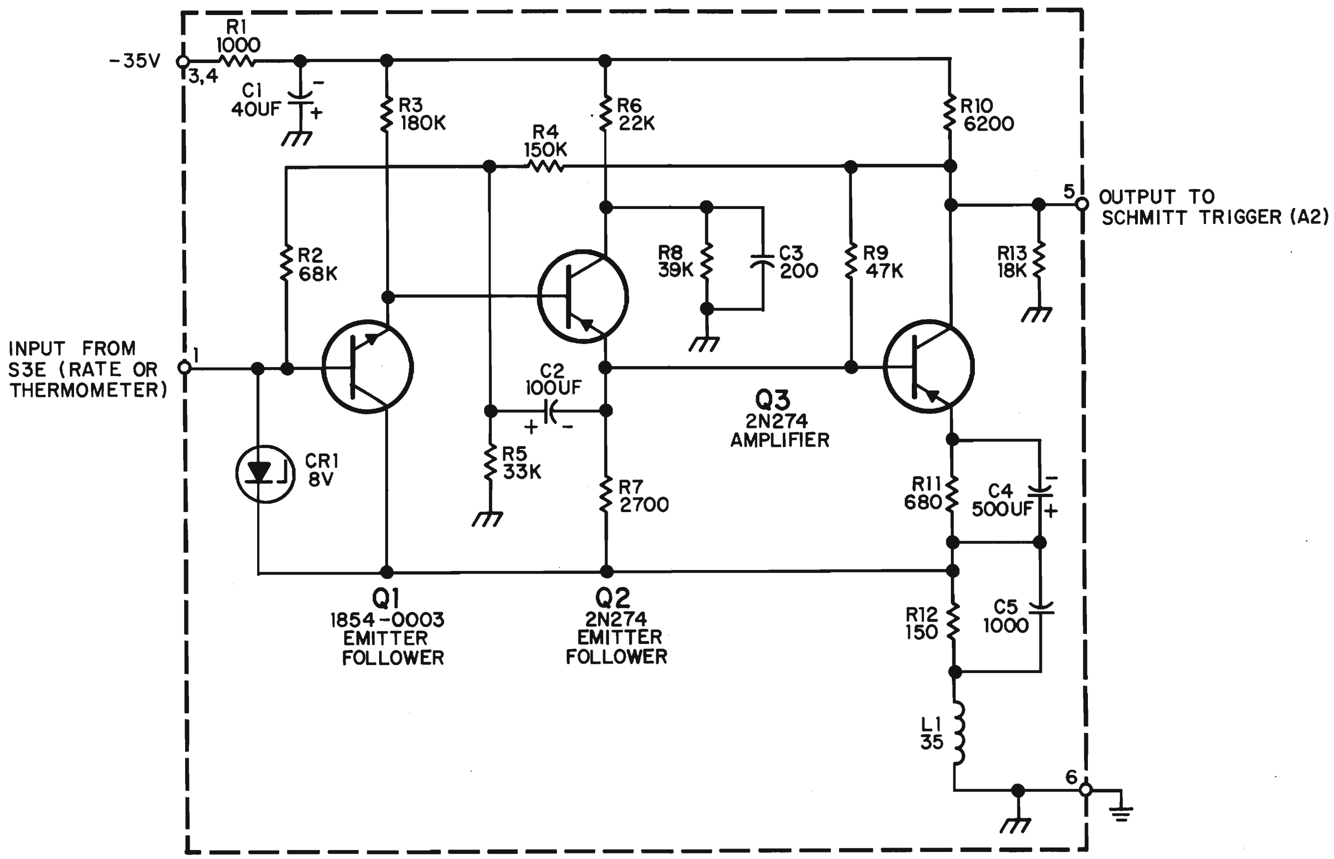


Figure 7-1. Composite Diagram, Quartz Thermometer; HP 2801A, HP 2801A-M1, and HP 2801A-M6

Scans by ArtekMedia => 2009


Q1
CR1
R6
R2
Q2
C3
R8
SPRAGUE
0180-0039
C2
100-12 D.C.
R1
R9
R3
R4
R5
Q3
0180-0050
40-50 D.C.
C1
R7
R10
SPRAGUE
0180-0053
C4
500-3 D.C.
R11
R12
R13
L1
C5

ART 0933

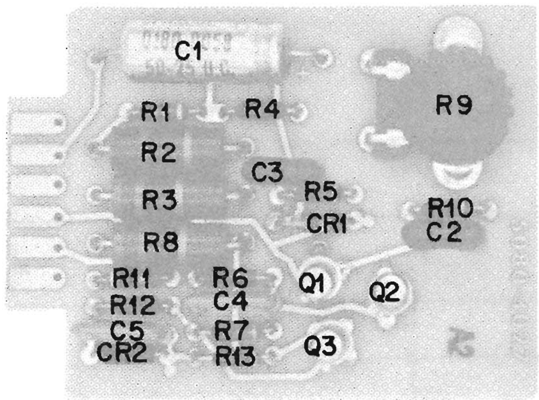


C5060-5004
HP-2801A: SERIAL PREFIX (TYPE) 517 AND ABOVE
HP-2800A: SERIAL PREFIX (TYPE) 523 AND ABOVE

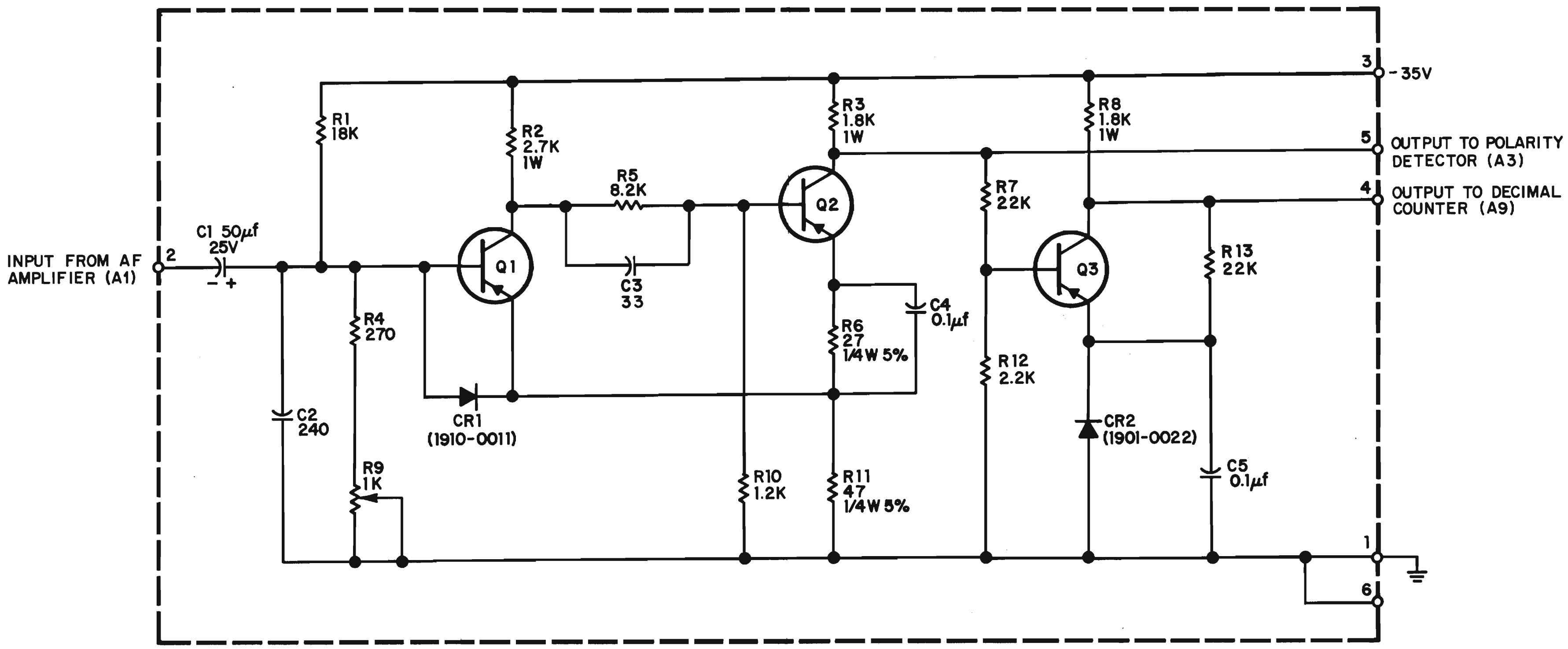
NOTES

UNLESS OTHERWISE SPECIFIED:
ALL RESISTANCE IN OHMS, 1/8W, 2%
ALL CAPACITANCE IN PICO-FARADS
ALL INDUCTANCE IN MICROHENRIES

Figure 7-2. (A1) Audio Frequency Amplifier


C1
R1
R4
R9
R2
C3
R3
R5
CR1
R10
C2
R8
R11
R6
Q1
Q2
R12
C4
C5
R7
Q3
CR2
R13

ART 0934

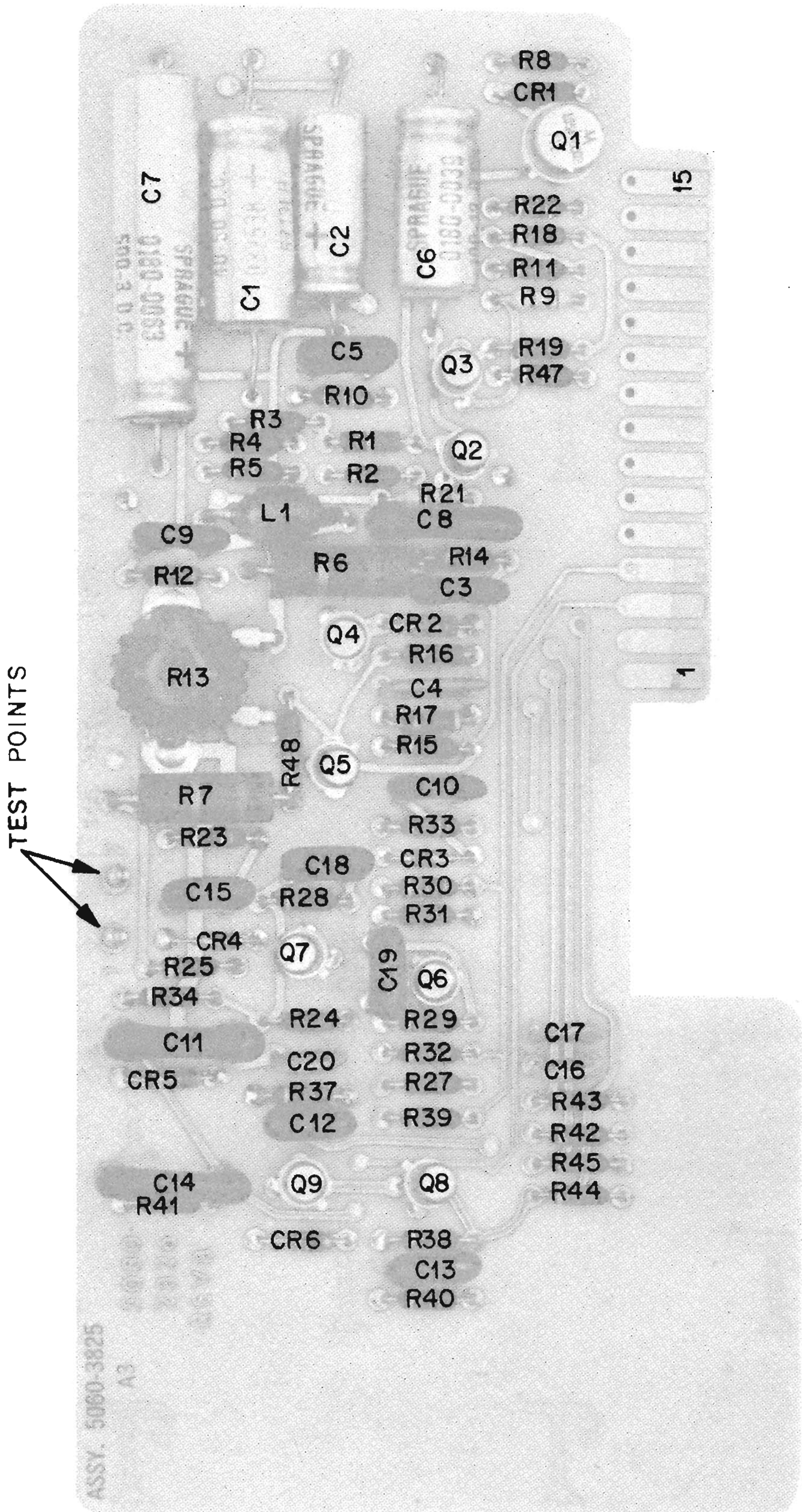


NOTES

UNLESS OTHERWISE SPECIFIED:
ALL RESISTANCE IN OHMS, 1/8W, 2%
ALL CAPACITANCE IN PICO-FARADS
ALL TRANSISTORS 1853-0009

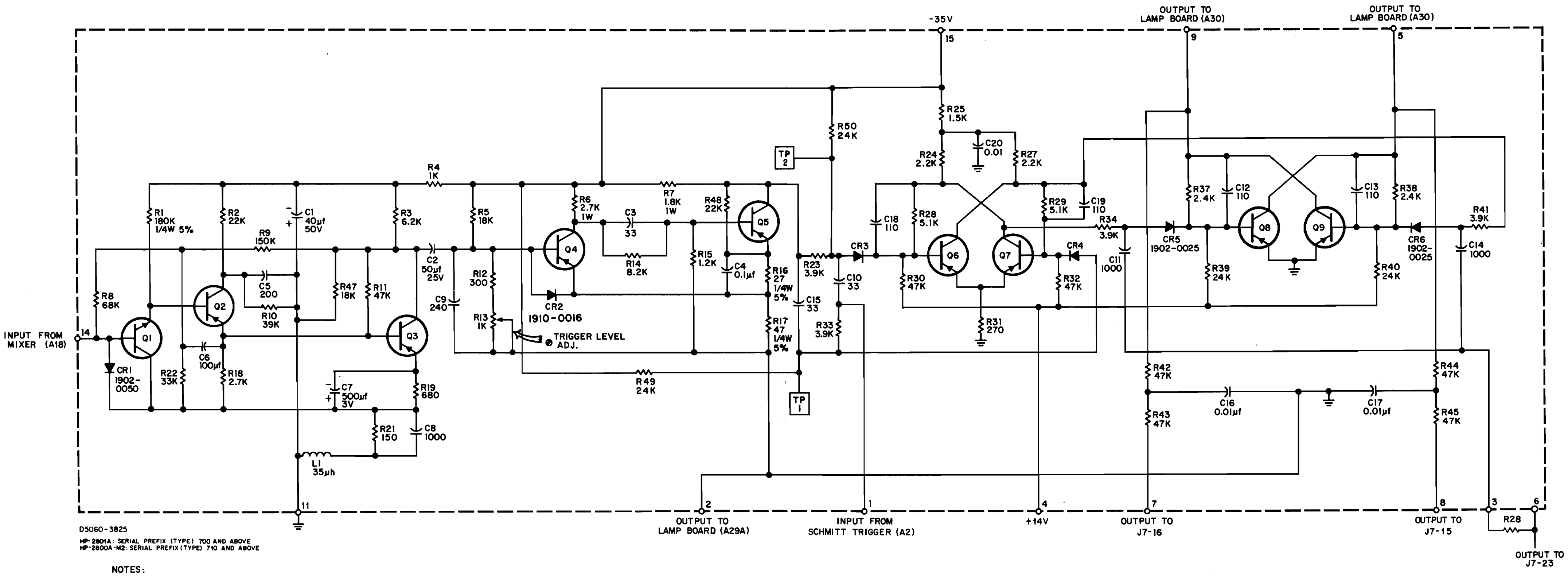
Serial Prefix (Type) 700 and above
C5060-5028

Figure 7-3. (A2) Schmitt Trigger



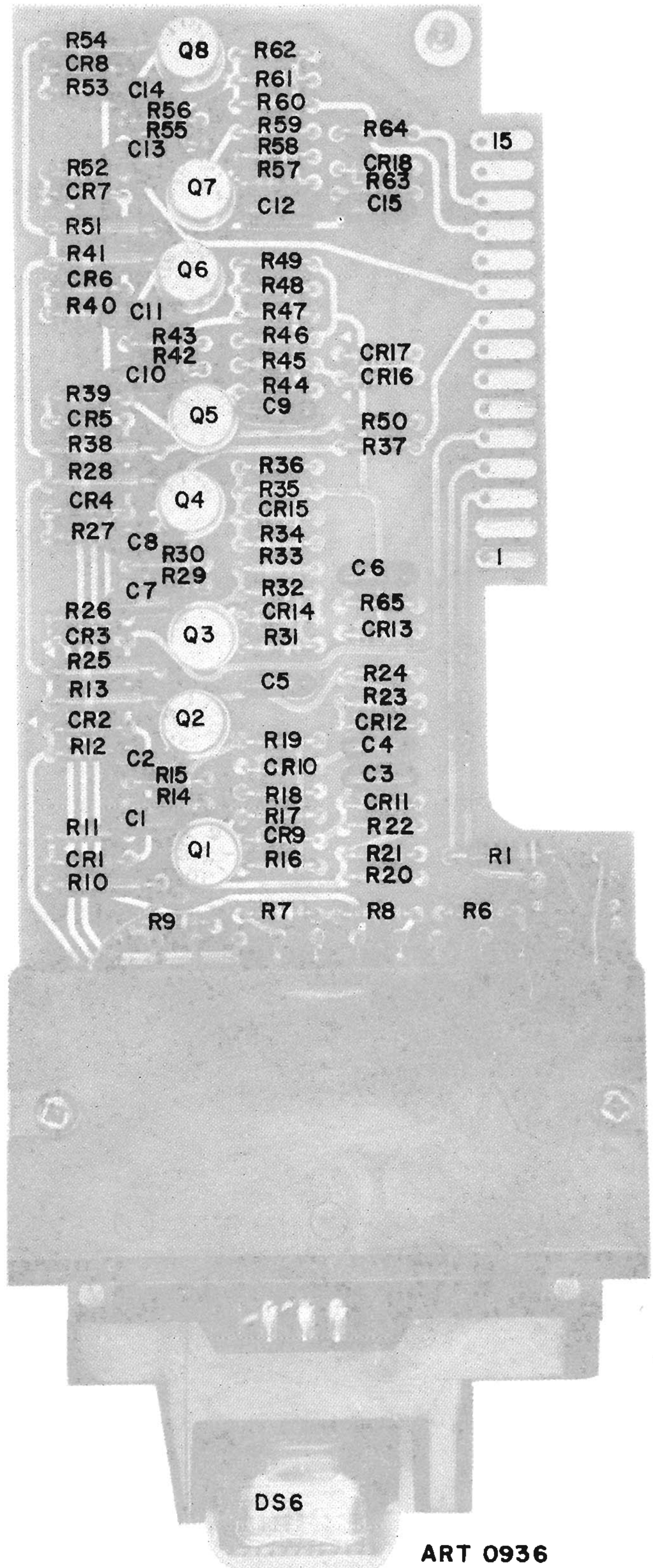
TEST POINTS
R8
CR1
Q1
15
C7
C1
C2
C6
R22
R18
R11
R9
C5
Q3
R19
R47
R10
R3
R4
R1
Q2
R5
R2
R21
L1
C8
C9
R6
R14
R12
C3
Q4
CR2
R16
R13
C4
R17
R15
R48
Q5
R7
C10
R23
R33
C18
CR3
C15
R28
R30
R31
CR4
Q7
R25
C19
Q6
R34
R24
R29
C17
C11
C20
R32
CR5
R37
R27
C16
C12
R39
R43
R42
R45
C14
Q9
Q8
R44
R41
CR6
R38
C13
R40
ASSY. 5060-3825
A3
1

ART 0935



NOTES:
UNLESS OTHERWISE SPECIFIED
ALL RESISTORS 1/8W, 2%
ALL RESISTANCE NOTED IN OHMS
ALL CAPACITANCE NOTED IN PICOFARADS
ALL DIODES 1901-0081
ALL TRANSISTORS 1853-0009
R1,16,17 1/4W 5%

Figure 7-4. (A3) Polarity Detector


R54
CR8
R53
Q8
C14
R56
R55
C13
R62
R61
R60
R59
R58
R57
R64
CR18
R63
C15
15
R52
CR7
Q7
C12
R51
R41
CR6
R40
Q6
C11
R49
R48
R47
R46
R45
R44
C9
R43
R42
C10
CR17
CR16
R39
CR5
R38
Q5
R50
R37
R28
CR4
R27
Q4
C8
R30
R29
C7
R36
R35
CR15
R34
R33
C6
1
R32
CR14
R31
R65
CR13
R26
CR3
R25
Q3
R13
CR2
R12
Q2
C5
R24
R23
CR12
C4
C2
R15
R14
C1
R19
CR10
R18
R17
CR9
R16
C3
CR11
R22
R21
R20
R1
R11
CR1
R10
Q1
R9
R7
R8
R6
DS6

ART 0936

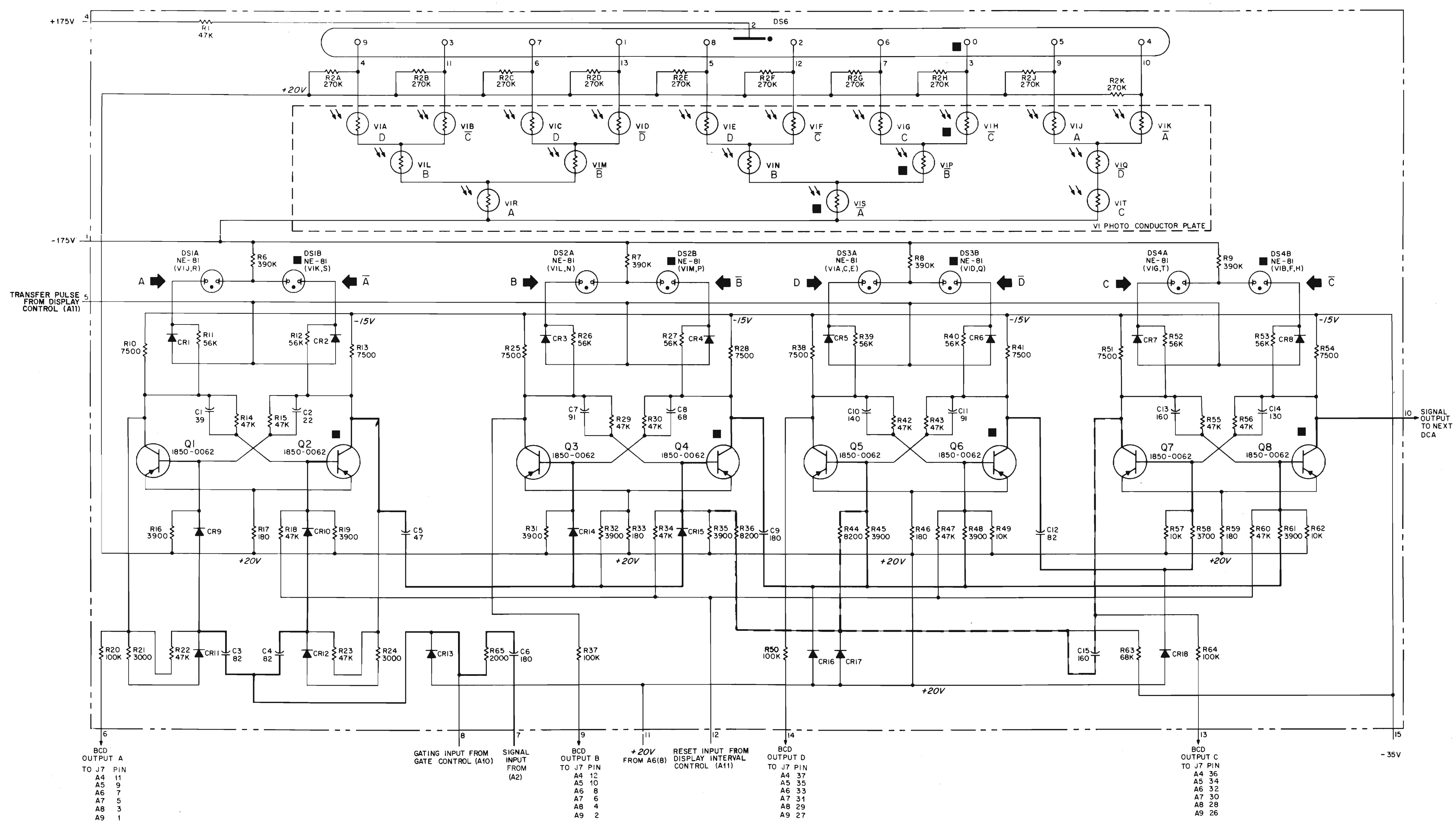
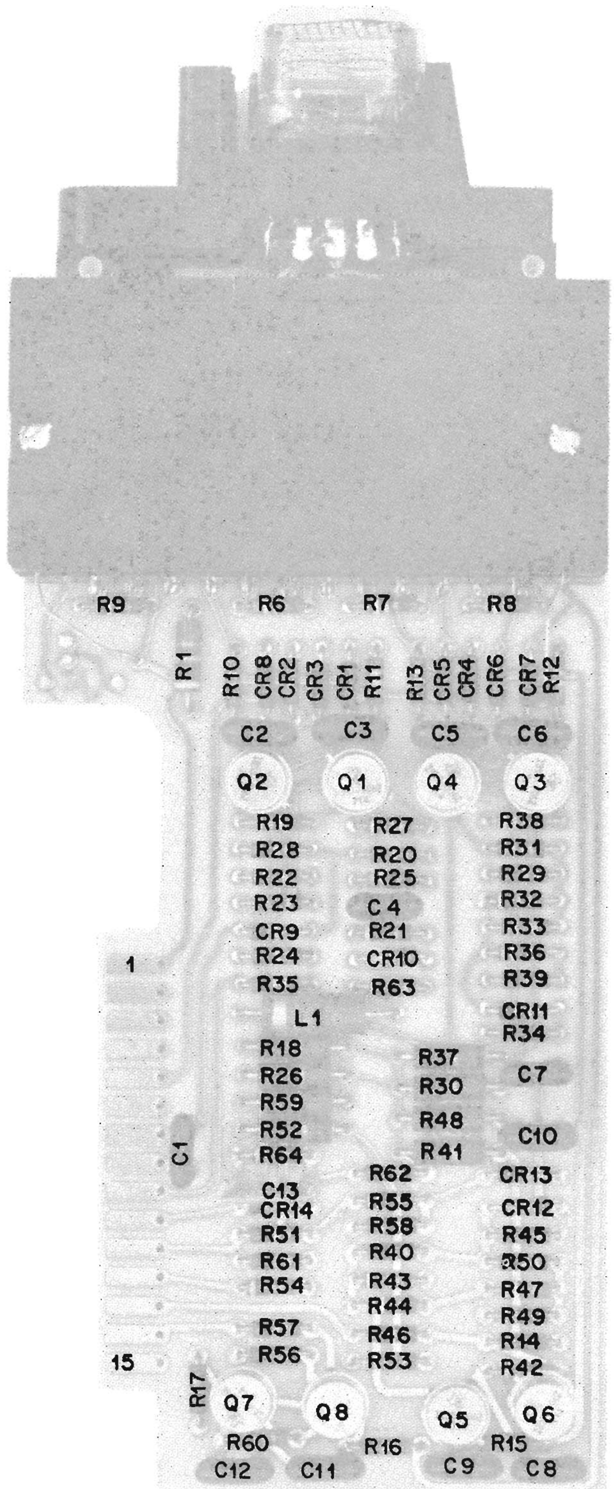


Figure 7-5. (A4 - A9) Decimal Counter, 4-2'-2-1 Positive - True Code (HP 2800A, HP 2801A)


R9
R6
R7
R8
R1
R10
CR8
CR2
CR3
CR1
R11
R13
CR5
CR4
CR6
CR7
R12
C2
C3
C5
C6
Q2
Q1
Q4
Q3
R19
R28
R22
R23
CR9
R24
R35
R27
R20
R25
C4
R21
CR10
R63
R38
R31
R29
R32
R33
R36
R39
CR11
R34
1
L1
R18
R26
R59
R52
R64
R37
R30
R48
R41
C7
C10
C1
C13
CR14
R51
R61
R54
R57
R56
R62
R55
R58
R40
R43
R44
R46
R53
CR13
CR12
R45
R50
R47
R49
R14
R42
15
R17
Q7
Q8
Q5
Q6
R60
R16
R15
C12
C11
C9
C8

ART 0937

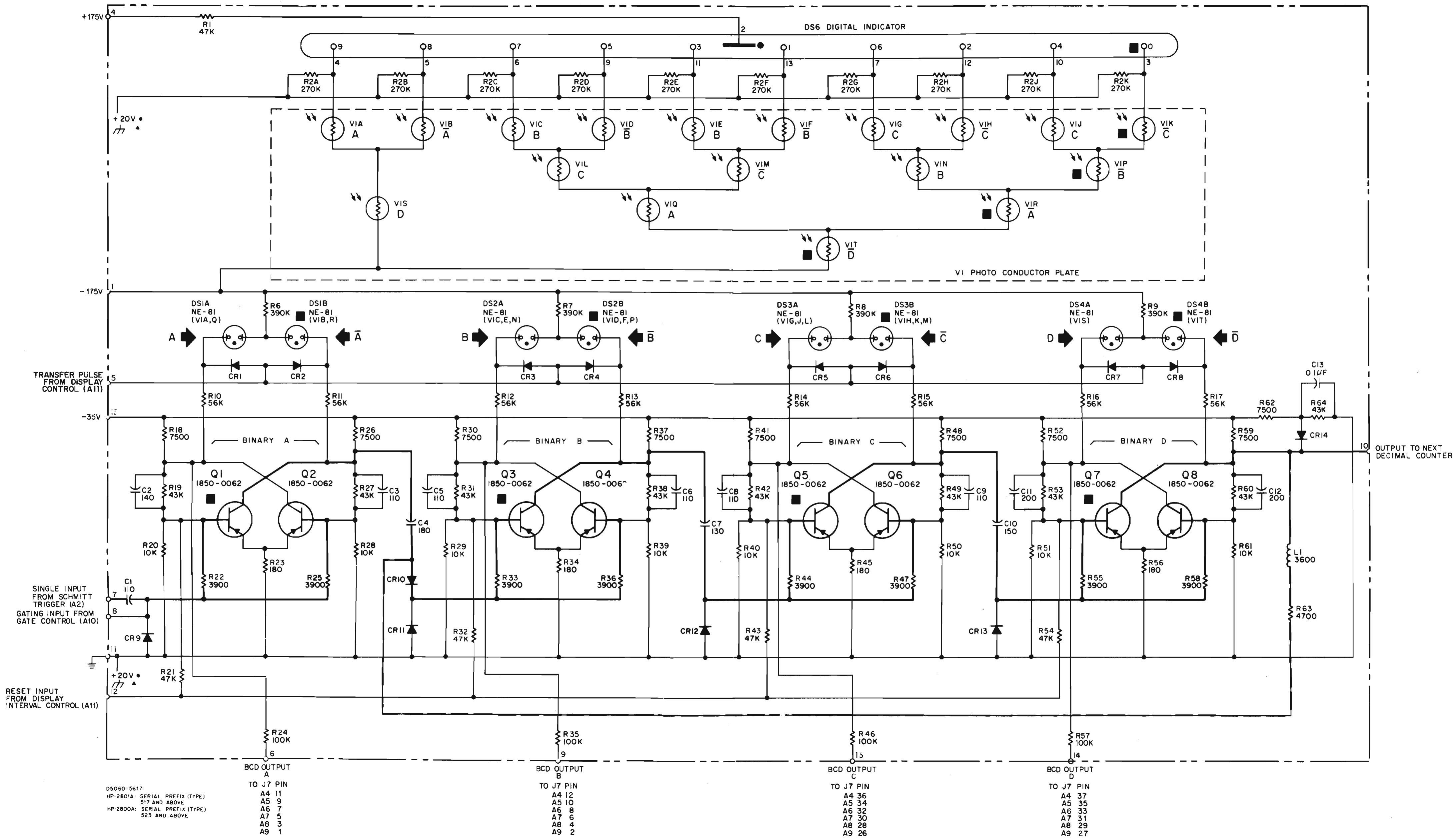
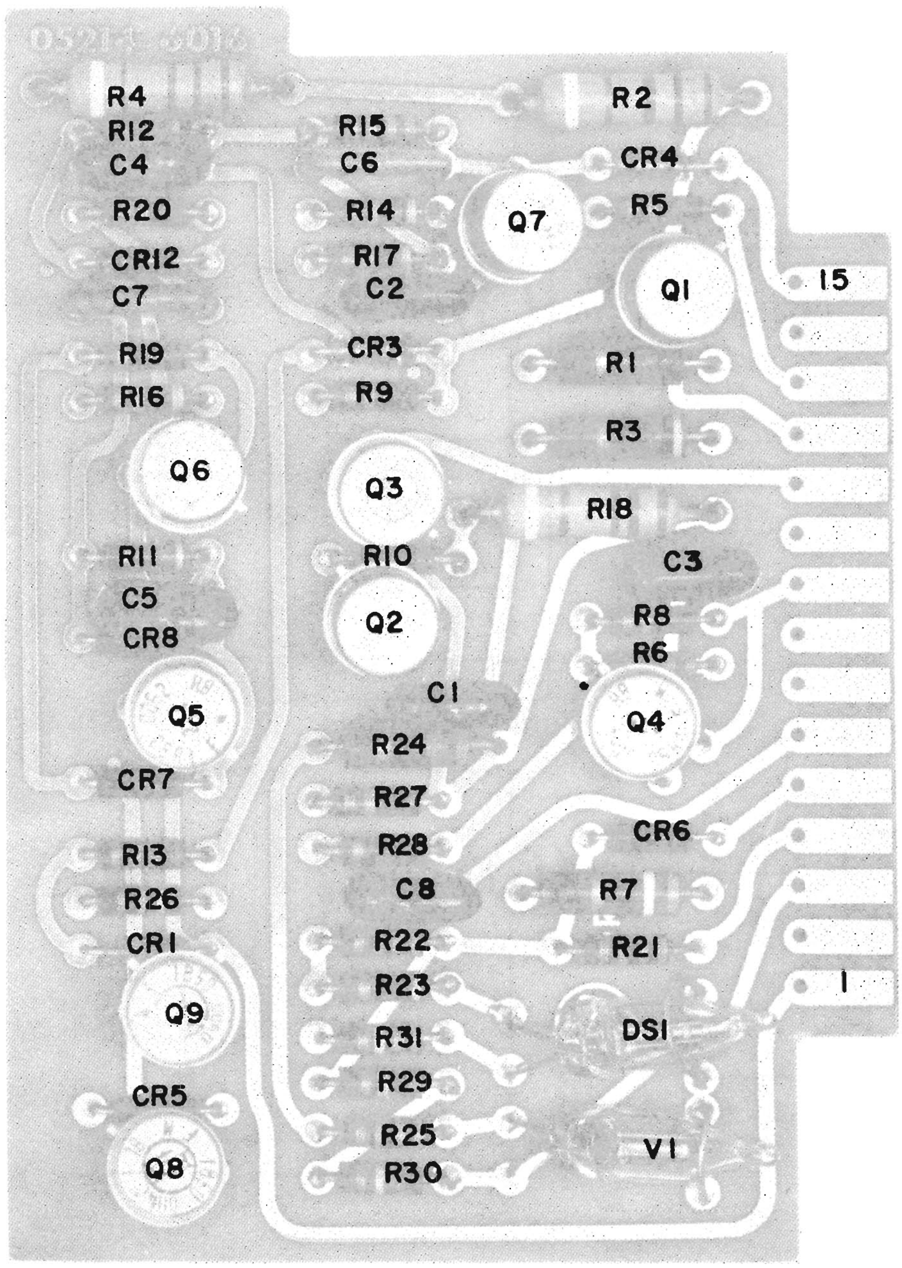
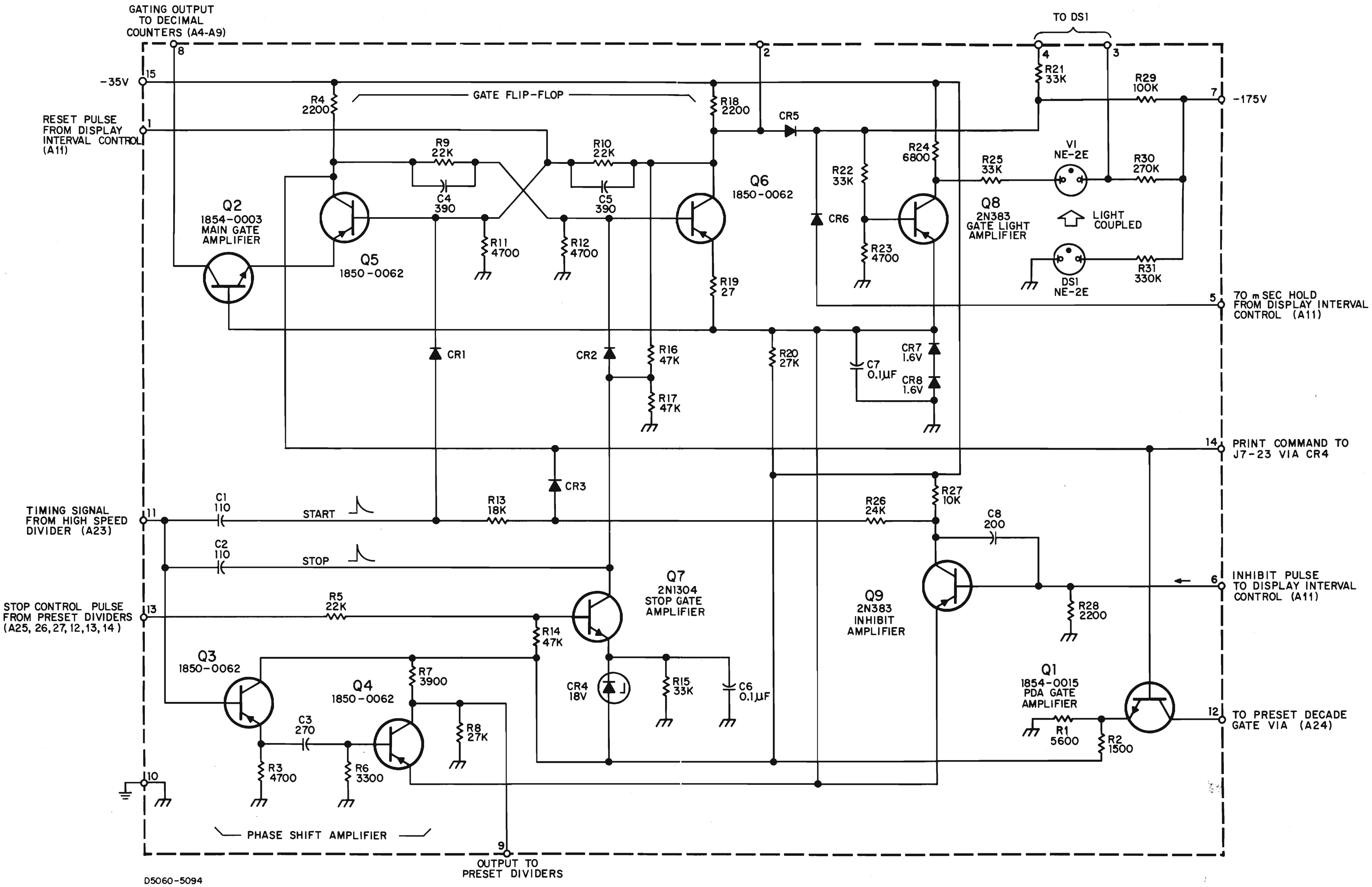


Figure 7-6. (A4 - A9) Decimal Counter Assembly, 8-4-2-1 Positive - True BCD Code (HP 2800A-M6, HP 2801A-M6)


R4
R2
R12
R15
C4
C6
CR4
R20
R14
Q7
R5
CR12
R17
C7
C2
Q1
15
R19
CR3
R1
R16
R9
R3
Q6
Q3
R18
R11
R10
C3
C5
Q2
R8
CR8
R6
C1
Q5
Q4
R24
CR7
R27
R28
CR6
R13
R26
C8
R7
CR1
R22
R21
R23
1
Q9
R31
DS1
R29
CR5
R25
V1
Q8
R30

ART 0938

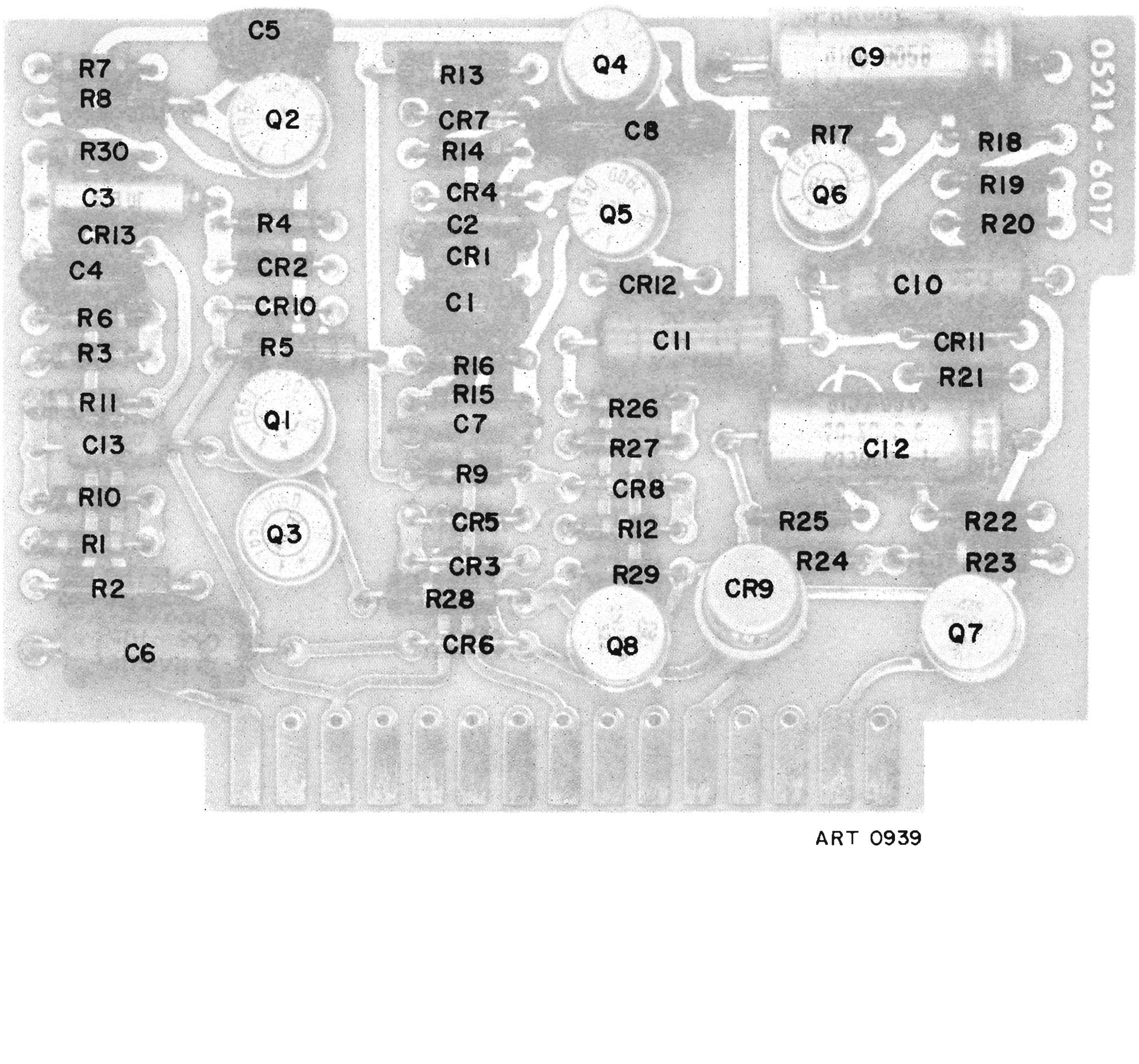


D5060-5094
HP-2801A: SERIAL PREFIX (TYPE) 517 AND ABOVE
HP-2800A: SERIAL PREFIX (TYPE) 523 AND ABOVE

NOTES:

1 UNLESS OTHERWISE INDICATED:
RESISTANCE IN OHMS;
CAPACITANCE IN PICOFARADS

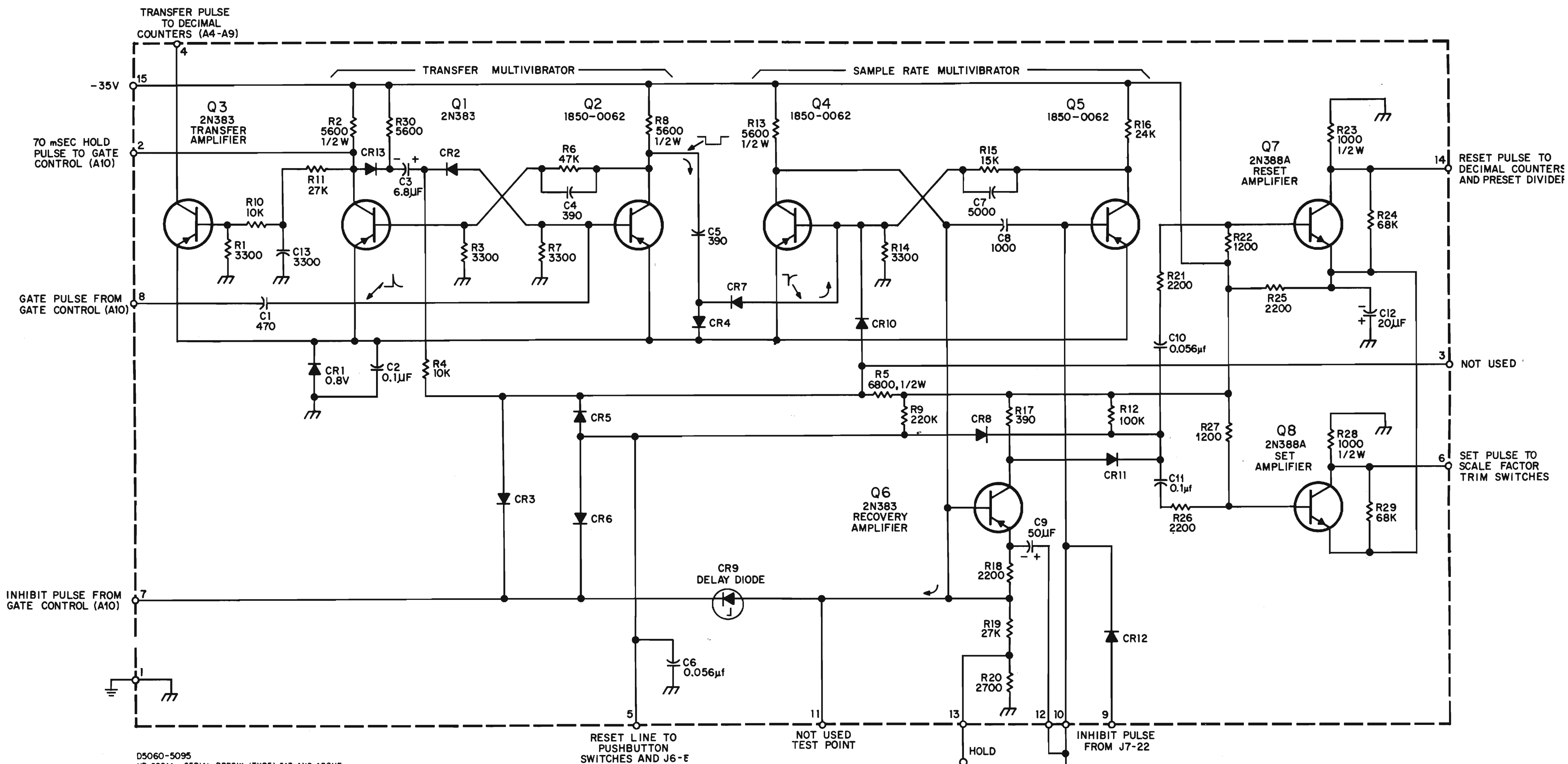
Figure 7-7. (A10) Gate Control


C5
R7
R8
Q2
R30
C3
CR13
C4
R6
R3
R11
C13
R10
R1
R2
C6
R4
CR2
CR10
R5
Q1
Q3
R13
CR7
R14
CR4
C2
CR1
C1
R16
R15
C7
R9
CR5
CR3
R28
CR6
Q4
C8
Q5
CR12
C11
R26
R27
CR8
R12
R29
Q8
C9
R17
Q6
R18
R19
R20
05214-6017
C10
CR11
R21
C12
R25
R24
CR9
R22
R23
Q7

ART 0939

$\frac{35}{6.8} \times 10^{-3}$

5 mS



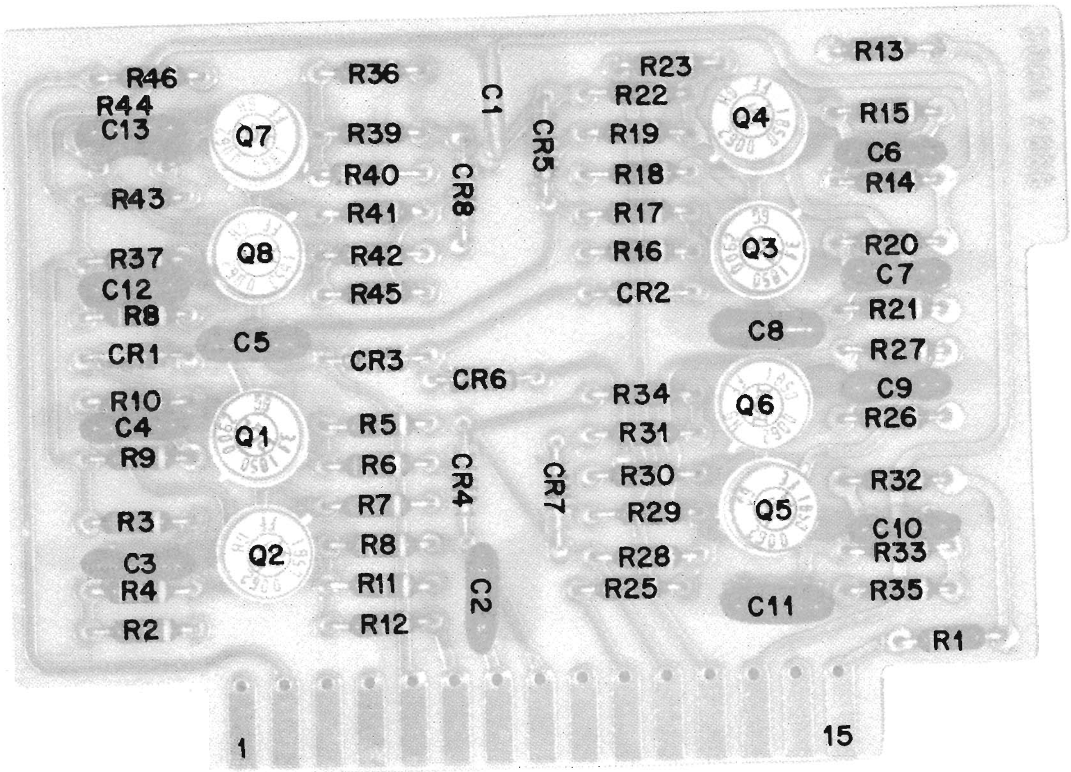
D5060-5095
HP-2801A: SERIAL PREFIX (TYPE) 517 AND ABOVE
HP-2800A: SERIAL PREFIX (TYPE) 523 AND ABOVE

NOTES

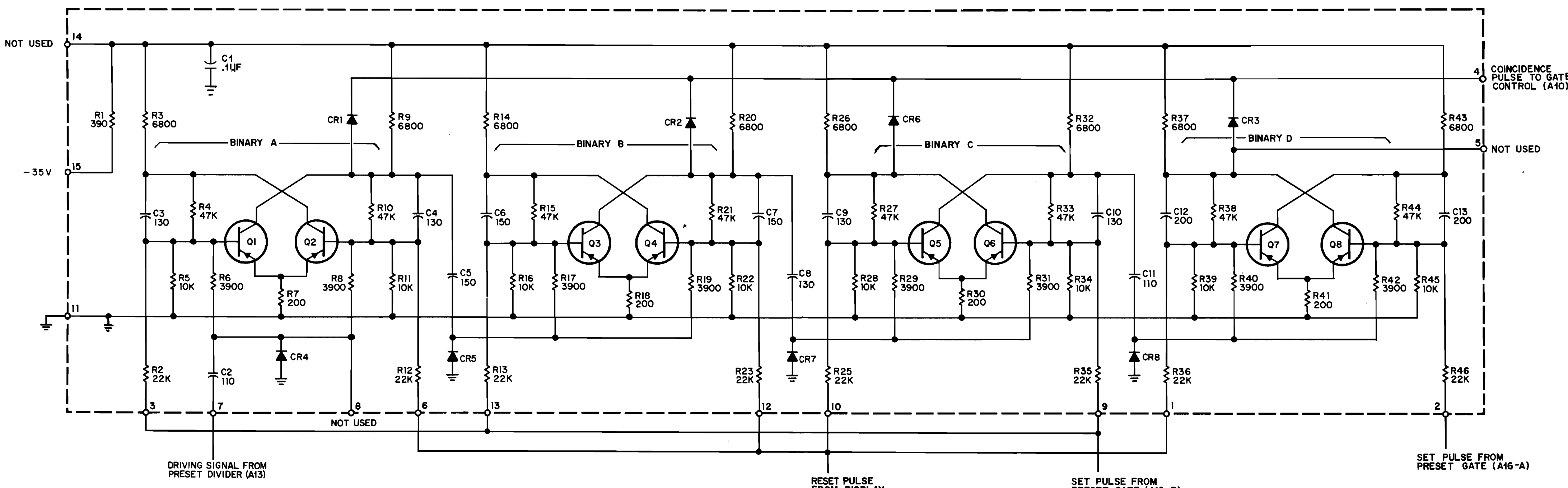
UNLESS OTHERWISE SPECIFIED:

ALL RESISTANCE IN OHMS, 1/4W, 2%
ALL CAPACITANCE IN PICO-FARADS

Figure 7-8. (A11) Display Control


R46
R36
R23
R13
R44
C13
Q7
R39
C1
R22
CR5
R19
Q4
R15
C6
R40
CR8
R18
R14
R43
R41
R17
R37
Q8
R42
R16
Q3
R20
C7
C12
R45
CR2
R21
R8
CR1
C5
CR3
C8
R27
CR6
R10
C4
Q1
R5
R34
Q6
C9
R26
R9
R6
CR4
R31
CR7
R30
R32
R3
R7
R29
Q5
C10
C3
Q2
R8
R28
R33
R4
R11
C2
R25
C11
R35
R2
R12
R1
1
15

ART 0940



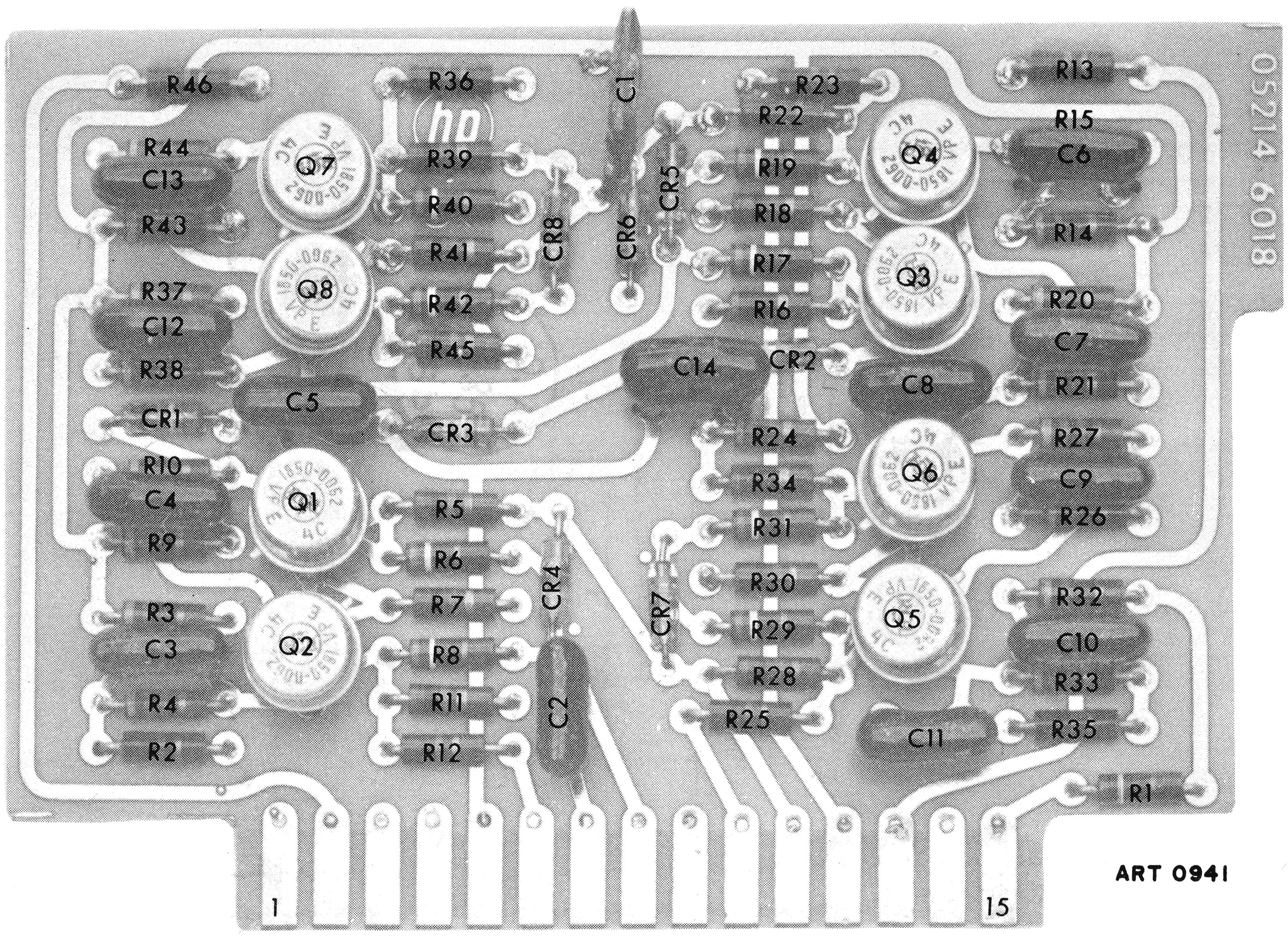
NOTES:

UNLESS OTHERWISE SPECIFIED:

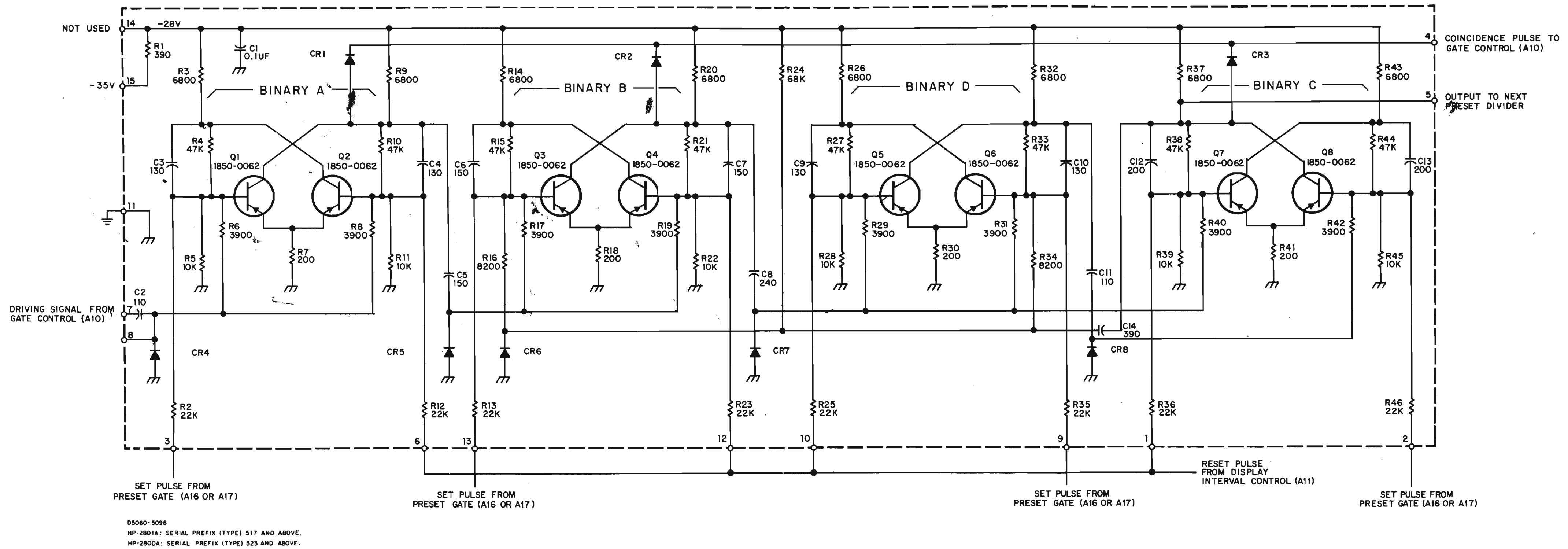
ALL RESISTORS 1/8W, 2%
ALL RESISTANCE IN OHMS
ALL CAPACITANCE IN PICOFARADS
CR1,2,3,6 } 1910-0016
CR4,5,7,8 }
ALL TRANSISTORS 1850-0062

D5060-5024
HP-2801A: SERIAL PREFIX (TYPE) 517 AND ABOVE
HP-2800A: SERIAL PREFIX (TYPE) 523 AND ABOVE

Figure 7-9. (A12) Low Speed Divider

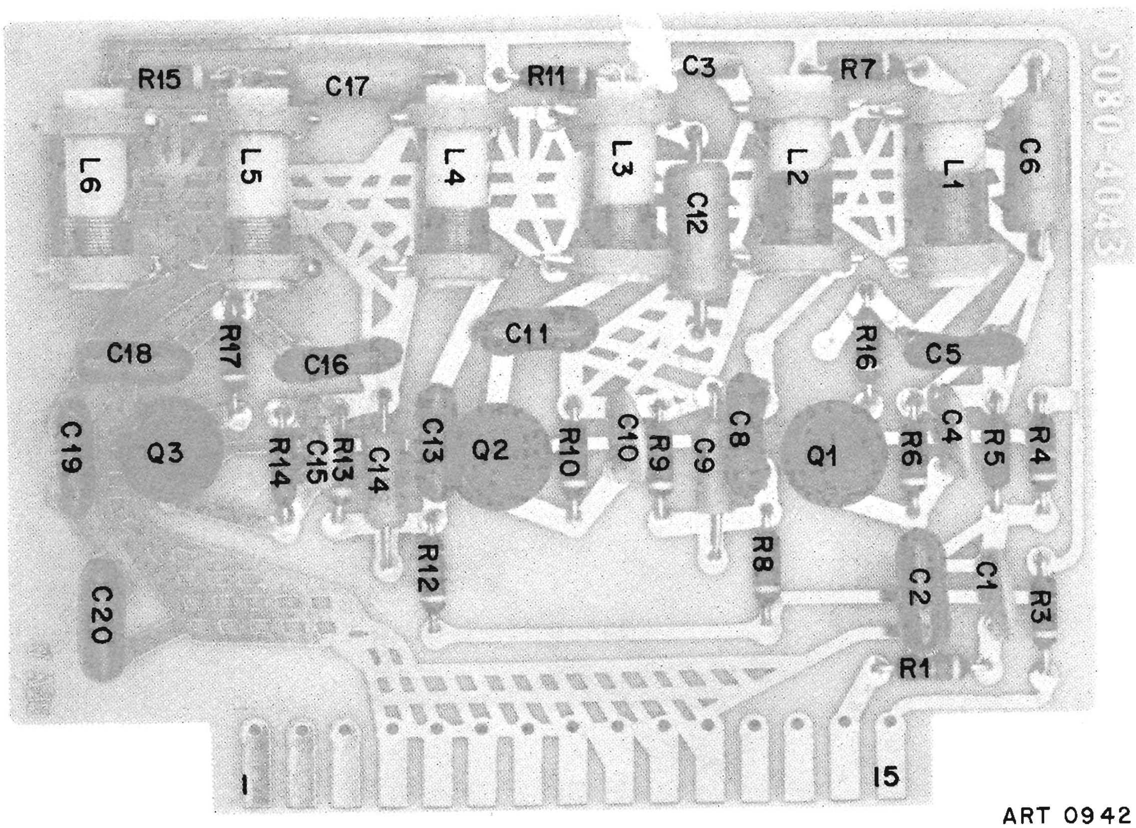

05214 6018
R46
R36
C1
R23
R13
R22
R15
R44
C13
Q7
R39
CR5
R19
Q4
C6
R40
R18
R43
CR8
CR6
R17
R14
Q8
R41
Q3
R37
R42
R16
R20
C12
R45
CR2
C7
R38
C14
C8
R21
C5
CR1
CR3
R24
R27
R10
R34
Q6
C9
C4
Q1
R5
R31
R26
R9
R6
CR4
R30
R3
R7
CR7
R32
Q5
Q2
C3
R8
R29
C10
R4
R11
C2
R28
R33
R2
R12
R25
C11
R35
R1
1
15

ART 0941

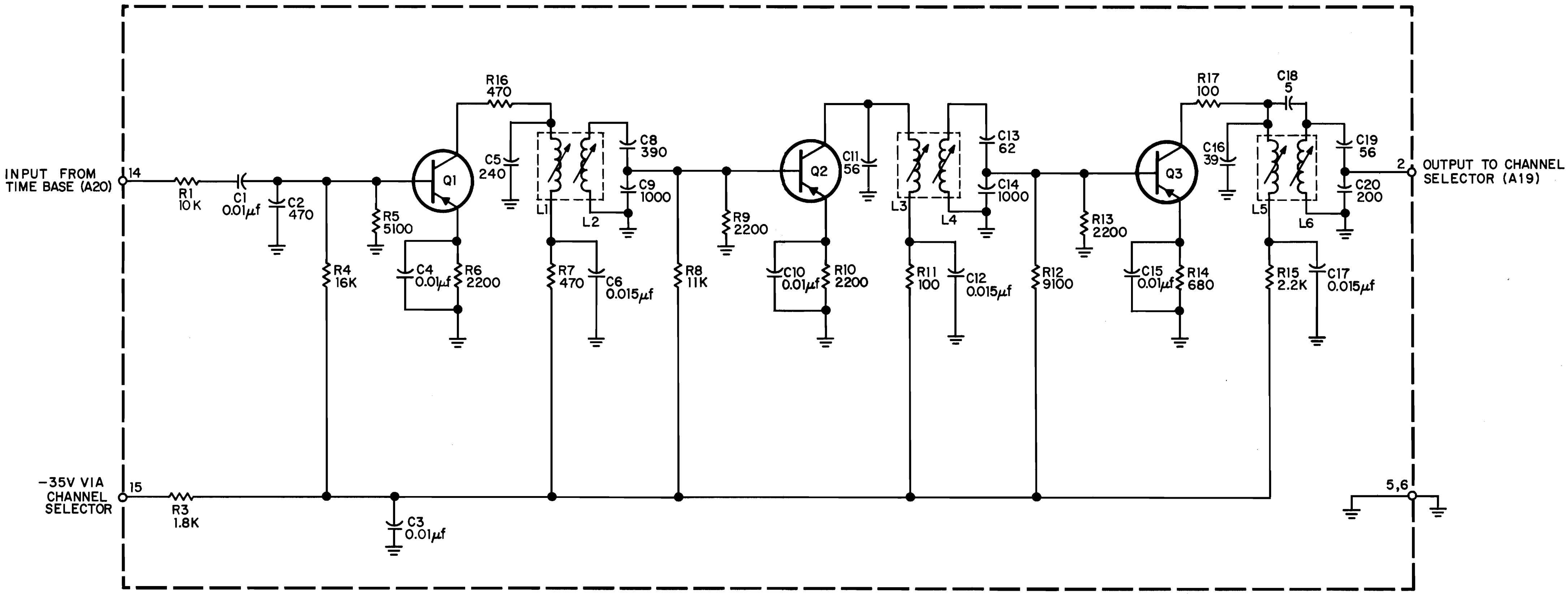


NOTES:
UNLESS OTHERWISE INDICATED
RESISTANCE IN OHMS
CAPACITANCE IN PICOFARADS
ALL DIODES ARE 1910-0016

Figure 7-10. (A13, A14, A25 - A27) Preset Divider


R15
C17
R11
C3
R7
L6
L5
L4
L3
L2
L1
C6
C12
5080-4043
C11
C18
R17
C16
R16
C5
C19
Q3
R14
C15
R13
C14
C13
Q2
R10
C10
R9
C9
C8
Q1
R6
C4
R5
R4
R12
R8
C2
C1
R3
C20
R1
1
15

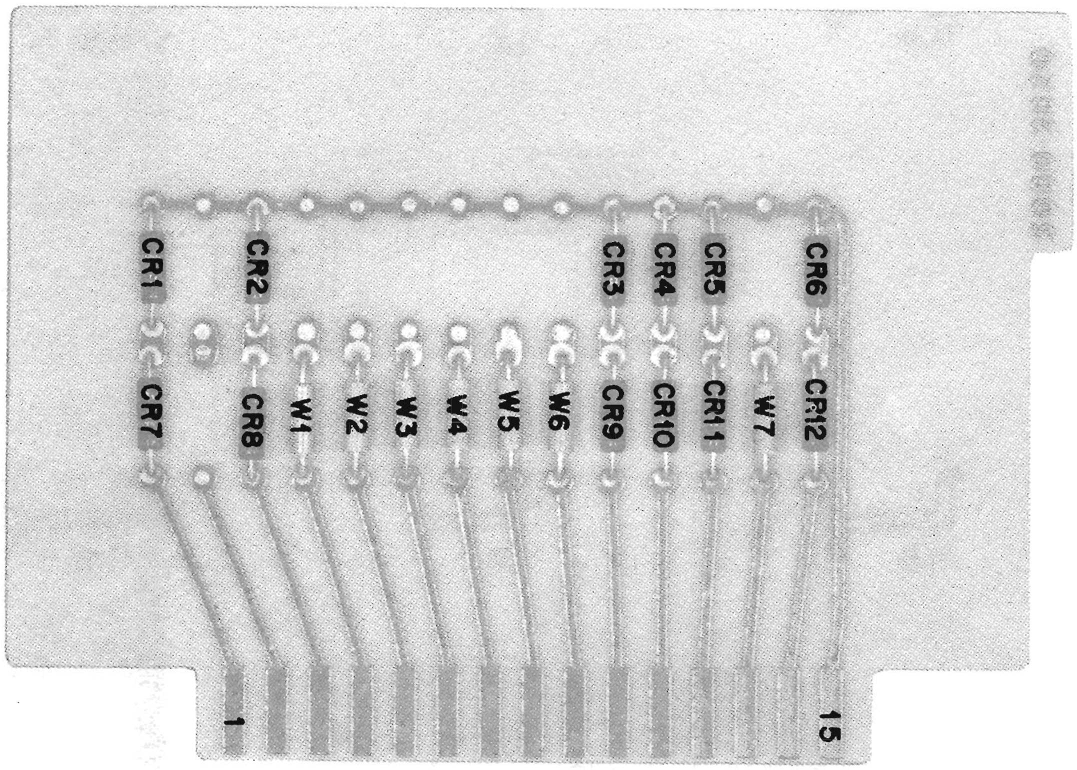
ART 0942



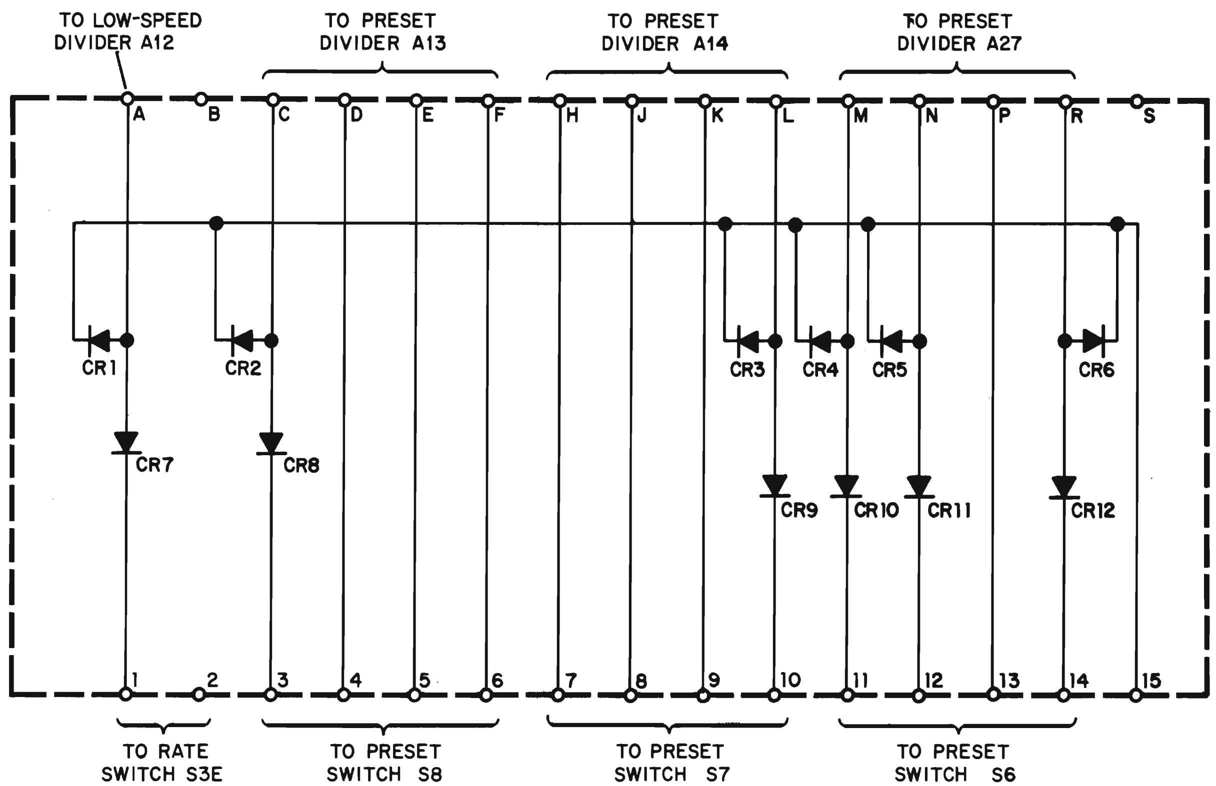
C5060-5043
HP-2801A: SERIAL PREFIX (TYPE) 701 AND ABOVE
HP-2800A: SERIAL PREFIX (TYPE) 710 AND ABOVE

UNLESS OTHERWISE SPECIFIED
ALL RESISTANCE IN OHMS
ALL RESISTORS 1/8W 2%
ALL CAPACITANCE IN pf
ALL TRANSISTORS 1850-0091

Figure 7-11. (A15) Frequency Multiplier


CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
W1
W2
W3
W4
W5
W6
CR9
CR10
CR11
W7
CR12
1
15

ART 0943

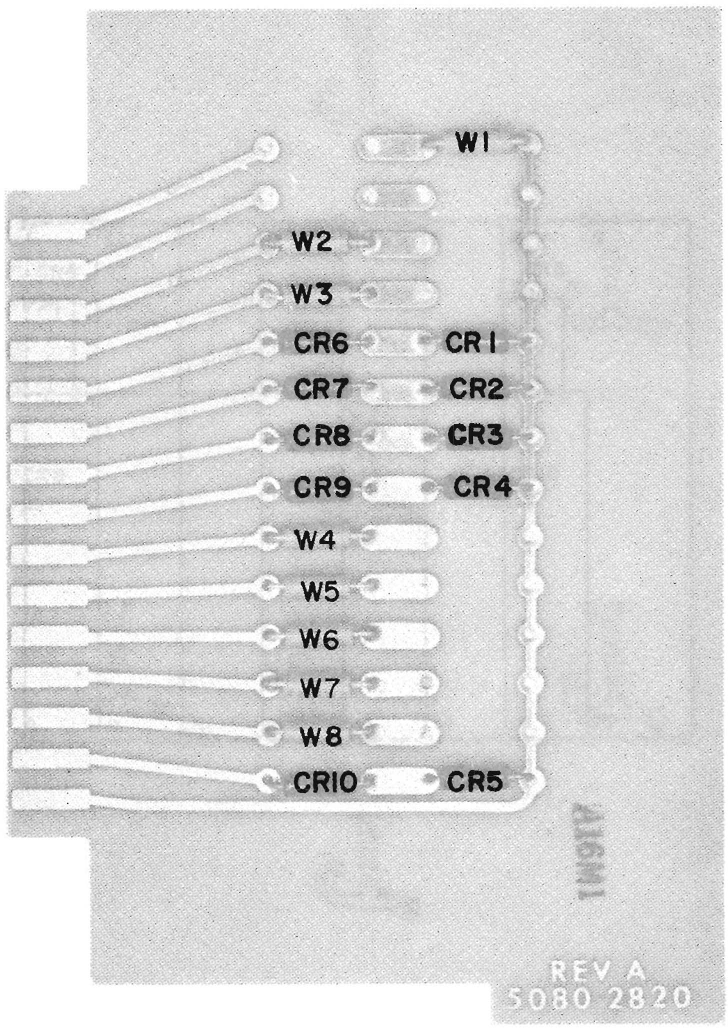


NOTE

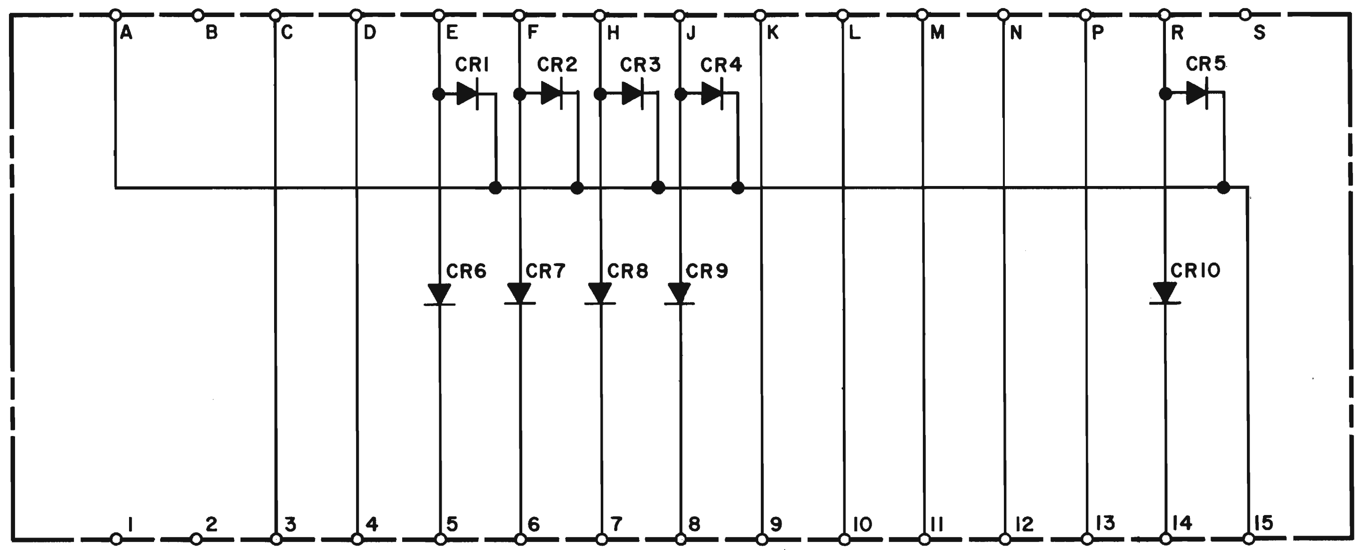
DIODES 1901-0081

Serial Prefix (Type) 536
B5060-5051

Figure 7-12. (A16A) Preset Gate

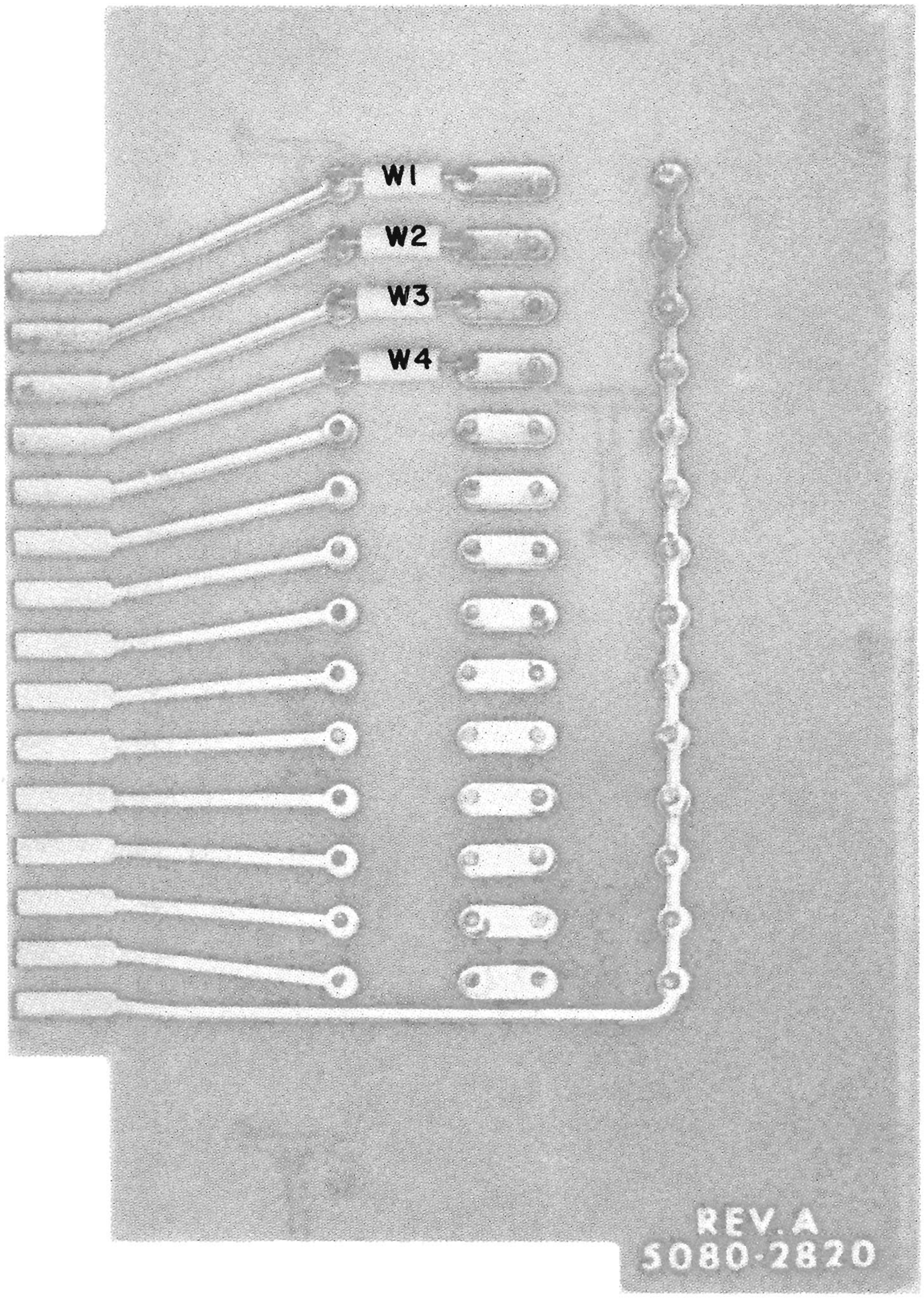

W1
W2
W3
CR6
CR1
CR7
CR2
CR8
CR3
CR9
CR4
W4
W5
W6
W7
W8
CR10
CR5
REV A
5080 2820

ART 0959

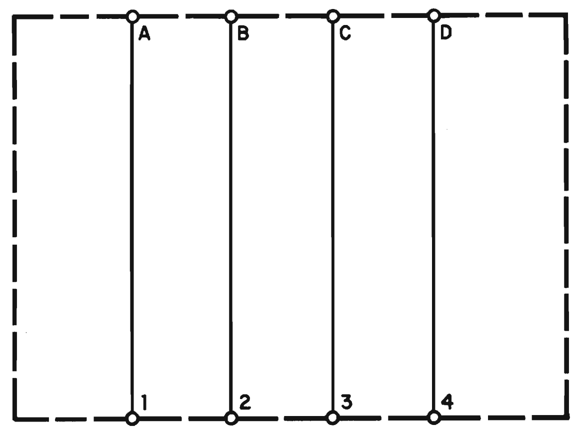


NOTE
DIODES ARE 1901-0081

Figure 7-13. (A16B) Preset Gate (HP 2801A-M1)

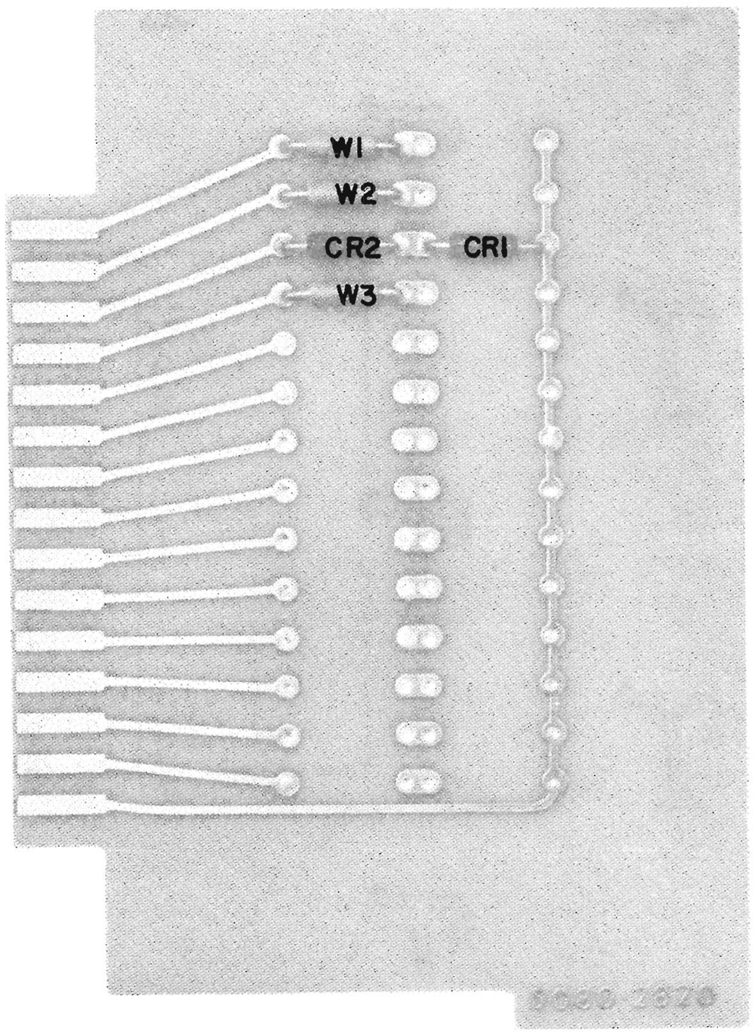


ART 0960

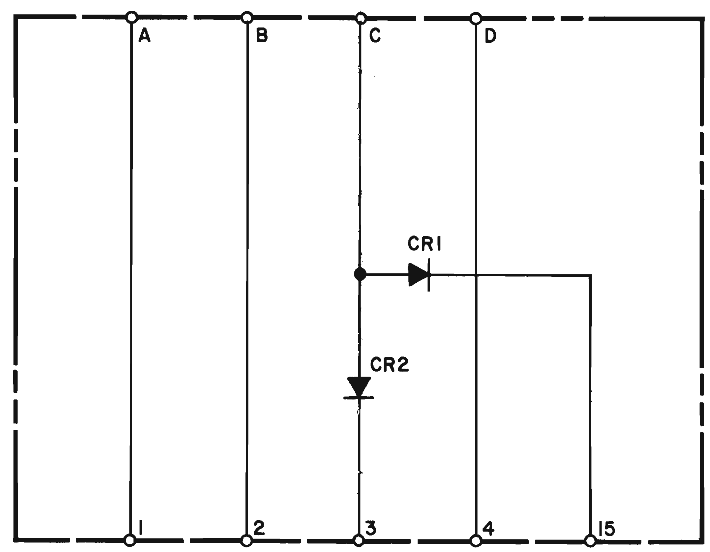


Serial Prefix (Type) 536
B5060-5052

Figure 7-14. (A17A) Preset Board

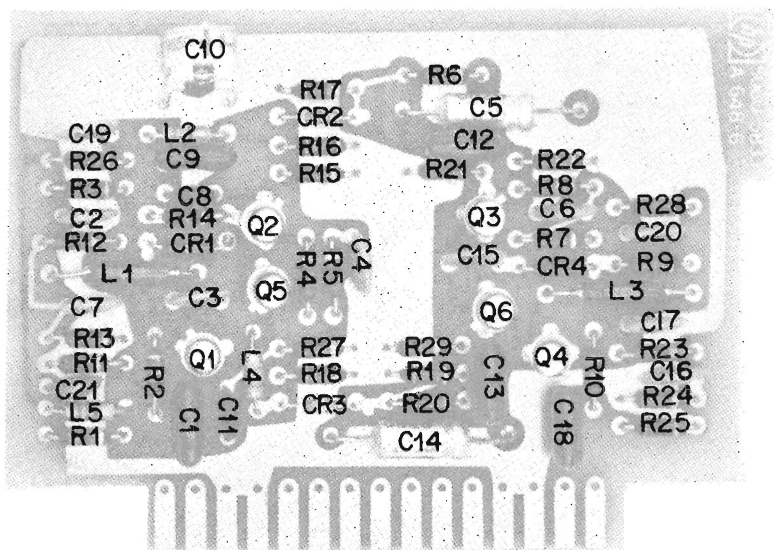


ART 0961

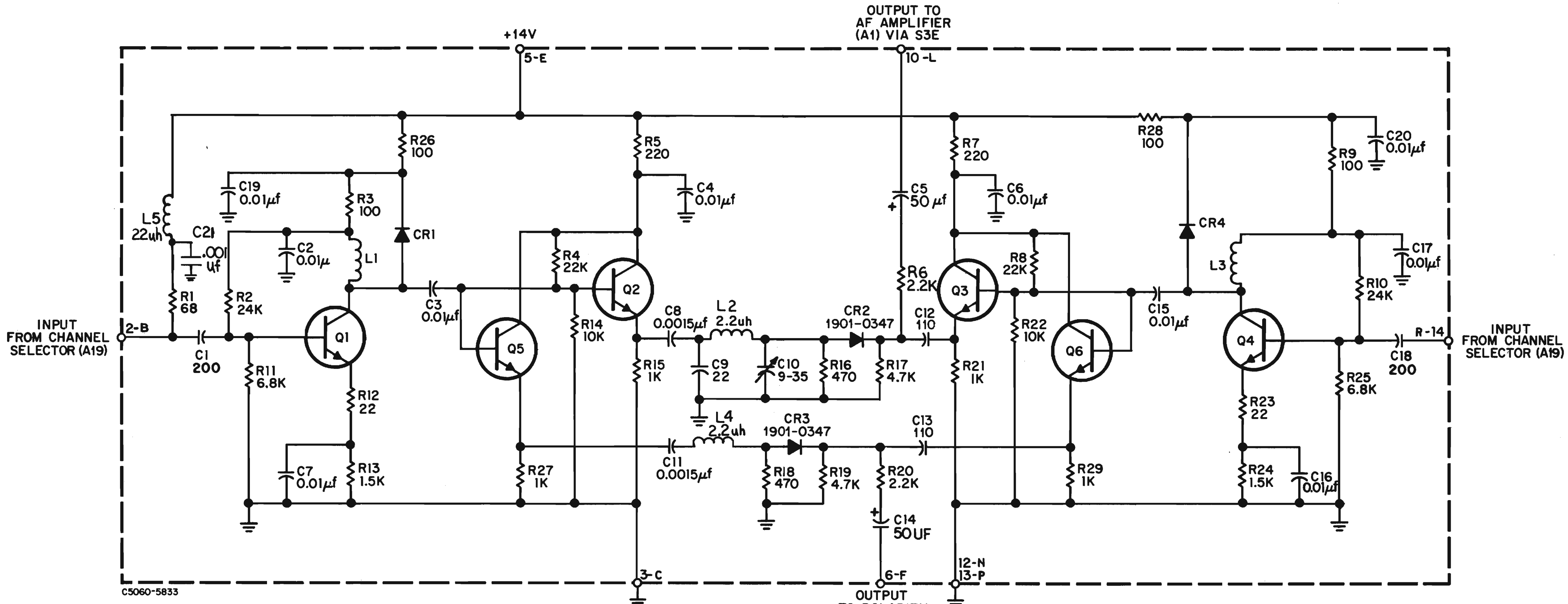


NOTES
DIODES ARE 1901-0081

Figure 7-15. (A17B) Preset Board (HP 2801A-M1)


C10
R17
CR2
R6
C5
C19
L2
R16
C12
R26
C9
R15
R21
R22
R8
R3
C8
C6
R28
C2
R14
Q2
Q3
R7
C20
R12
CR1
C15
CR4
R9
L1
R5
R4
C4
C3
Q5
L3
C7
Q6
C17
R13
R27
R29
R23
R11
R2
Q1
L4
R18
R19
C13
Q4
R10
C16
C21
CR3
R20
R24
L5
C1
C11
C18
R25
R1
C14

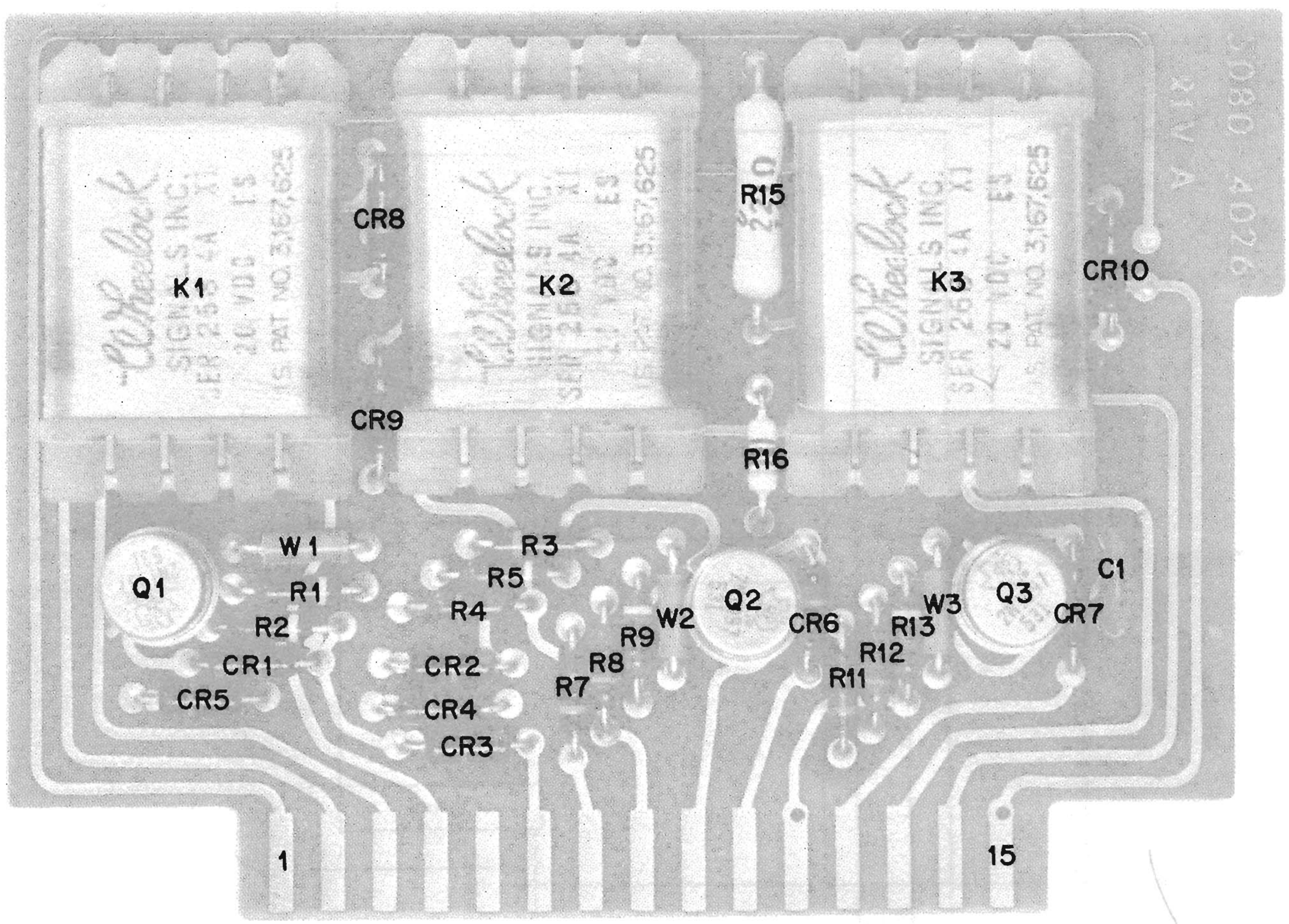
ART 0944



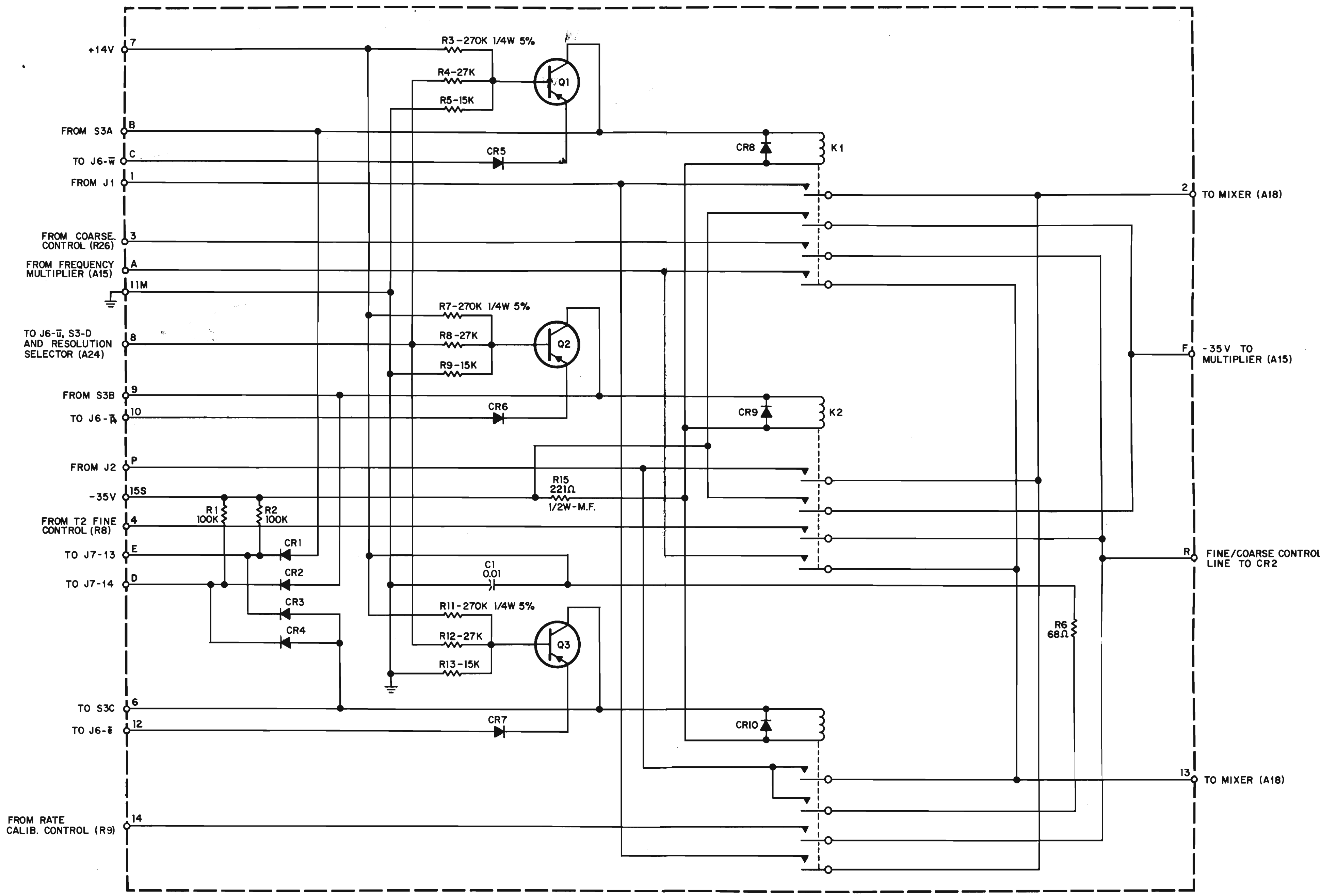
HP-2801A: SERIAL PREFIX (TYPE) 700 AND ABOVE
HP-2800A: SERIAL PREFIX (TYPE) 710 AND ABOVE

UNLESS OTHERWISE SPECIFIED
- ALL RESISTANCE IN OHMS
- ALL RESISTORS 1/8W ±2%
- ALL CAPACITANCE IN PICO-FARADS
- ALL TRANSISTORS ARE 1854-0019
- ALL DIODES ARE 1901-0081
- R12, 23 ARE 1/4W, 5%

Figure 7-16. (A18) Mixer


CR8
R15
K1
K2
K3
CR10
CR9
R16
W1
R3
R5
Q1
R1
R4
W2
Q2
W3
Q3
C1
R2
R9
CR6
R13
CR7
CR1
CR2
R8
R12
CR5
R7
R11
CR4
CR3
1
15

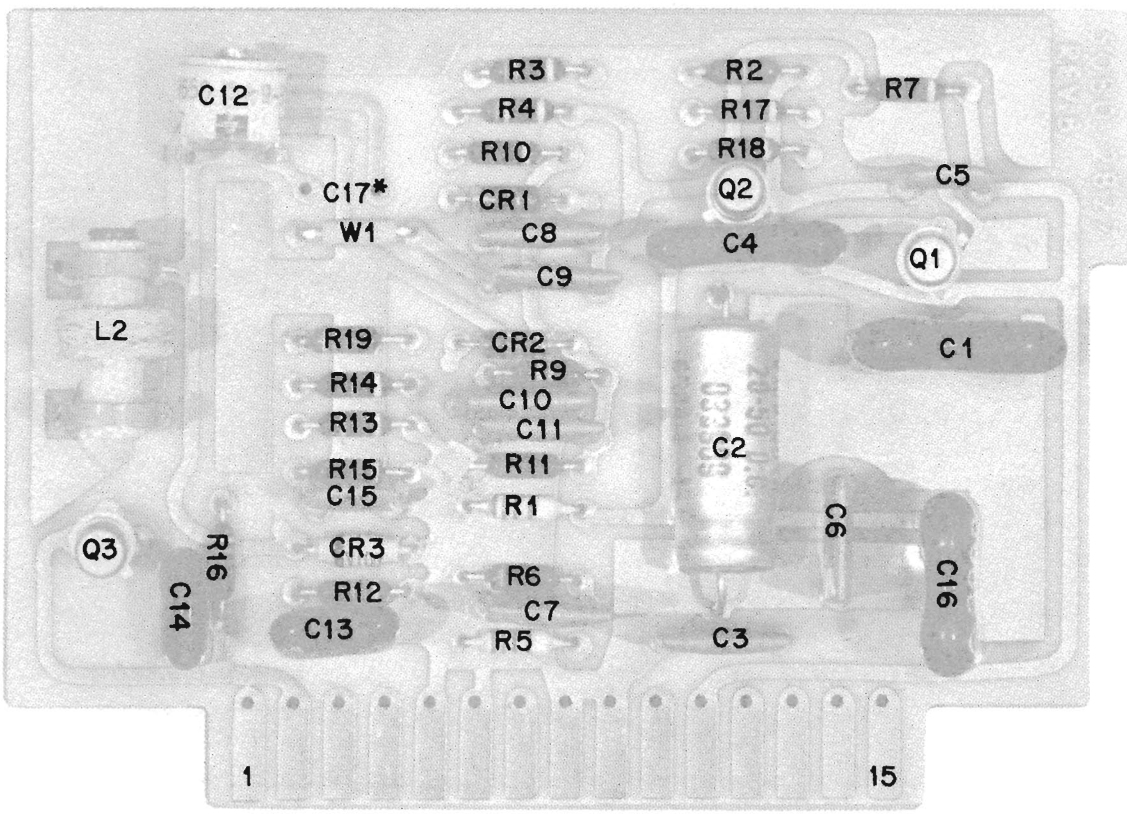
ART 0945



D5060-5027
SERIAL PREFIX (TYPE) 517 AND ABOVE

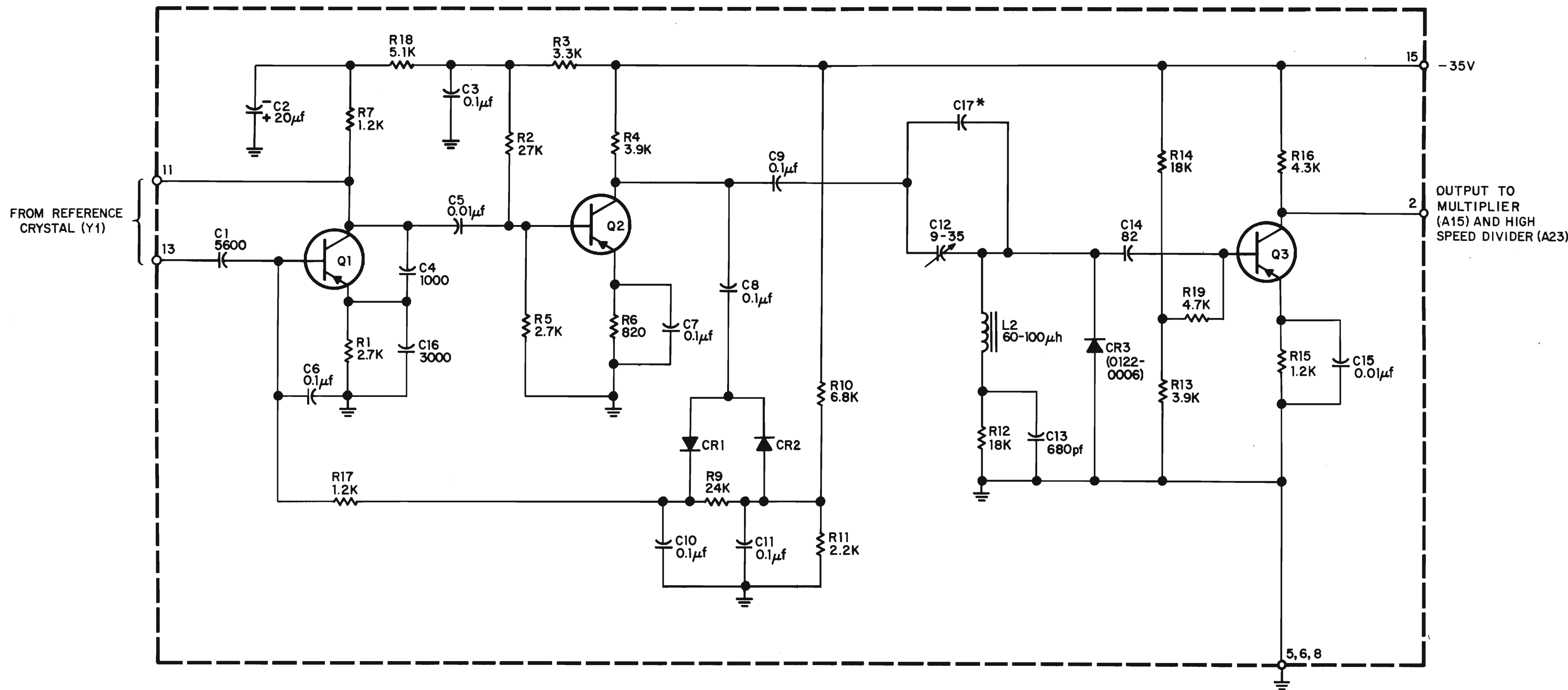
UNLESS OTHERWISE SPECIFIED
ALL RESISTANCE IN OHMS
ALL RESISTORS 1/8W ±2%
R3, R7, R11 ARE 1/4W 5%
ALL TRANSISTORS ARE 1850-0113
ALL DIODES ARE 1901-0081
ALL RELAYS ARE 0490-0130

Figure 7-17. (A19) Channel Selector



* FACTORY SELECTED

ART 0946



NOTES

UNLESS OTHERWISE SPECIFIED:

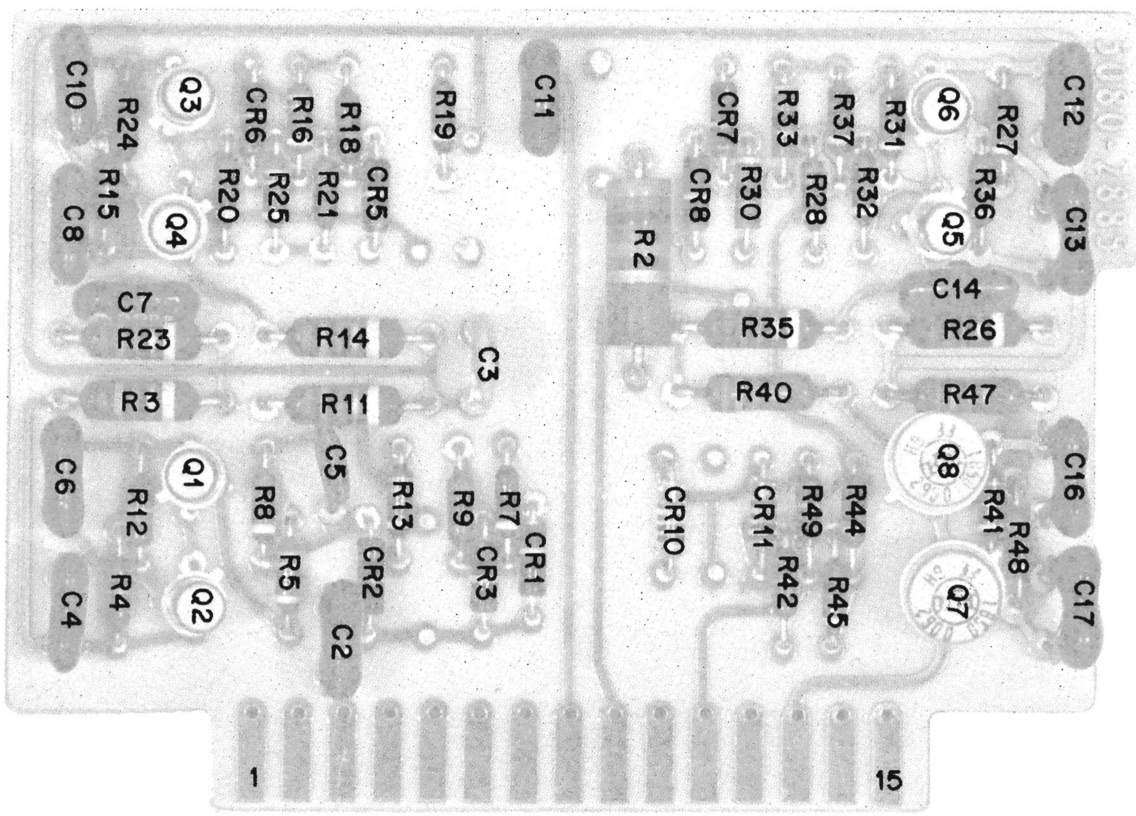
ALL RESISTANCE IN OHMS, 1/8W, 2%
ALL CAPACITANCE IN PICO-FARADS
ALL DIODES 1910-0016
ALL TRANSISTORS 1853-0009

* FACTORY SELECTED; OMITTED IF NOT REQUIRED.

Serial Prefix (Type) 536 and above

C5060-3826

Figure 7-18. (A20) Reference Oscillator


C10
R24
Q3
CR6
R16
R18
R19
C11
CR7
R33
R37
R31
Q6
R27
C12
R15
C8
Q4
R20
R25
R21
CR5
R2
CR8
R30
R28
R32
Q5
R36
C13
C7
R23
R14
C3
C14
R35
R26
R3
R11
R40
R47
C6
Q1
R12
R8
C5
R13
R9
R7
CR1
CR3
CR2
R5
Q2
R4
C4
C2
CR10
CR11
R49
R44
Q8
R41
R48
C16
R42
R45
Q7
C17
1
15

ART 0947

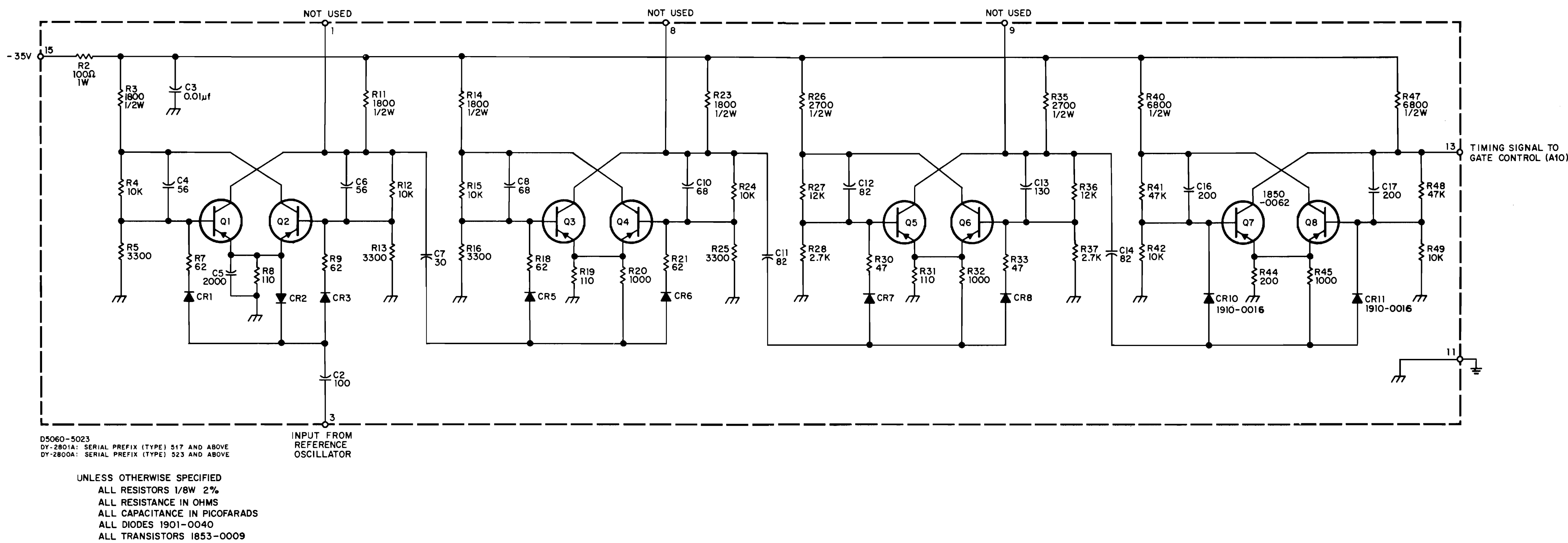
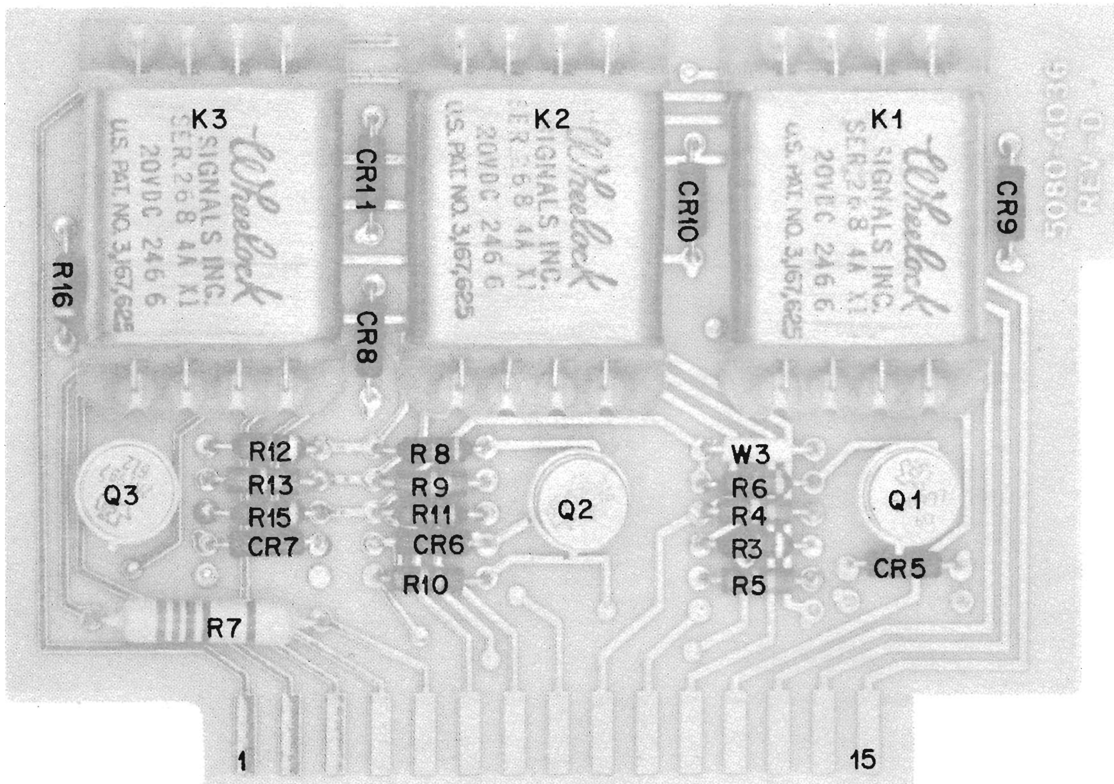
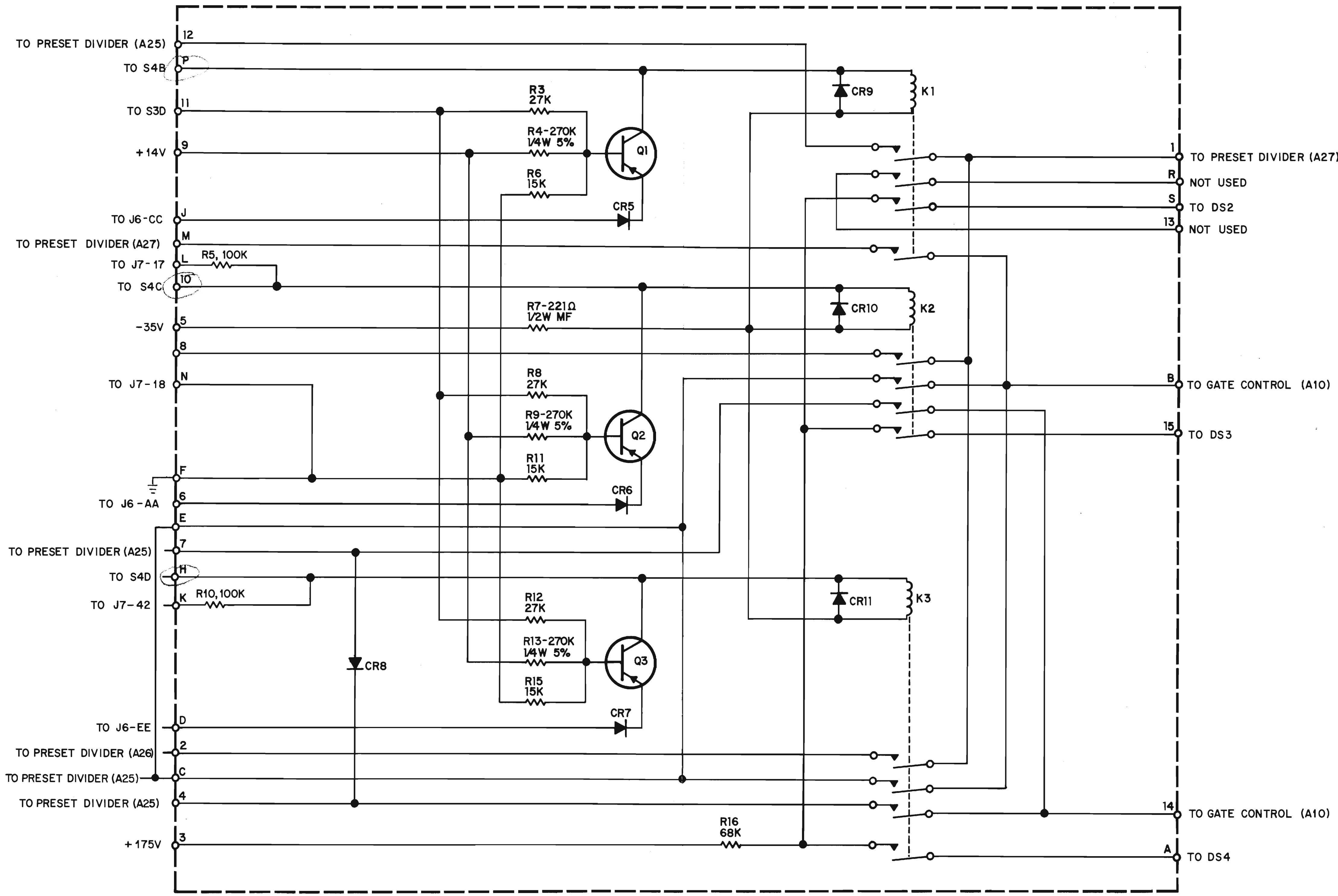


Figure 7-19. (A23) High Speed Divider


K3
K2
K1
CR11
CR10
CR9
CR8
R16
5080-4036
REV-0
Wheelock
SIGNALS INC.
R12
R13
R15
CR7
R8
R9
R11
CR6
R10
Q3
Q2
Q1
W3
R6
R4
R3
R5
CR5
R7
1
15

ART 0948



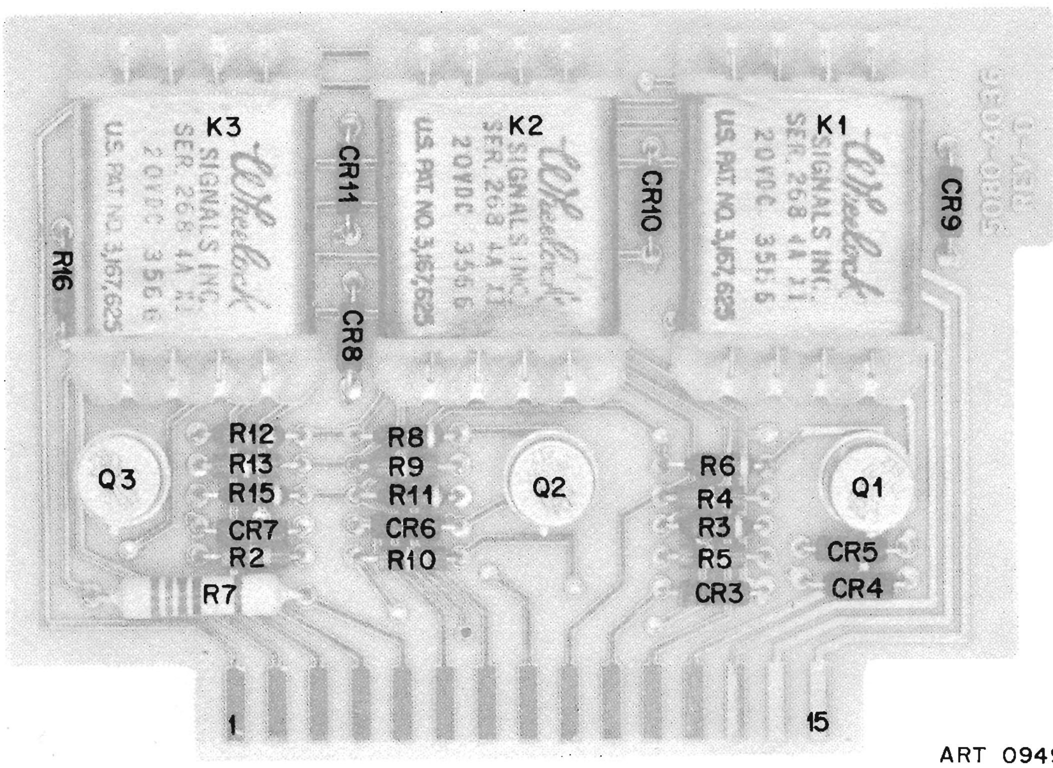
NOTES

UNLESS OTHERWISE SPECIFIED:

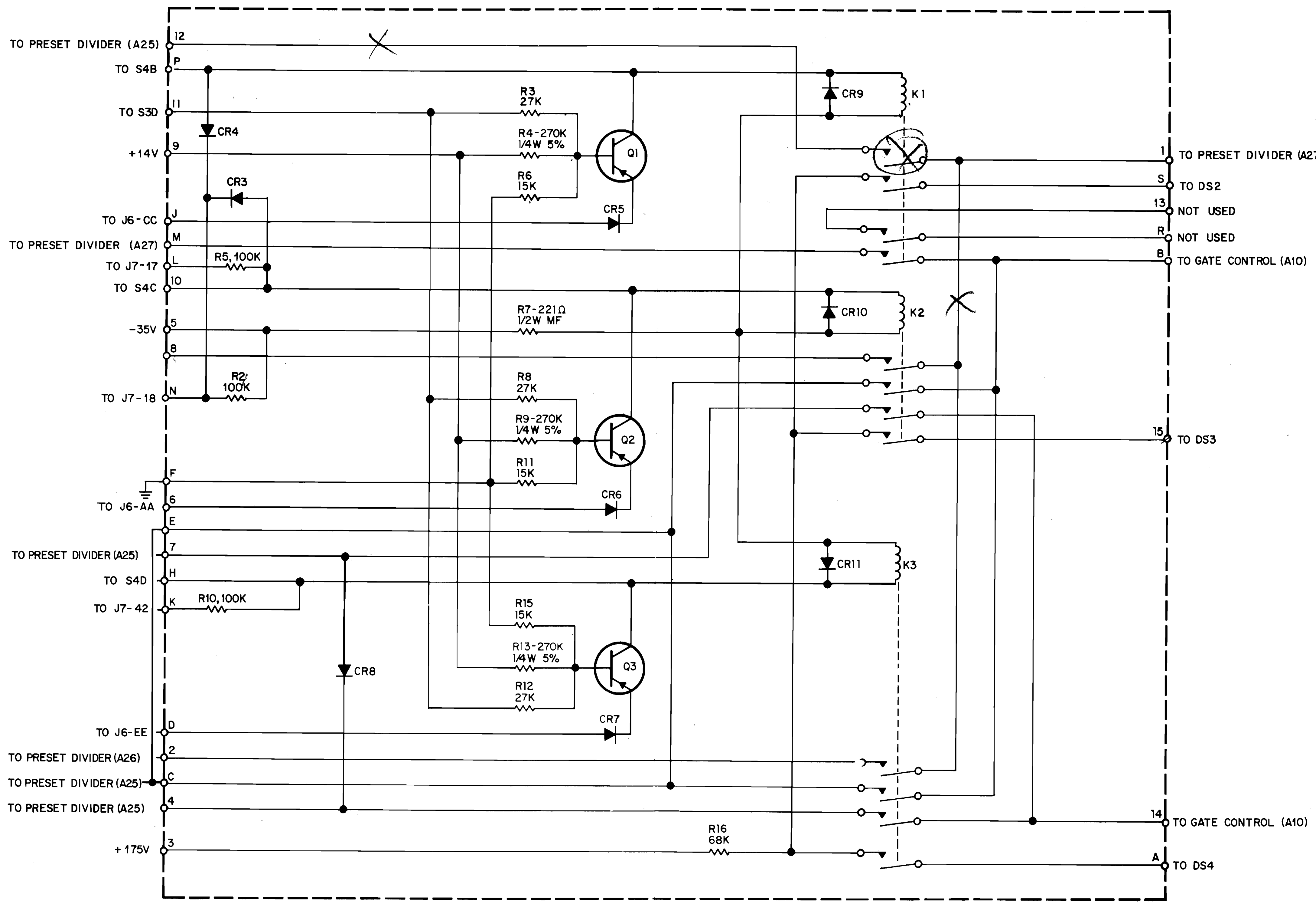
ALL RESISTANCE IN OHMS, 1/8W, 2%
ALL TRANSISTORS ARE 1850-0113
ALL DIODES ARE 1901-0081
ALL RELAYS ARE 0490-0130

Serial Prefix (Type) 700 and above
C5060-5038

Figure 7-20. (A24A) Resolution Selector (4-2'-2-1)


K3
K2
K1
CR11
CR10
CR9
R16
CR8
R12
R13
R15
CR7
R2
R7
Q3
R8
R9
R11
CR6
R10
Q2
R6
R4
R3
R5
CR3
Q1
CR5
CR4
1
15

ART 0949



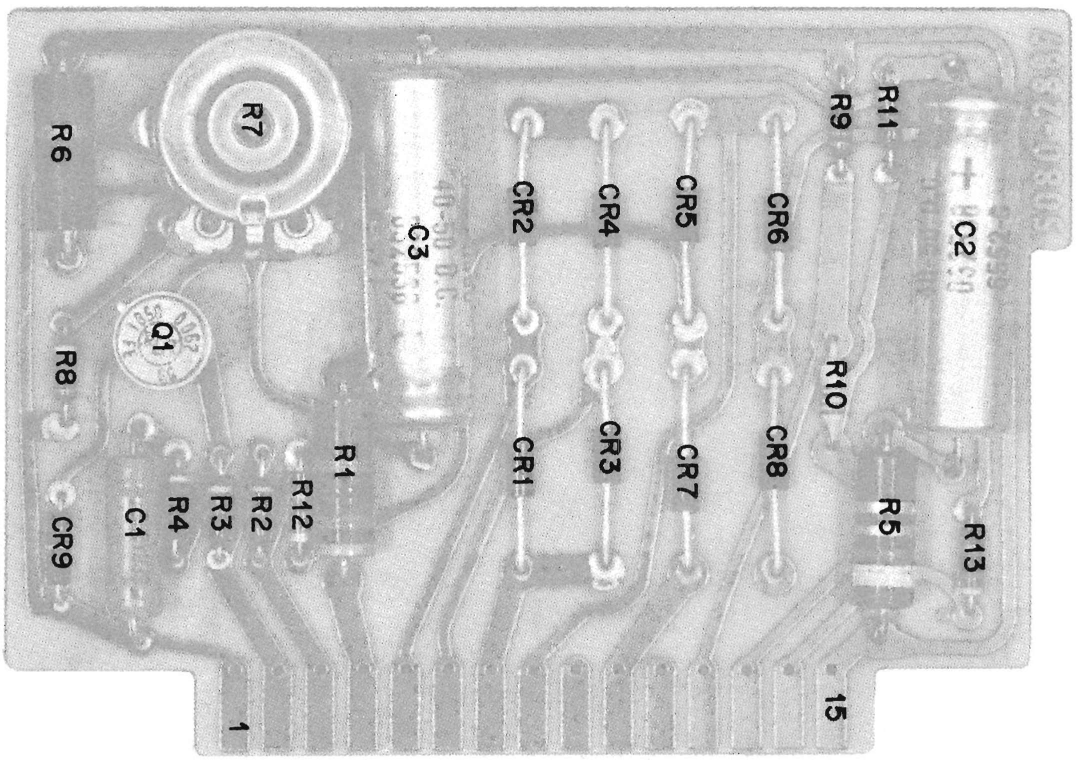
NOTES

UNLESS OTHERWISE SPECIFIED:

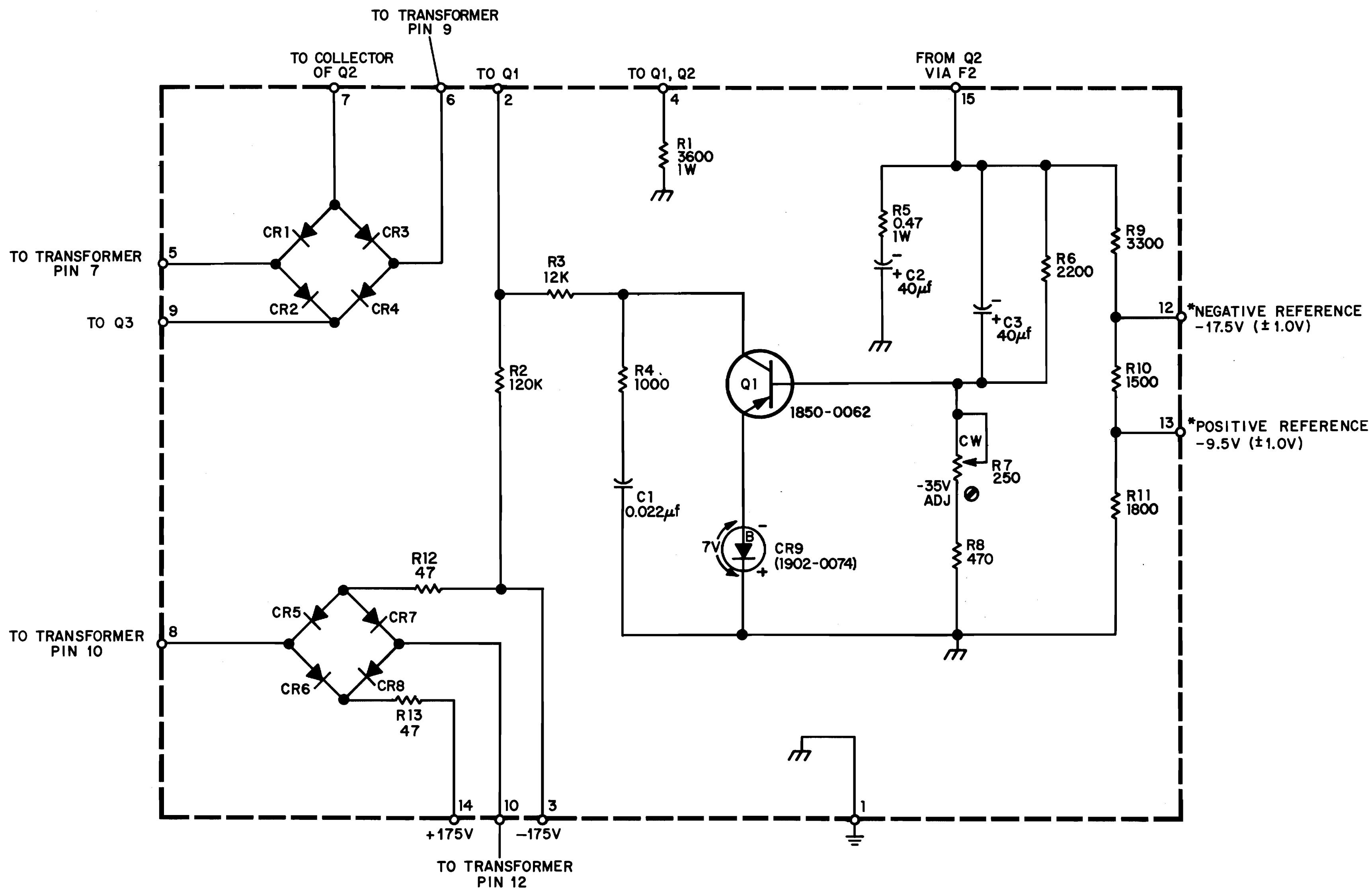
ALL RESISTANCE IN OHMS, 1/8W, 2%
ALL TRANSISTORS ARE 1850-0113
ALL DIODES ARE 1901-0081
ALL RELAYS ARE 0490-0130

Serial Prefix (Type) 700 and above
C5060-5174

Figure 7-21. (A24B) Resolution Selector (HP 2801A-M6, 8-4-2-1)


R6
R7
C3
CR2
CR4
CR5
CR6
R9
R11
C2
Q1
R8
R10
CR9
C1
R4
R3
R2
R12
R1
CR1
CR3
CR7
CR8
R5
R13
1
15

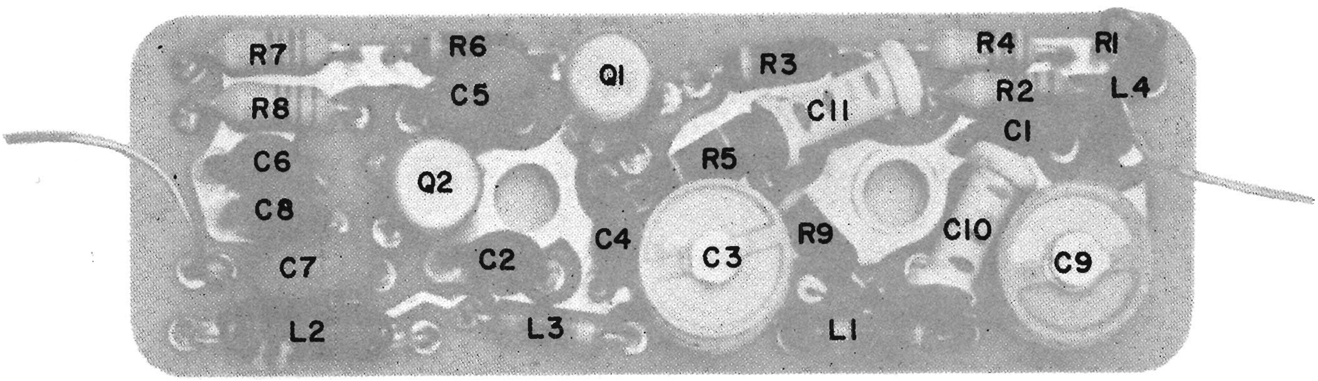
ART 0950



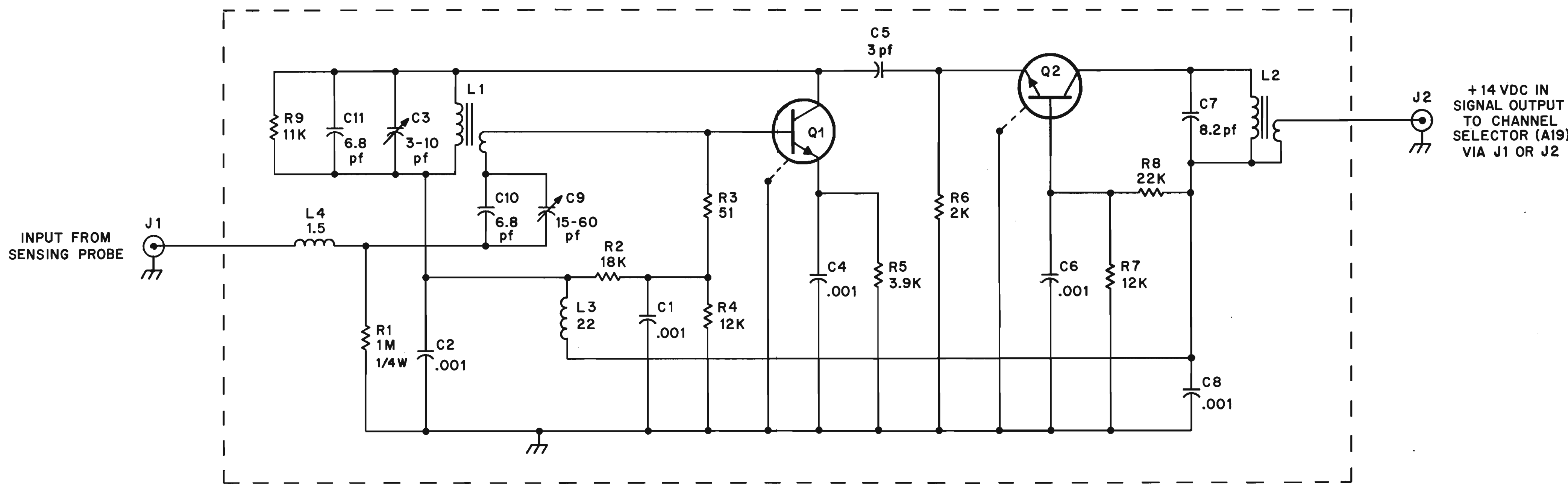
NOTES:
UNLESS OTHERWISE SPECIFIED:
ALL RESISTORS 1/8 2%
ALL DIODES 1901-0028
*REFERENCED TO GROUND

Serial Prefix (Type) 536 and above
C5060-5022

Figure 7-22. (A28) Power Supply


R7
R6
Q1
R3
R4
R1
R8
C5
C11
R2
L4
C1
C6
R5
Q2
C8
R9
C10
C4
C7
C2
C3
C9
L2
L3
L1

ART 0962



UNLESS OTHERWISE SPECIFIED:

ALL RESISTANCE IN OHMS 1/8 W, 2%
ALL TRANSISTORS ARE 1854-0073
ALL CAPACITANCE IN MICROFARADS
ALL INDUCTANCE IN MICROHENRIES

TAPEMASTERS B5080-5943-1 & 2
ASSEMBLY DRAWING B5060-5828-1

Figure 7-23. Schematic Diagram 2830A Sensor Oscillator

CODE LIST OF MANUFACTURERS

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

Code No.	Manufacturer	Address
00000	U. S. A. Common	Any supplier of U. S.
00136	McCoy Electronics	Mount Holly Springs, Pa.
00213	Sage Electronics Corp.	Rochester, N. Y.
00287	Cemco Inc.	Danielson, Conn.
00334	Humidial	Colton, Calif.
00348	Microtron Co., Inc.	Valley Stream, N. Y.
00373	Garlock Inc., Electronics Products Div.	Camden, N. J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp. Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N. J.
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Co., Pickens Div.	Pickens, S. C.
00866	Goe Engineering Co.	Los Angeles, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
00929	Microlab Inc.	Livingston, N. J.
01002	General Electric Co., Capacitor Dept.	Hudson Falls, N. Y.
01009	Alden Products Co.	Brockton, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc., Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
01589	Pacific Relays, Inc.	Van Nuys, Calif.
01930	Amerock Corp.	Rockford, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.
02114	Ferroxcube Corp. of America	Saugerties, N. Y.
02116	Wheelock Signals, Inc.	Long Branch, N. J.
02286	Cole Rubber and Plastics Inc.	Sunnyvale, Calif.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America, Semiconductor and Materials Div.	Somerville, N. J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Calif.
03508	G. E. Semiconductor Prod. Dept.	Syracuse, N. Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electric Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co., Inc.	Cedar Knolis, N. J.
03954	Singer Co., Diehl Div. Finderne Plant	Sumerville, N. J.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04013	Taurus Corp.	Lambertville, N. J.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S. C.
04354	Precision Paper Tube Co.	Chicago, Ill.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04651	Sylvania Electric Products, Microwave Device Div.	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Div.	Culver City, Calif.
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire Co.	Redwood City, Calif.
04811	Precision Coil Spring Co.	El Monte, Calif.
04870	P. M. Motor Company	Westchester, Ill.
04919	Component Mfg. Service Co.	W. Bridgewater, Mass.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.
05277	Westinghouse Electric Corp. Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	San Mateo, Calif.
05397	Union Carbide Corp., Linde Div., Kemet Dept.	Cleveland, Ohio
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.
05616	Cosmo Plastic (c/o Electrical Spec. Co.)	Cleveland, Ohio
05624	Barber Colman Co.	Rockford, Ill.
05728	Tiffen Optical Co.	Roslyn Heights, Long Island, N. Y.
05729	Metro-Tel Corp.	Westbury, N. Y.
05783	Stewart Engineering Co.	Santa Cruz, Calif.
05820	Wakefield Engineering Inc.	Wakefield, Mass.
06004	Bassick Co., The	Bridgeport, Conn.
06090	Raychem Corp.	Redwood City, Calif.
06175	Bausch and Lomb Optical Co.	Rochester, N. Y.
06402	E. T. A. Products Co. of America	Chicago, Ill.
06540	Amatom Electronic Hardware Co., Inc.	New Rochelle, N. Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N. H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Semcor Div. Components Inc.	Phoenix, Ariz.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
06980	Varian Assoc. Eimac Div.	San Carlos, Calif.
07088	Kelvin Electric Co.	Van Nuys, Calif.
07126	Digitran Co.	Pasadena, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N. Y.
07149	Filmohm Corp.	New York, N. Y.
07233	Cinch-Graphik Co.	City of Industry, Calif.
07261	Avnet Corp.	Culver City, Calif.
07263	Fairchild Camera & Inst. Corp. Semiconductor Div.	Mountain View, Calif.
07322	Minnesota Rubber Co.	Minneapolis, Minn.
07387	Birtcher Corp., The	Monterey Park, Calif.
07397	Sylvania Elect. Prod. Inc., Mt. View Operations	Mountain View, Calif.
07700	Technical Wire Products Inc.	Cranford, N. J.
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Calif.
07980	Hewlett-Packard Co., Boonton Radio Div.	Rockaway, N. J.
08145	U. S. Engineering Co.	Los Angeles, Calif.
08289	Blinn, Delbert Co.	Pomona, Calif.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08524	Deutsch Fastener Corp.	Los Angeles, Calif.
08664	Bristol Co., The	Waterbury, Conn.
08717	Sloan Company	Sun Valley, Calif.
08718	ITT Cannon Electric Inc., Phoenix Div.	Phoenix, Arizona
08792	CBS Electronics Semiconductor Operations, Div of C. B. S. Inc.	Lowell, Mass.
08984	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays Div.	Costa Mesa, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09145	Atohm Electronics	Sun Valley, Calif.
09250	Electro Assemblies, Inc.	Chicago, Ill.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
10214	General Transistor Western Corp.	Los Angeles, Calif.
10411	Ti-Tal, Inc.	Berkeley, Calif.
10646	Carborundum Co.	Niagara Falls, N. Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11242	Bay State Electronics Corp.	Waltham, Mass.
11312	Teledyne Inc., Microwave Div.	Palo Alto, Calif.
11534	Duncan Electronics Inc.	Costa Mesa, Calif.
11711	General Instrument Corp., Semiconductor Div., Products Group	Newark, N. J.
11717	Imperial Electronic, Inc.	Buena Park, Calif.
11870	Melabs, Inc.	Palo Alto, Calif.
12136	Philadelphia Handie Co.	Camden, N. J.
12361	Grove Mfg. Co., Inc.	Shady Grove, Pa.
12574	Gulton Ind. Inc., CG Elect. Div.	Albuquerque, N. M.
12697	Clarostat Mfg. Co.	Dover, N. H.
12728	Elmar Filter Corp.	W. Haven, Conn.
12859	Nippon Electric Co., Ltd.	Tokyo, Japan
12881	Metex Electronics Corp.	Clark, N. J.
12930	Delta Semiconductor Inc.	Newport Beach, Calif.
12954	Dickson Electronics Corp.	Scottsdale, Arizona
13103	Thermolloy	Dallas, Texas
13396	Telefunken (GmbH)	Hanover, Germany
13835	Midland-Wright Div. of Pacific Industries, Inc.	Kansas City, Kansas
14099	Sem-Tech	Newbury Park, Calif.
14193	Calif. Resistor Corp.	Santa Monica, Calif.
14298	American Components, Inc.	Conshohocken, Pa.
14433	ITT Semiconductor, A Div. of Int. Telephone & Telegraph Corp.	West Palm Beach, Fla.
14493	Hewlett-Packard Company	Loveland, Colo.
14655	Cornell Dublier Electric Corp.	Newark, N. J.
14674	Corning Glass Works	Corning, N. Y.
14752	Electro Cube Inc.	So. Pasadena, Calif.
14960	Williams Mfg. Co.	San Jose, Calif.
15203	Webster Electronics Co.	New York, N. Y.
15287	Scionics Corp.	Northridge, Calif.
15291	Adjustable Bushing Co.	N. Hollywood, Calif.
15558	Micron Electronics	Garden City, Long Island, N. Y.
15566	Amprobe Inst. Corp.	Lynbrook, N. Y.
15631	Cabletronics	Costa Mesa, Calif.
15772	Twentieth Century Coil Spring Co.	Santa Clara, Calif.
15818	Amelco Inc.	Mt. View, Calif.
15909	Daven Div. Thomas A. Edison Ind. McGraw-Edison Co.	Long Island City, N. Y.
16037	Spruce Pine Mica Co.	Spruce Pine, N. C.
16179	Omni-Spectra Inc.	Detroit, Ill.
16352	Computer Diode Corp.	Lodi, N. J.
16688	Ideal Prec. Meter Co., Inc. De Jur Meter Div.	Brooklyn, N. Y.
16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.
17109	Thermonetics Inc.	Canoga Park, Calif.
17474	Tranex Company	Mountain View, Calif.
17675	Hamlin Metal Products Corp.	Akron, Ohio
17745	Angstrohm Prec. Inc.	No. Hollywood, Calif.
18042	Power Design Pacific Inc.	Palo Alto, Calif.
18083	Clevite Corp., Semiconductor Div.	Palo Alto, Calif.
18476	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
18486	TRW Elect. Comp. Div.	Des Plaines, Ill.
18583	Curtis Instrument, Inc.	Mt. Kisco, N. Y.
18873	E. I. DuPont and Co., Inc.	Wilmington, Del.
18911	Durant Mfg. Co.	Milwaukee, Wis.
19315	Bendix Corp., The Eclipse-Poineer Div.	Teterboro, N. J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N. J.
19589	Concoa	Baldwin Park, Calif.
19644	LRC Electronics	Horseheads, N. Y.
19701	Electra Mfg. Co.	Independence, Kansas
20183	General Atronics Corp.	Philadelphia, Pa.
21226	Executone, Inc.	Long Island City, N. Y.

From: FSC. Handbook Supplements
H4-1 Dated AUGUST 1966
H4-2 Dated NOV 1962

CODE LIST OF MANUFACTURERS (Cont'd)

Code No.	Manufacturer	Address
21335	Fafnir Bearing Co., The	New Britain, Conn.
21520	Fansteel Metallurgical Corp.	N. Chicago, Ill.
23783	British Radio Electronics Ltd.	Washington, D.C.
24455	G.E. Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26365	Gries Reproducer Corp.	New Rochelle, N.Y.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
28520	Heyman Mfg. Co.	Kenilworth, N.J.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
36196	Stanwyck Coil Products Ltd.	Hawkesbury, Ontario, Canada
36287	Cunningham, W.H. & Hill, Ltd.	Toronto Ontario, Canada
37942	P.R. Mallory & Co. Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
43990	C.A. Norgren Co.	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill.
46384	Penn Eng. & Mfg. Corp.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer & Inst. Co.	Southampton, Pa.
49956	Microwave & Power Tube Div.	Waltham, Mass.
52090	Rowan Controller Co.	Westminster, Md.
52983	Sanborn Company	Waltham, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Raytheon Co. Commercial Apparatus & Systems Div.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
59446	Telex, Inc.	St. Paul, Minn.
59730	Thomas & Betts Co.	Elizabeth, N.J.
60741	Triplett Electrical Inst. Co.	Bluffton, Ohio
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.
62119	Universal Electric Co.	Owosso, Mich.
63743	Ward-Leonard Electric Co.	Mt. Vernon, N.Y.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Inc. Weston-Newark	Newark, N.J.
66295	Wittek Mfg. Co.	Chicago, Ill.
66346	Revere Wollansak Div. Minn. Mining & Mfg. Co.	St. Paul, Minn.
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control	New York, N.Y.
70318	Allmetal Screw Product Co., Inc.	Garden City, N.Y.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	Union City, N.J.
70674	ADC Products Inc.	Minneapolis, Minn.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
71218	Bud Radio, Inc.	Willoughby, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Cardwell Condenser Corp.	Lindenhurst L.I., N.Y.
71400	Bussmann Mfg. Div. of McGraw-Edison Co.	St. Louis, Mo.
71436	Chicago Condenser Corp.	Chicago, Ill.
71447	Calif. Spring Co., Inc.	Pico-Rivera, Calif.
71450	CTS Corp.	Elkhart, Ind.
71468	ITT Cannon Electric Inc.	Los Angeles, Calif.
71471	Cinema, Div. Aerovox Corp.	Burbank, Calif.
71482	C.P. Clare & Co.	Chicago, Ill.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71616	Commercial Plastics Co.	Chicago, Ill.
71700	Cornish Wire Co., The	New York, N.Y.
71707	Coto Coil Co., Inc.	Providence, R.I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A.O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Co., Howard B. Jones Div.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72354	John E. Fast Co., Div. Victoreen Instr. Co.	Chicago, Ill.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	Indiana General Corp., Electronics Div.	Keasby, N.J.
72699	General Instrument Corp., Cap. Div.	Newark, N.J.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72964	Robert M. Hadley Co.	Los Angeles, Calif.
72982	Erie Technological Products, Inc.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73076	H.M. Harper Co	Chicago, Ill.
73138	Helipot Div. of Beckman Inst., Inc.	Fullerton, Calif.
73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73586	Circle F Mfg. Co.	Trenton, N.J.
73682	George K. Garrett Co., Div. MSL Industries Inc.	Philadelphia, Pa.
73734	Federal Screw Products Inc.	Chicago, Ill.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	General Industries Co., The	Elyria, Ohio
73846	Goshen Stamping & Tool Co.	Goshen, Ind.
73899	JFD Electronics Corp.	Brooklyn, N.Y.
73905	Jennings Radio Mfg. Corp.	San Jose, Calif.
74276	Signalite Inc.	Neptune, N.J.
74455	J.H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.
74970	E.F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75378	CTS Knights Inc.	Sandwich, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C.W. Marwedel	San Francisco, Calif.
76433	General Instrument Corp., Micamold Division	Newark, N.J.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76493	J.W. Miller Co.	Los Angeles, Calif.
76530	Cinch-Monadnock, Div. of United Carr Fastener Corp.	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76703	National Union	Newark, N.J.
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Corp., The Bendix Pacific Div.	N. Hollywood, Calif.
77075	Pacific Metals Co.	San Francisco, Calif.
77221	Phanostran Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine & Foundry Co. Potter & Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div.	Camden, N.J.
77638	General Instrument Corp., Rectifier Div.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
77969	Rubbercraft Corp. of Calif.	Torrance, Calif.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
78283	Signal Indicator Corp.	New York, N.Y.
78290	Struthers-Dunn Inc.	Pitman, N.J.
78452	Thompson-Bremer & Co.	Chicago, Ill.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78493	Standard Thomson Corp.	Waltham, Mass.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	San Gabriel, Calif.
78947	Ucinite Co.	Newtonville, Mass.
79136	Waldes Kohinoor Inc.	Long Island City, N.Y.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80120	Schnitzer Alloy Products Co.	Elizabeth, N.J.
80131	Electronic Industries Association. Any brand Tube meeting EIA Standards-Washington, DC.	
80207	Unimax Switch, Div. Maxon Electronics Corp.	Wallingford, Conn.
80223	United Transformer Corp.	New York, N.Y.
80248	Oxford Electric Corp.	Chicago, Ill.
80294	Bourns Inc.	Riverside, Calif.
80411	Acro Div. of Robertshaw Controls Co.	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80509	Avery Adhesive Label Corp.	Monrovia, Calif.
80583	Hammarlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments Inc.	Orange, Conn.
81073	Grayhill Co.	LaGrange, Ill.
81095	Triad Transformer Corp.	Venice, Calif.
81312	Winchester Elec. Div. Litton Ind., Inc.	Oakville, Conn.
81349	Military Specification	. . . . . .
81483	International Rectifier Corp.	El Segundo, Calif.
81541	Airpax Electronics, Inc.	Cambridge, Mass.
81860	Barry Controls, Div. Barry Wright Corp.	Watertown, Mass.
82042	Carter Precision Electric Co.	Skokie, Ill.
82047	Sperti Faraday Inc., Copper Hewitt Electric Div.	Hoboken, N.J.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Fairchild Camera & Inst. Corp., Defense Prod. Division	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc. Electronic Tube Division	Emporium, Pa.
82376	Astron Corp.	East Newark, Harrison, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals & Controls Inc. Spencer Products	Attleboro, Mass.
82768	Phillips-Advance Control Co.	Joliet, Ill.

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CODE LIST OF MANUFACTURERS (Cont'd)

Code No.	Manufacturer	Address
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Mfg. Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83053	Western Washer Mfg. Co.	Los Angeles, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.
83125	General Instrument Corp., Capacitor Div.	Darlington, S.C.
83148	ITT Wire and Cable Div.	Los Angeles, Calif.
83186	Victory Eng. Corp.	Springfield, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83315	Hubbell Corp.	Mundelein, Ill.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.
83332	Tech Labs	Palisade's Park, N.J.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Co. Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp. Electronic Tube Div.	Plainfield, N.J.
83740	Union Carbide Corp. Consumer Prod. Div.	New York, N.Y.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
83942	Aeronautical Inst. & Radio Co.	Lodi, N.J.
84171	Arco Electronics Inc.	Great Neck, N.Y.
84396	A.J. Glesener Co., Inc.	San Francisco, Calif.
84411	TRW Capacitor Div.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.
85471	A.B. Boyd Co.	San Francisco, Calif.
85474	R.M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	Hamden, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86197	Clifton Precision Products Co., Inc.	Clifton Heights, Pa.
86579	Precision Rubber Products Corp.	Dayton, Ohio
86684	Radio Corp. of America, Electronic Comp. & Devices Div.	Harrison, N.J.
87034	Marco Industries	Anaheim, Calif.
87216	Philco Corporation (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.
87664	Van Waters & Rogers Inc.	San Francisco, Calif.
87930	Tower Mfg. Corp.	Providence, R.I.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
88421	Federal Telephone & Radio Corp.	Clifton, N.J.
88698	General Mills, Inc.	Buffalo, N.Y.
89231	Graybar Electric Co.	Oakland, Calif.
89665	United Transformer Co.	Chicago, Ill.
90179	US Rubber Co., Consumer Ind. & Plastics Prod. Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91146	ITT Cannon Elect., Inc., Salem Div.	Salem, Mass.
91260	Connor Spring Mfg. Co.	San Francisco, Calif.
91345	Miller Dial & Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Willow Grove, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Calif.
91886	Malco Mfg. Co., Inc.	Chicago, Ill.
91929	Honeywell Inc., Micro Switch Div.	Freeport, Ill.
91961	Nahm-Bros. Spring Co.	Oakland, Calif.
92180	Tru-Connector Corp.	Peabody, Mass.
92367	Elgeet Optical Co. Inc.	Rochester, N.Y.
92196	Universal Industries, Inc.	City of Industry, Calif.
92607	Tensolite Insulated Wire Co., Inc.	Tarrytown, N.Y.
92702	IMC Magnetics Corp.	Wesbury Long Island, N.Y.
92966	Hudson Lamp Co.	Kearney, N.J.
93332	Sylvania Electric Prod. Inc. Semiconductor Div.	Woburn, Mass.
93369	Robbins and Myers, Inc.	New York, N.Y.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93929	G.V. Controls	Livingston, N.J.
94137	General Cable Corp.	Bayonne, N.J.
94144	Raytheon Co., Comp. Div., Ind. Comp. Operations	Quincy, Mass.
94148	Scientific Electronics Products, Inc.	Loveland, Colo.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp. Electronics Div.	East Paterson, N.J.
94222	South Chester Corp.	Chester, Pa.
94310	Tru-Ohm Products Memcor Components Div.	Huntington, Ind.
94330	Wire Cloth Products, Inc.	Bellwood, Ill.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
94696	Magnecraft Electric Co.	Chicago, Ill.
95023	George A. Philbrick Researchers, Inc.	Boston, Mass.
95236	Allies Products Corp.	Miami, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	Long Island, N.Y.
95264	Lerco Electronics, Inc.	Burbank, Calif.
95265	National Coil Co.	Sheridan, Wyo.
95275	Vitramon, Inc.	Bridgeport, Conn.
95348	Gordos Corp.	Bloomfield, N.J.
95354	Methode Mfg. Co.	Chicago, Ill.
95566	Arnold Engineering Co.	Marengo, Ill.
95712	Dage Electric Co., Inc.	Franklin, Ind.
95984	Siemon Mfg. Co.	Wayne, Ill.
95987	Weckesser Co.	Chicago, Ill.
96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Div. of Aerovox Corp.	Olean, N.Y.
96256	Thordarson-Meissner Inc.	Mt. Carmel, Ill.
96296	Solar Manufacturing Co.	Los Angeles, Calif.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Calif.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic & Precision Mfg.	Englewood, N.J.
97979	Reon Resistor Corp.	Yonkers, N.Y.
97983	Litton System Inc., Adler-Westrex Commun. Div.	New Rochelle, N.Y.
98141	R-Troncis, Inc.	Jamaica, N.Y.
98159	Rubber Teck, Inc.	Gardena, Calif.
98220	Hewlett-Packard Co., Moseley Div.	Pasadena, Calif.
98278	Microdot, Inc.	So. Pasadena, Calif.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98376	Zero Mfg. Co.	Burbank, Calif.
98731	General Mills Inc., Electronics Div.	Minneapolis, Minn.
98734	Paeco Div. of Hewlett-Packard Co.	Palo Alto, Calif.
98821	North Hills Electronics, Inc.	Glen Cove, N.Y.
98978	International Electronic Research Corp.	Burbank, Calif.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Calif.
99378	Atlee Corp.	Winchester, Mass.
99515	Marshall Ind. Elect. Products Div.	San Marino, Calif.
99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99942	Hoffman Electronics Corp. Semiconductor Div.	El Monte, Calif.
99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.

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

0000F	Malco Tool and Die	Los Angeles, Calif.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AB	ETA	England
000BB	Precision Instrument Components Co.	Van Nuys, Calif.
000CS	Hewlett-Packard Co., Colorado Springs	Colorado Springs, Colorado
000MM	Rubber Eng. & Development	Hayward, Calif.
000NN	A "N" D Mfg. Co.	San Jose, Calif.
000QQ	Cooltron	Oakland, Calif.
000WW	California Eastern Lab.	Burlington, Calif.
000YY	S.K. Smith Co.	Los Angeles, Calif.

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