INSTRUCTION MANUAL
MODEL 4210
R.F. MICROWATTMETER

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Figure 1-1 Microwattmeter, Model 4210

SECTION I
INTRODUCTION

1-1. SCOPE OF MANUAL.

1-2. This instruction manual provides descriptive data, operating instructions, theory of operation, maintenance instructions, and a parts list for the Model 4210 R. F. Microwattmeter. (See Figure 1-1.)

SAFETY NOTICE

Although this instrument has been designed in accordance with international safety standards, general safety precautions must be observed during all phases of operation and maintenance of the instrument. Failure to comply with the precautions listed in the Safety Summary located in the front of this manual could result in serious injury or death. Service and adjustment should be performed only by qualified service personnel.

1-3. PURPOSE OF EQUIPMENT.

1-4. The instrument is a microprocessor-controlled, solid-state unit that features ease of operation, high sensitivity, low input s.w.r., and low noise. It measures r.f. power levels from 1 nW (-60 dBm) to 100 mW (+20 dBm). The calibrated frequency range extends from 0.2 MHz to 18 GHz, depending upon the accessory sensor used; useful response for relative measurements is obtained from 20 kHz to approximately 20 GHz. Representative uses of the instrument include:

a. Low-power transmitter, signal generator, and oscillator measurements

b. S.W.R. and return-loss measurements with directional couplers and slotted lines

c. Gain and insertion-loss measurements

d. R.F. attenuation and s.w.r. measurements

e. Antenna measurements

1-5. DESCRIPTION OF EQUIPMENT.

1-6. The instrument is packaged as a compact bench unit. When operated with Boonton Series 4210-4/5 sensors, the instrument displays r.f. power by measuring the voltage across a precision, non-inductive resistor in the sensor head with specially selected diodes. Panel indications are calibrated in terms of power according to the relationship $P = E^2/R$. This detection system has important performance advantages over power meters that use bolometer or thermo-electric detection. The instrument sensitivity of 1 nanowatt (-60 dBm) is orders of magnitude better; temperature stability of better than 0.001 dB/°C supports this sensitivity; and burnout levels exceed 300 milliwatts.

1-7. Diode sensors are r.m.s.-responding for low-power levels (below 20 microwatts for Series 4210-4 sensors and 200 microwatts for Series 4210-5 sensors). At these low-power levels, the instrument measures and displays true average power for all types of waveforms. Above these levels, the instrument displays, by means of internal shaping, the true average power of c.w. signals. If the r.f. signal is gated or amplitude modulated, the indicated power may not be the true average power. The signal may be attenuated to bring it within the r.m.s. region of measurement. Alternatively, the instrument can be used with thermal sensors Model 4210-7E/8E; in this case, the instrument measures and displays the true average power for all waveforms.

1-8 The outstanding design features are:

a. **Wide Frequency Range.** The calibrated frequency range of the instrument is determined by the sensor used with the instrument. The instrument is normally ordered with one of the following sensors:

Model	FREQUENCY RANGE - 60/+10 dBm (Impedance)	Power Range
4210-4A	200 kHz to 7 GHz (50 ohms)	1 nW to 10 mW
4210-4B	200 kHz to 12.4 GHz (50 ohms)	1 nW to 10 mW
4210-4C	200 kHz to 1 GHz (75 ohms)	1 nW to 10 mW
4210-4E	200 kHz to 18 GHz (50 ohms)	1 nW to 10 mW
4210-5B	200 kHz to 12.4 GHz (50 ohms)	10 nW to 100 mW
4210-5E	200 kHz to 18 GHz (50 ohms)	10 nW to 100 mW
4210-7E	10 MHz to 18 GHz (50 ohms)	1 μW to 10 mW
4210-8E	10 MHz to 18 GHz (50 ohms)	10 μW to 100 mW

b. **Wide Power Range.** Depending on the selected sensor, the instrument will measure r.f. power from 1 nW up to 100 mW. Temporary overloads up to 300 mW with Series 4210-4 sensors, and up to 2 W with Series 4210-5 sensors, will do no permanent harm to the instrument or the sensor. When measuring pulsed signals, the power indications are accurate up to 20 microwatts peak power (up to 200 microwatts with Series 4210-5 sensors). External attenuators may be used to extend the measurement range of the instrument.

c. **Low Noise.** The instrument has been designed and constructed to minimize noise from all sources. The sensor cable is of a special low-noise design; vigorous flexing causes only momentary minor excursions of the display on the most sensitive range of the instrument. The sensors are insensitive to shock and vibration; even sharp tapping on the sensor barrel causes no visible excursions on any range. Internal signal amplification occurs at approximately 94 Hz, thereby reducing susceptibility to 50- or 60-Hz fields. A low-noise solid-state chopper is used.

d. **LED Display.** Measured power levels are displayed by a 4-digit, LED-type readout with decimal points and minus sign. Annunciators associated with the LED display indicate the units of measurement. The result is a clear, unambiguous readout that minimizes the possibility of misinterpretation.

e. **Analog Indications.** A front-panel analog meter provides relative power indications for peaking or nulling applications. The display is proportional to power on each range (PWR mode) or to dB over the entire range (dB mode).

f. **Pushbutton Measurement-Mode Selection.** A choice of measurement modes is available to the operator. Indications in terms of power or of dBm can be selected by pressing the appropriate front-panel key switch. A dB reference level equal to the last displayed dBm value can be entered through the keyboard REF switch, and a display mode can be selected to indicate power levels in dBr relative to that dB reference level.

g. **Automatic Ranging.** Autoranging under control of the microprocessor eliminates the need for manual ranging. Applications of power levels that exceed the maximum capability of the instrument result in an error indication on the LED display.

h. **Automatic Zeroing.** An automatic zeroing circuit eliminates the need for tedious, often inaccurate, manual zeroing. With zero input to the sensor, pressing a front-panel ZERO key switch directs the microprocessor to compute and store zero corrections for each range, and the instrument is thereafter corrected on each range in accordance with the stored data. This method is considerably simpler, faster, and more accurate than manual zeroing.

i. **Sensor Compensation.** Calibration factors in dB are selected by a front-panel rotary control calibrated in 0.1 dB steps from 1.10 to -1.10 dB. The sensor itself is marked with the appropriate calibration factors as a function of frequency.

j. **Solid-state Chopper.** Signal amplification in the instrument occurs at approximately 94 Hz. Input signals from the sensor are converted into a 94-Hz signal by a solid-state, low-level input modulator (chopper), which represents a distinct improvement over electromechanical choppers. Extended service life is assured through the elimination of contact wear, contamination, and other problems associated with electromechanical choppers.

k. **Signature-Analysis Maintenance.** Connection facilities to permit signature-analysis maintenance are incorporated. Digital circuit troubles can be localized rapidly and accurately using the signature-analysis maintenance technique, thereby reducing instrument down-time. An adapter (P/N 950028) is available from Boonton Electronics Corporation for signature-analysis maintenance.

1-9. ACCESSORIES.

1-10. The basic instrument is supplied complete with power cord, sensor cable and sensor. It is designed to operate with any Boonton Electronics Corporation Series 4210 sensor, the characteristics of which are listed in Table 1-1. The calibration data for the particular sensor ordered are written into microprocessor memory before shipment of the instrument.

1-11. Inquiries regarding special applications of the instrument to specific customer requirements are invited. Direct such inquiries to the Applications Engineering Department of Boonton Electronics Corporation.

1-12. SPECIFICATIONS.

1-13. Pertinent performance specifications for the instrument are listed in Table 1-1.

1-14. OUTLINE DIMENSIONS.

1-15. Outline dimensions of the instrument are shown in Figure 1-4.

TABLE 1-1. PERFORMANCE SPECIFICATIONS

Parameter	Specifications
FREQUENCY RANGE:	200 kHz to 18 GHz (depending on power sensor used)
MODES:	
Power	Display in nW, μW, or mW
dBm	Display in dB relative to 1 mW
dBr	Display in dB relative to the previous dBm display
POWER RANGE:	
With all 4210-4 series sensors	70 dB dynamic range with 7 full-scale ranges of -50, -40, -30, -20, -10, 0 and +10 dBm (10 nW to 10 mW f.s.)
With all 4210-5 series sensors	70 dB dynamic range with 7 full-scale ranges of -40, -30, -20, -10, 0, +10 and +20 dBm (100 nW to 100 mW f.s.)

TABLE 1-1. PERFORMANCE SPECIFICATIONS (cont.)

Parameter	Specifications
With 4210-7E sensor	40 dB dynamic range with 4 full-scale ranges of −20, −10, 0, and +10 dBm (10 μW to 10 mW f.s.)
With 4210-8E sensor	40 dB dynamic range with 4 full-scale ranges of −10, 0, +10, and +20 dBm (100 μW to 100 mW f.s.)
Ranging	Automatic
INSTRUMENTATION ACCURACY:	(Uncertainties include instrumentation, non-linearity, range zero corrections, and noise).

Modes	Ranges		
	All But Lowest (All Sensors)	Lowest (4210-4 & −5 Sensors)	Lowest (4210-7E Sensor)
PWR MODE	±1.5% rdg. ± 0.1% f.s	±2% rdg. ± 1.5% f.s.	±1% rdg. ± 3% f.s.
dB Modes	±0.07 dB ± $\frac{dB_{f.s.} - dB_{rdg.}}{250}$	±0.15 dB ± $\frac{dB_{f.s.} - dB_{rdg.}}{15}$	±0.1 dB ± $\frac{dB_{f.s.} - dB_{rdg.}}{10}$

Parameter	Specifications
Zero	Automatic, operated by front-panel key switch
Zero drift	With all 4210-4 series sensors: 1 nW/h, max., on 10 nW range With all 4210-5 series sensors: 10 nW/h, max., on 100 nW range With 4210-7E sensor: 1 μW/h, max., on 10 μW range With 4210-8E sensor: 1 μW/h, max., on 100 μW range
Temperature effect	See table below

Range	Instrument	Sensor
21° C to 25° C	0 dB	0 dB
18° C to 30° C	0 dB	±0.1 dB
10° C to 40° C	±0.2 dB	±0.2 dB

Parameter	Specifications
GENERAL:	
Cal. Factor	Range 1.10 dB to −1.10 dB, entered via calibrated front-panel control
Waveform Response	With all 4210-4 series sensors: True average power to 20 μW; above 20 μW, average power of sine wave With all 4210-5 series sensors: True average power to 200 μW; above 200μW, average power of sine wave With 4210-7E/8E sensor: True average power
Measurement Speed	With 4210-4 and -5 sensors: Typically 1.0s to 2.5s. Worst case below −40dBm, 8s for increasing and 27s for decreasing levels With 4210-7E and 4210-8E sensors: Typically 2s to 5s for increasing levels and 2s to 23s for decreasing levels
Display	4-digit LED. 3-1/2 digit display of power, 4-digit display of dB with 0.01 dB resolution Auxiliary analog display, uncalibrated, proportional to power (PWR mode) or dB (dB mode)
Annunciators	LED display of nW, μW, mW, dBm and dBr
Error Indication	Display shows overrange condition
Power Consumption	100, 120, 220, 240 V, 50 - 400 Hz, 18 VA
Weight	2.27 kg (5 lbs.), approx.
Size	114 mm high x 216 wide x 257 deep (4.5 in. x 8.5 x 10.1)

TABLE 1-2. SENSOR CHARACTERISTICS

Sensor Type	Full-wave diode						Thermocouple type	
Model	4210-4A	4210-4B	4210-4C	4210-4E	4210-5B	4210-5E	4210-7E	4210-8E
Input	50Ω	50Ω	75Ω	50Ω	50Ω	50Ω	50Ω	
Frequency Range	200kHz-7GHz	200kHz-12.4GHz	200kHz-1GHz	200kHz-18GHz	200kHz-12.4GHz	200kHz-18GHz	10MHz-18GHz	
Power Range	1 nW to 10 mW				10 nW to 100 mW		1μW to 10 mW	10 μW to 10 mW
Sum of Calibration Factor Uncertainty	1%, 0.2-300 MHz 1.3%,300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-7GHz	1%, 0.2-300MHz 1.3%, 300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-8GHz 4.0%, 8GHz-10GHz 4.5%, 10GHz-12GHz 6.0%, 12GHz-18GHz Add 0.05 dB/mW above 4 GHz			1%, 0.2-300MHz 1.3%, 300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-8GHz 4.0%, 8GHz-10GHz 4.5%, 10GHz-12GHz 6.0%, 12GHz-18GHz Add 0.005 dB/mW above 4 GHz		1%, 10-300MHz 1.3%, 300MHz-2GHz 3.0%, 2GHz-4GHz 3.5%, 4GHz-8GHz 4.0%, 8GHz-10GHz 4.5%, 10GHz-12GHz 6.0%, 12GHz-18GHz	
Max. SWR	1.12, 200kHz-2GHz 1.2, 2GHz-4GHz 1.4, 4GHz-7GHz	1.12, 200kHz-2GHz 1.2, 2GHz-4GHz 1.4, 4GHz-11GHz 1.6, 11GHz-12.4GHz	1.18, 200kHz-1GHz	1.3, 200kHz-4GHz 1.5, 4GHz-10GHz 1.7, 10GHz-18GHz	1.07, 200kHz-1GHz 1.10, 1GHz-2GHz 1.12, 2GHz-4GHz 1.18, 4GHz-12.4GHz	1.07, 200kHz-1GHz 1.10, 1GHz-2GHz 1.12, 2GHz-4GHz 1.18, 4GHz-12.4GHz 1.28, 12.4GHz-18GHz	1.5, 10 MHz-15MHz 1.35, 15MHz-10GHz 1.6, 10GHz-18GHz	
Max Average Power	10 mW (+10 dBm)				100 mW (+20 dBm)		10 mW (+10 dBm)	100 mW (+20 dBm)
Overload Rating	300 mW (+25 dBm)				2W (+33 dBm)		30 mW (+14 dBm)*	200 mW (+23 dBm)
RF Connector	Precision Type N male							
Calibration Factor	Individually calibrated at up to 9 frequencies, depending on sensor.							

*While this sensor will withstand short periods of overload, extended overload operation may result in permanent change in characteristics, or even burnout.

MAXIMUM RESPONSE TIME IN SECONDS WITH 4210-4/5 SENSORS

INCREASING LEVEL L1 TO L2

L1 (dBm) \ L2 (dBm)	+10 to 0	0 to -10	-10 to -20	-20 to -30	-30 to -40	-40 to -50	-50 to -60
+10 to 0	1						
0 to -10	2	1					
-10 to -20	2	1.5	1				
-20 to -30	2	2	1.5	1			
-30 to -40	2.5	2.5	2	1.75	1		
-40 to -50	2.5	2.5	2	2	2	2.5	
-50 to -60	2.5	2.5	2.5	2.5	2.5	4	8

NOTE

For Series 5 sensors increase levels by 10 dB.

MAXIMUM RESPONSE TIME IN SECONDS WITH 4210-4/5 SENSORS

DECREASING LEVEL L1 to L2

L1 (dBm) \ L2 (dBm)	+10 to 0	0 to -10	-10 to -20	-20 to -30	-30 to -40	-40 to -50	-50 to -60
+10 to 0	1	1.5	1.75	2	3	7	27
0 to -10		1.5	2	2	2	7	18
-10 to -20			1.5	1.75	2	3	15
-20 to -30				1.25	2	2	10
-30 to -40					1	3	5
-40 to -50						3	10
-50 to -60							11

NOTE

For Series 5 sensors increase levels by 10 dB.

Figure 1-2 Response-Time Chart for Series 4210-4/5 Sensors

MAXIMUM RESPONSE TIME IN SECONDS WITH 4210-7E/8E SENSORS

INCREASING LEVEL L1 to L2

L1 dBm \ L2 dBm	+10 – 0	0 – −10	−10 – −20	−20 – −30
+10 – 0	2			
0 – −10	2	2		
−10 – −20	2	3	5	
−20 – −30	3	3	4	3

NOTE

For Series 8E sensors increase levels by 10 dB.

MAXIMUM RESPONSE TIME IN SECONDS WITH 4210-7E/8E SENSORS

DECREASING LEVEL L1 to L2

L1 dBm \ L2 dBm	+10 – 0	0 – −10	−10 – −20	−20 – −30
+10 – 0	2	17	23	73
0 – −10		3	7	15
−10 – −20			3	13
−20 – −30				8

NOTE

For Series 8E sensors increase levels by 10 dB.

Figure 1-3 Response-Time Chart for Instrument and 4210-7E/8E Sensor

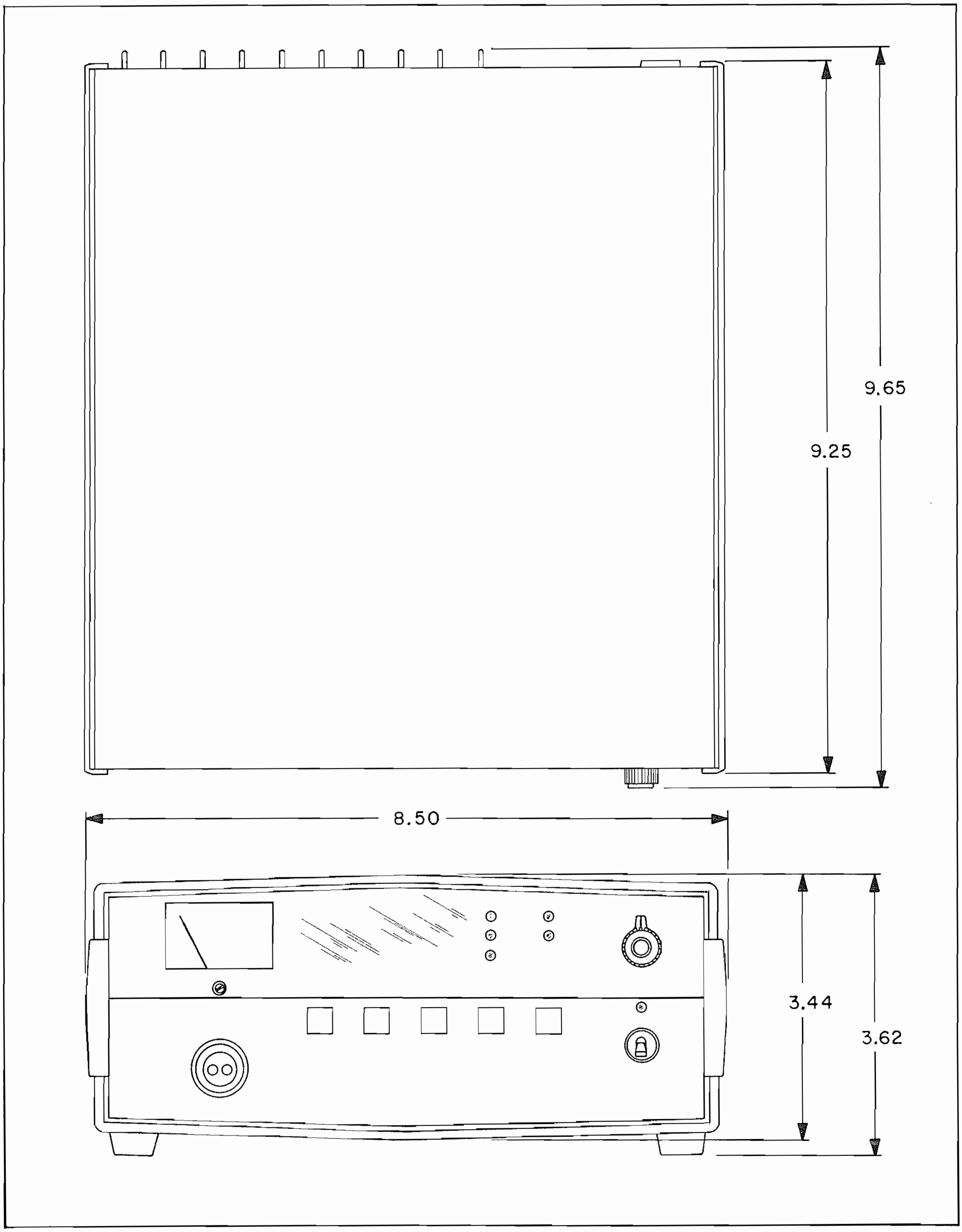


Figure 1-4 Outline Dimensions

SECTION II
OPERATION

2-1. GENERAL.

2-2. This section provides instructions for installation and operation of the instrument. Although the design of the instrument emphasizes ease of operation, it is recommended that the operator familiarize himself thoroughly with the material in this section before attempting to operate the instrument; otherwise, the full capabilities of the instrument may not be realized in use.

2-3. INSTALLATION.

2-4. Unpacking. The instrument is shipped complete with sensor, and is ready for use upon receipt. Packaging details are shown in Figure 2-1. Unpack the instrument carefully, and inspect it for any signs of shipping damage. Should any damage be noted, notify the carrier and the factory immediately.

NOTE

Save the packing material and container for possible use in reshipment of the instrument.

2-5. Mounting. For bench use, choose a clean, sturdy, uncluttered surface. See Figure 1-4 for space requirements.

2-6. Power Requirements. The instrument has a tapped power transformer which permits operation from 100, 120, 220, or 240 volt ± 10%, 50 to 400 Hz, single-phase a.c. power sources. Power consumption is approximately 18 volt-amperes at 60 Hz.

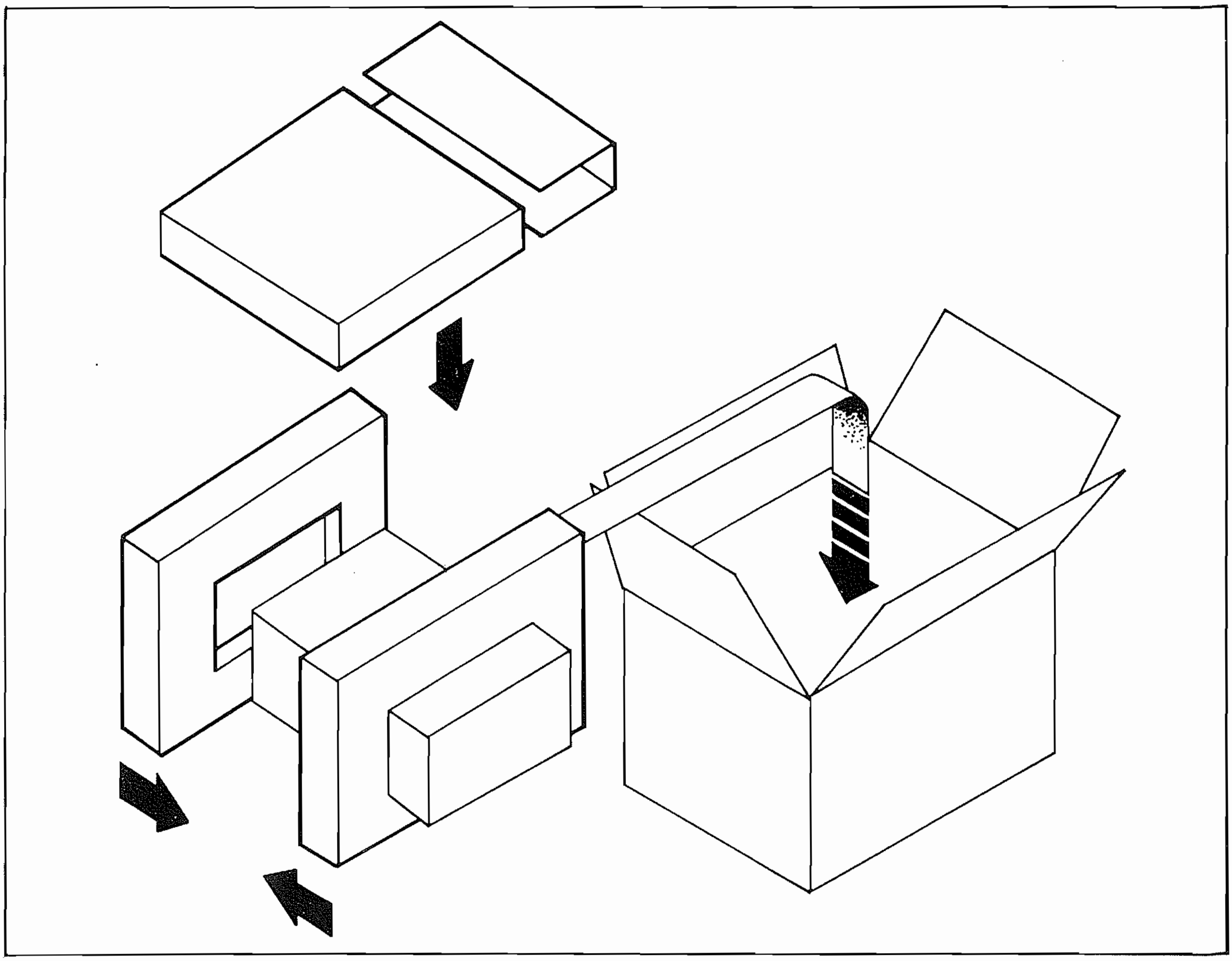


Figure 2-1 Packaging Diagram

2-7. Cable Connections. A line cord and sensor cable are supplied with the instrument. Any other cables required must be supplied by the user. Cable connections that may be required are:

a. **Sensors.** The sensor cable supplied with the basic instrument connects directly to the front-panel SENSOR connector, and the sensor that is to be used for power measurements connects directly to the other end of the sensor cable. Although the sensors are insulated against extreme temperature variations, it is advisable to locate the sensor away from heat sources when using the most-sensitive ranges of the instrument. If the instrument is to be used to measure the output of equipment that generates heat significantly above the ambient temperature, a short length of coaxial cable or solid line having the same characteristic impedance as the sensor may be used between the sensor and the equipment undergoing test to allow heat to dissipate before reaching the sensor. If such a cable is used, the length must be kept as short as possible for operation at the high end of the frequency range; cable losses and an increase in s.w.r. will tend to degrade measurement accuracy.

2-8. OPERATING CONTROLS, INDICATORS, AND CONNECTORS.

2-9. Controls, indicators, and connectors used during operation of the instrument are shown in Figures 2-2 and 2-3. Table 2-1 lists their functions.

2-10. SENSOR CALIBRATION DATA.

2-11. Low-frequency calibration corrections for sensors ordered with the instrument are written into microprocessor memory at the factory before shipment of the instrument and sensor. High-frequency calibration data appear on the chart on the sensor barrel and the proper dB correction is entered using the CAL FACTOR dB control. For the procedure for determining the calibration factor, refer to paragraph 4-21. The field replacement of any sensor with

TABLE 2-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS

Control, Indicator, or Connector	Figure and Index No.	Function
METER	2-2, 1	Provides relative indication of power or dB for peaking and nulling operations.
LED display	2-2, 2	Four-digit LED display with minus sign and decimal points; provides numerical indication of measured power, dBm, or dBr.
mW, μW, and nW annunciators	2-2, 3	Indicate units of power when instrument is operating in power mode.
dBm and dBr annunciators	2-2, 4	Indicate mode of dB operation.
CAL FACTOR control	2-2, 5	Provides means of entering calibration factors in dB.
LINE switch	2-2, 6	Provides means for switching a.c. line power on and off.
REF key	2-2, 7	Provides means for storing a displayed dBm reading as the reference for future dBr measurements.
dBr key	2-2, 8	Provides means for displaying dB measurements offset by the selected reference (see 2-2, 7).
PWR/dBm keys	2-2, 9	Provide means for selecting power or dBm mode of display.
ZERO key	2-2, 10	Provides means for generating and storing zero corrections for all ranges with zero input to sensor.
SENSOR connection	2-2, 11	Provides means for connecting sensor.
Power connection	2-3, 1	Provides connection for a.c. power cord.
Fl fuse	2-3, 2	Accepts 0.3 A (100/120 V a.c.) or 0.2 A (220/240 V a.c.) fuses.
A.C. power switch	2-3, 3	Provides means for selecting a.c. power of 100, 120, 220, or 240 V.
Fuse chart	2-3, 4	Describes required fuse value for various a.c. line voltages.

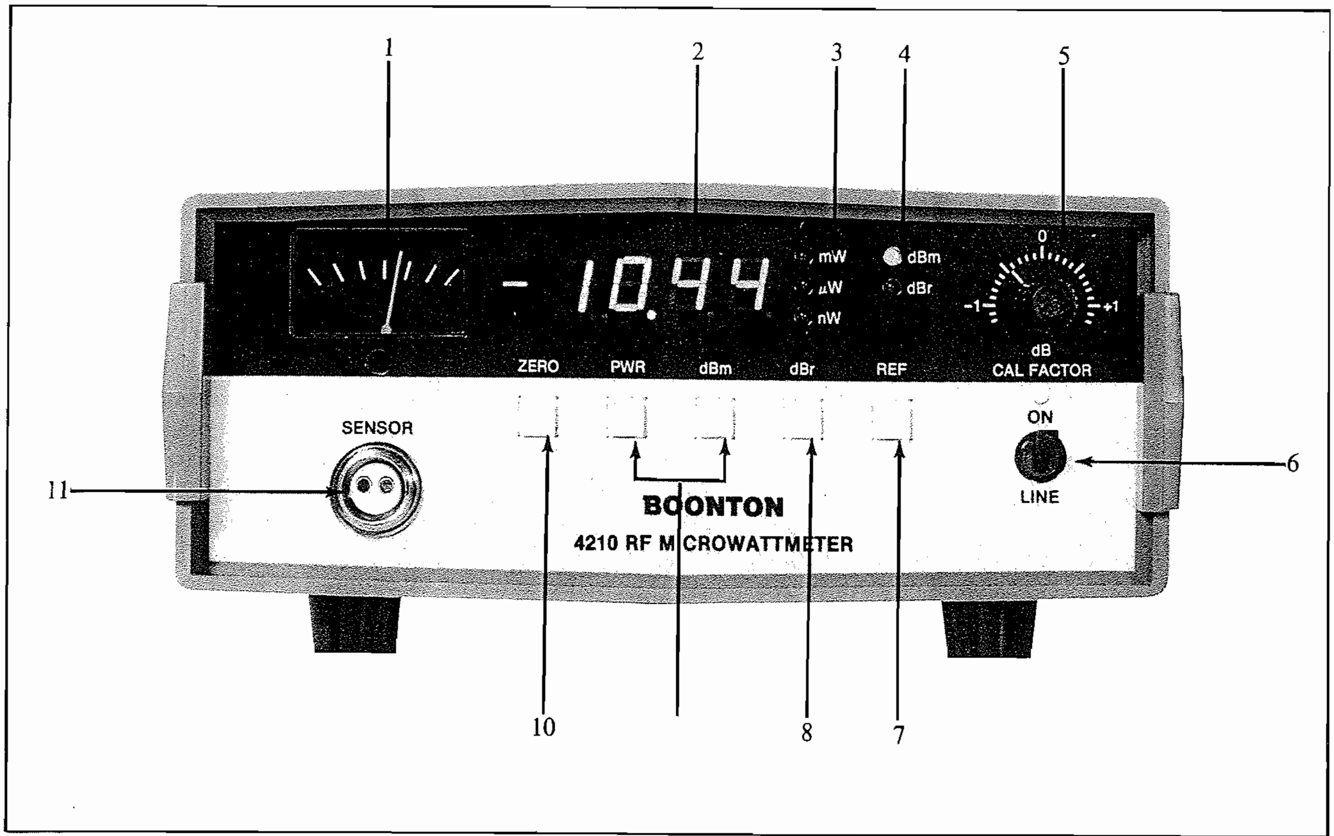


Figure 2-2 Front View of Instrument

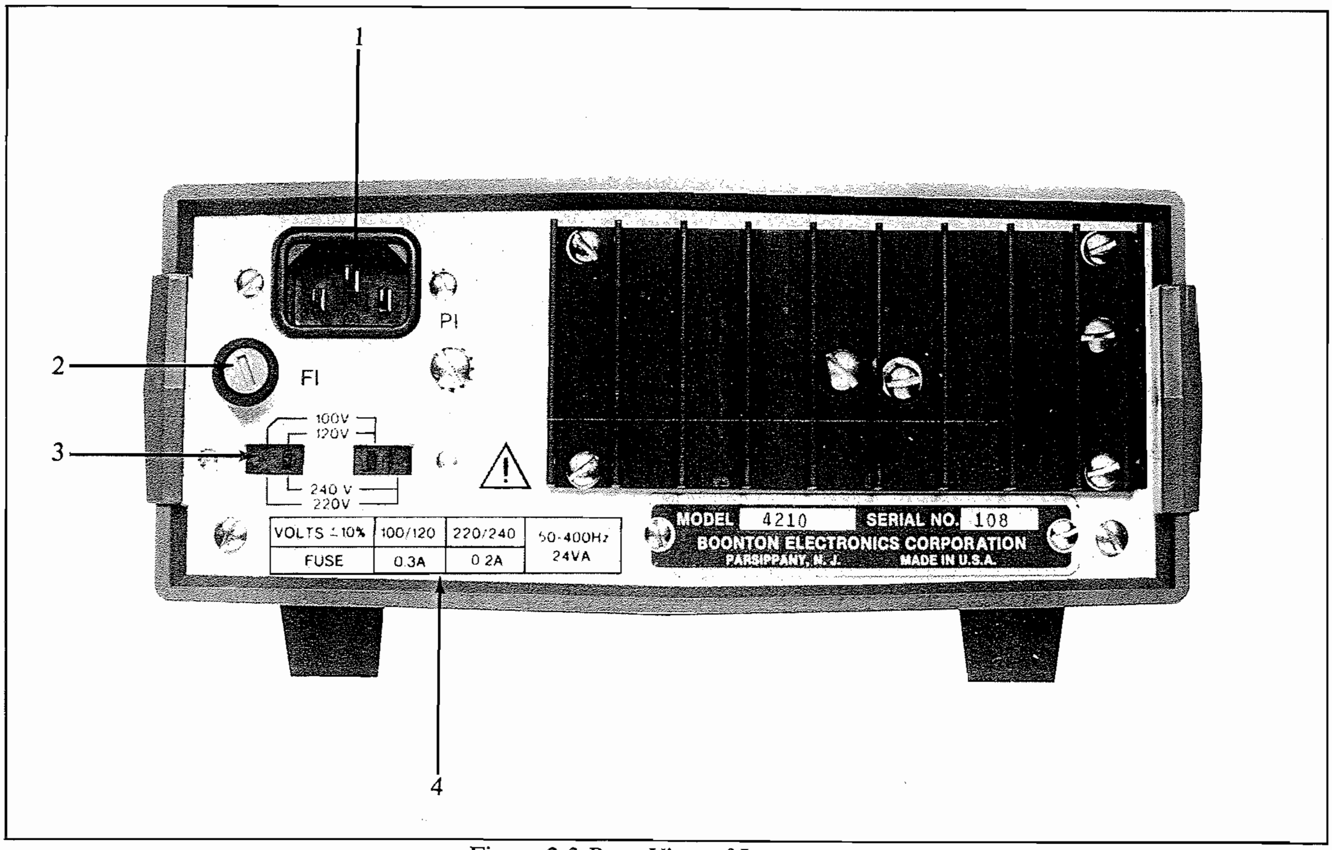


Figure 2-3 Rear View of Instrument

another of the same type requires only a simple recalibration procedure (see Section IV). If a sensor is replaced with one of a different type, a replacement PROM is also required to reconfigure the 4210 to the new sensor.

a. **General.** Power sensors used with the Model 4210 can be thought of as four-part items: the power sensor itself, an EPROM, and two resistors. If you change the *type* of sensor from that with which the 4210 was originally supplied, it may be necessary to change the EPROM and the resistors as well. The following table gives the part number for ordering a new sensor; it is in fact the part number for a kit that includes the sensor, an EPROM and two resistors.

In some cases you may receive an EPROM with the same part number as that of the EPROM already installed in the instrument. However, since the new one may be an updated version, it is preferable to install the new EPROM. Note that even if neither the EPROM nor the resistors need be changed, it will always be necessary to recalibrate the 4210 when changing sensors.

Model 4210 Power-Sensor Configuration

Part No.	Sensor Type	EPROM	Resistors
95101801A	4210-4A	53427600A	341325000
95101901A	4210-4B	53427600A	341325000
95102001A	4210-4C	53427600A	341325000
95102101A	4210-4E	53427600A	341325000
95102201A	4210-5B	53428300A	341325000
95102301A	4210-5E	53428300A	341325000
95102401A	4210-7E*	53429200A	**
95102501A	4210-8E*	53430700A	**
		534388000	**
		534389000	**

* Add two (2) (343729000) 20M 5% 1/4 W resistors to the Chopper Board.

** A selected resistor value between 4.32K to 8.25K must be used.

b. **Installation.**

(1) Remove line power from the 4210.

(2) Remove the instrument's top cover.

(3) Replace U29 (EPROM) in the instrument with the EPROM supplied in the kit. Note that if you are replacing a sensor with one of the same type, you do not *have* to replace U29 but, as noted earlier, it may be desirable to do so.

(4) Use the Overlay drawing on page 6-7 to help locate resistors R21 and R23. (They are at the very bottom of the drawing, just to the right of center.) Replace these resistors with the ones that are supplied in the kit: 1.8 k-ohm for diode-type sensors; and 7.5 k-ohm for thermal sensors. Note that if you are replacing a sensor with one of the same type, there is no need to change R21 and R23.

(5) If parts have been replaced or if you are changing sensors (even though the sensors are the same type), the Model 4210 must be recalibrated. Refer to page 4-2, 4-14.

2-12. POWER APPLICATION.

2-13. The basic instrument is designed for operation from a.c. line voltages of 100, 120, 220, or 240, 50 to 400 Hz, single phase. To apply a.c. power, proceed as follows:

a. Determine the line voltage at the a.c. power output receptacle.

b. Position the two voltage-selector slide switches on the rear panel to agree with the a.c. line voltage.

c. Check the rating of the fuse in the rear-panel fuseholder. For 100- or 120-volt operation, the fuse should be a 0.3-ampere, MDL Slo-Blo type; for 220- or 240-volt operation, it should be a 0.2-ampere, MDL Slo-Blo type. If the rating of the fuse is incorrect, install a fuse of the required rating in the fuseholder.

WARNING

The instrument is designed to operate from a 3-terminal (one ground) a.c. power receptacle. If only a 2-terminal a.c. power receptacle is available, use a 3-prong-to-2 prong adapter. Connect the ground wire of the adapter to the power receptacle ground, to eliminate a potential shock hazard to the operator.

d. Connect the power cord between the a.c. power connector on the rear panel of the instrument and the a.c. power receptacle (with adapter, if necessary).

2-14. PRELIMINARY CHECK OF INSTRUMENT.

NOTE

The following checkout procedure is intended merely to demonstrate that the major circuits of the instrument are operating, before the instrument is placed in service. For a detailed check of the instrument against performance specifications, refer to paragraph 2-28.

2-15. To perform a preliminary operational checkout, proceed as follows:

a. Set the LINE switch to the ON position. The LED annunciator directly above the switch should light.

b. Immediately at power-on all the LED display digits, the minus sign, and all annunciators should light for approximately 1 second, blank for 0.5 second, and then commence normal indications. Their failure to exhibit this sequence is an indication of instrument malfunction.

c. Connect the correct power sensor to the front-panel SENSOR connector.

d. With no signal connected to the sensor, press the PWR key and then press the ZERO key. A "good zero" is indicated by equal positive and negative excursions of the display, and by the minus sign flashing on and off. If necessary, press the ZERO key a second time to obtain a good zero.

NOTE

Always have the instrument in the power display mode before executing a zero. This assures that the quality of the zero correction can be monitored by observing the fluctuations of the display around zero. If the instrument is in the dBm mode, the error signal LO appears on the display for signals that are less than −70 dBm, and the quality of the zero therefore cannot be observed.

e. Connect any suitable signal source of frequency greater than 200 kHz to the sensor input and verify a proper display of power.

f. Press the dBm key and verify an equivalent dBm display.

g. Press the REF key to enter the dBm level displayed in (f) above,as the reference for all subsequent dBr displays.

h. Press the dBr key and verify that the dB display has been offset by the reference established in (g),above.

i. Press the dBm key, check the displayed reading, and then rotate the CAL FACTOR control by a given amount. Verify that the dBm display changes by that amount.

j. Reset the CAL FACTOR control to 0.

k. This concludes the preliminary operational checkout. To check the instrument for minimum performance standards, refer to paragraph 2-28.

2-16. OPERATING PROCEDURES.

2-17. Programming Measurement Parameters.

a. **General.** Measurement parameters are entered into the microprocessor through the front-panel controls. When the instrument is turned on, the PWR key is automatically activated and no dBm offset is stored for dBr measurements.

b. **Mode Selection.** Two mode keys select either power units or dBm. When the PWR key is pressed, measured power levels are displayed in mW, μW, or nW; the annunciators associated with the LED display indicate the appropriate unit.When the dBm key is pressed, measurement values are displayed in terms of dBm (0 dBm is equivalent to 1 mW across 50 ohms). An annunciator associated with the LED display indicates when the dBm mode is selected.

c. Two mode keys select a dB display offset by a reference value. Any displayed dBm reading may be stored as the reference by pressing the REF key. When the dBr key is then pressed, all future dB readings will be offset by that reference. As an example, if the instrument is displaying a reading of −10.00 dBm, pressing the REF key will store this value. When the dBr key is pressed, assuming no change in the input power level to the sensor, the display will indicate 0.00 dBr [−10.00 dBm − (−10.00 dBm)].

NOTE

Since the difference of two dB values is the same as the ratio of the two equivalent power values, offset measurements provide ratio capabilities. Additionally, an offset dB display is a convenient means for normalizing future readings to the reference value.

d. **Range Selection.** Range selection is entirely automatic and always results in the best possible display resolution.

e. **CAL FACTOR Selection.** The sensors used with the instrument are frequency-sensitive; that is, with a constant input power level applied, their output signal level does not remain constant as the measurement frequency is changed. Each sensor is marked with its required corrections as a function of frequency. The front-panel CAL FACTOR rotary control provides the means for entering these corrections into the microprocessor. As an example, if a sensor has a CAL FACTOR of −0.35 dB at a particular frequency, setting the CAL FACTOR control to −0.35 dB will correct the display value for that frequency

2-18. Zeroing the Instrument. For greatest accuracy, especially on the most-sensitive ranges, the instrument must be zeroed. To eliminate tedious and less-accurate manual zeroing, the instrument incorporates an automatic zeroing capability. When automatic zeroing is initiated, the microprocessor reads and averages the offset and stores the zero correction required on the most sensitive range, as well as scaled corrections required for the other ranges. The instrument then applies the proper zero correction for the range in use for all subsequent measurements. During instrument warmup, or when used in an environment with varying ambient temperatures, the instrument should be zeroed frequently if measurements are being made on the lowest ranges. To zero the instrument, proceed as follows:

CAUTION

Never press the ZERO key with a signal applied to the sensor; to do so will result in large, erroneous zero corrections and grossly inaccurate measurements.

a. Remove all input power to the sensor.

NOTE

If the instrument is subjected to strong r.f. fields, shield the sensor in accordance with the instructions in paragraph 2-27.

b. If the instrument is in the power mode, press the ZERO key. If the instrument is in the dBm or dBr mode, first press the PWR key, then press the ZERO key. A "good zero" is indicated by equal positive and negative excursions of the display and by the minus sign flashing on and off. If necessary, press the ZERO key a second time to obtain a good zero.

2-19. Making Absolute Power Measurements. Once the instrument is zeroed, it is ready for power-level measurements. Merely connect the sensor to the source whose power level is to be measured and press the PWR key, for display in power units, or press the dBm key for display in dBm units.

2-20. Making Relative or Offset Power Measurements. If the instrument is in the dBm mode of operation, any displayed dBm value may be used as a reference for subsequent relative power measurements, as follows:

a. Press the REF key. This stores the current dBm value as a reference.

b. Press the dBr key. The dBr annunciator will light, indicating that the instrument is displaying dB values relative to the stored reference. The stored reference remains unchanged for all subsequent measurements until a new reference is entered or the instrument is turned off.

2-21. MAKING MEASUREMENTS.

2-22. Low-Level Measurements. The instrument will provide reliable, reproducible measurements of c.w., a.m., and f.m. power levels as low as 1 nW (−60 dBm). It can also be used for pulse measurements but with slightly decreased accuracy (±1 dB). Peak power levels for pulse measurements should not exceed 200 μW (20 μW for Series 4210-4 sensors); above this level the sensor enters the region where it operates out of the square-law region, and accuracy at such signal levels is correct for c.w. and f.m. only.

2-23. High-Level Measurements. Zeroing of the instrument is not critical when making high-level measurements (10 μW to 100 mW). C.W. and f.m. power measurements can be obtained within the specified accuracy up to 100 mW; accuracy cannot be guaranteed for pulse power measurements with instantaneous peaks exceeding 350 μW (35 μW for Series 4210-4 sensors).

2-24. High-Frequency Measurements. At frequencies above 1 GHz, the appropriate sensor-calibration factor must be entered by the CAL FACTOR control if the specified accuracy of the instrument is to be realized. (Refer to paragraph 2-17e.)

NOTE

Model 4210-4A, 4210-4B, 4210-4E, 4210-5B, 4210-5E and 4210-7E sensors are calibrated for use with a 50-ohm source; model 4210-4C sensors are calibrated for use with a 75-ohm source. Impedance mismatch results in increased s.w.r., which affects measurement accuracy. (Refer to paragraph 4-30 and Figure 4-7.) This effect can be reduced by inserting a low-s.w.r. attenuator (s.w.r. less than 1.10) or a low-loss tuner between the source and the sensor.

2-25. Temperature Effects. Specified instrument accuracies apply over an ambient temperature range of 21° C to 25° C. Operation outside this temperature range causes some additional error. Figure 2-4 shows typical temperature characteristics of a Series 4210 sensor, and Figure 2-5 shows typical temperature characteristics of the instrument and sensor combined.

NOTE

For best zero stability of the instrument, allow the instrument and sensor to reach a stable temperature.

2-26. S.W.R. Measurements. The high upper-frequency limit and sensitivity of the instrument facilitates s.w.r. measurements with a slotted line. S.W.R. measurements require only comparative, rather than absolute, measurement values; therefore, the instrument may be used up to 20 GHz with a model 4210-4E sensor. The front-panel meter is especially useful for rapid determination of maximum and minimum power points. S.W.R. is determined by measuring the dB difference between a maximum and a minimum voltage point on a slotted line and converting this difference to s.w.r. An adapter, usually available from the slotted-line manufacturer, is required to couple the sensor to the slotted line. To make slotted-line s.w.r. measurements, proceed as follows:

a. Connect the sensor to the sliding carriage, using a suitable adapter.

b. Ascertain that the signal source is turned off; then, zero the instrument.

c. Turn on the signal source and slide the carriage along the slotted line until a point of maximum indication is located. Adjust the source signal level and the probe setting for the least coupling that yields a −41 dBm reading at the maximum point. (The incident power should be at least 0 dBm.)

d. Slide the carriage along the slotted line until a minimum indication is located. Read the level at this point. Subtract the measured level at the minimum point from that at the maximum point, ignoring signs. Convert the resultant ΔdB into s.w.r., either through use of the s.w.r. conversion chart (Figure 2-6) or by computation. S.W.R. is the antilog, base 10, of ΔdB/20.

2-27. Shielding Recommendations. If the instrument is subjected to strong r.f. fields, accurate zeroing may be difficult unless the sensor is shielded during the zeroing operation. The simplest method of shielding is to connect the sensor to the device whose power level is to be measured, first making sure that the device is turned off; however, in some instances, the device may act as an antenna and introduce additional noise voltage into the sensor. If this happens, disconnect the sensor from the device, stand the sensor, end down, on a copper plate, and hold it down firmly so that the rim of the sensor connector makes good contact with the copper plate at all points. Alternatively, wrap a piece of thin copper foil around the body of the connector body, and crimp the foil around the open end of the connector, making certain that the center pin of the connector is not shorted. If frequent zeroing in strong noise fields is necessary, construct an adapter, using a Type N connector permanently fitted with a copper foil shield.

2-28. MINIMUM PERFORMANCE STANDARDS.

2-29. Test Equipment Required. For minimum performance testing of the instrument, a precision adjustable power source, such as the Boonton Model 25A Power Meter Calibrator, is required.

NOTE

A 1 MHz power source, such as the Boonton Model 25A, is recommended for testing the instrument and its sensors, except when the instrument is fitted with a 4210-7E sensor. In that case, an equivalent 50 MHz power source is required.

2-30. Preliminary Setup.

a. Turn on the instrument and the adjustable power source and allow a warmup period of at least one hour. The ambient temperature should be 21° C (70° F) to 25° C (77° F).

b. Set the adjustable power source to zero and connect the sensor between the power source and the front-panel SENSOR connector of the Model 4210, using the sensor cable.

c. If the instrument is in its power mode, as indicated by the nW, μW, or mW annunciators, press the ZERO key of the instrument. If the instrument is in either dBm or dBr modes, as indicated by those annunciators, first press the PWR key followed by the ZERO key. A good zero is indicated by equal excursions of the display in both the positive and negative directions, with the minus sign flashing on and off. Repeat the zeroing process, if necessary, to obtain a good zero.

2-31. Ranging Test. To check the autoranging function of the instrument, set the output level of the adjustable power source to each of the values listed below. If the instrument is ranging properly, the indications will be approximately as shown, with correct decimal point and annunciators.

Power Source	Indications with Sensor 4210-4	4210-5	4210-7E	Annunciators
10 nW	10.00			nW
100 nW	100.0	100.0		nW
1 μW	1.000	1.000		μW
10 μW	10.00	10.00	10.00	μW
100 μW	100.0	100.0	100.0	μW
1 mW	1.000	1.000	1.000	mW
10 mW	10.00	10.00	10.00	mW
100 mW		100.0		mW

2-32. dBm Mode. When the instrument is turned on it always reverts to the power mode. To check the dBm mode of the instrument, proceed as follows:

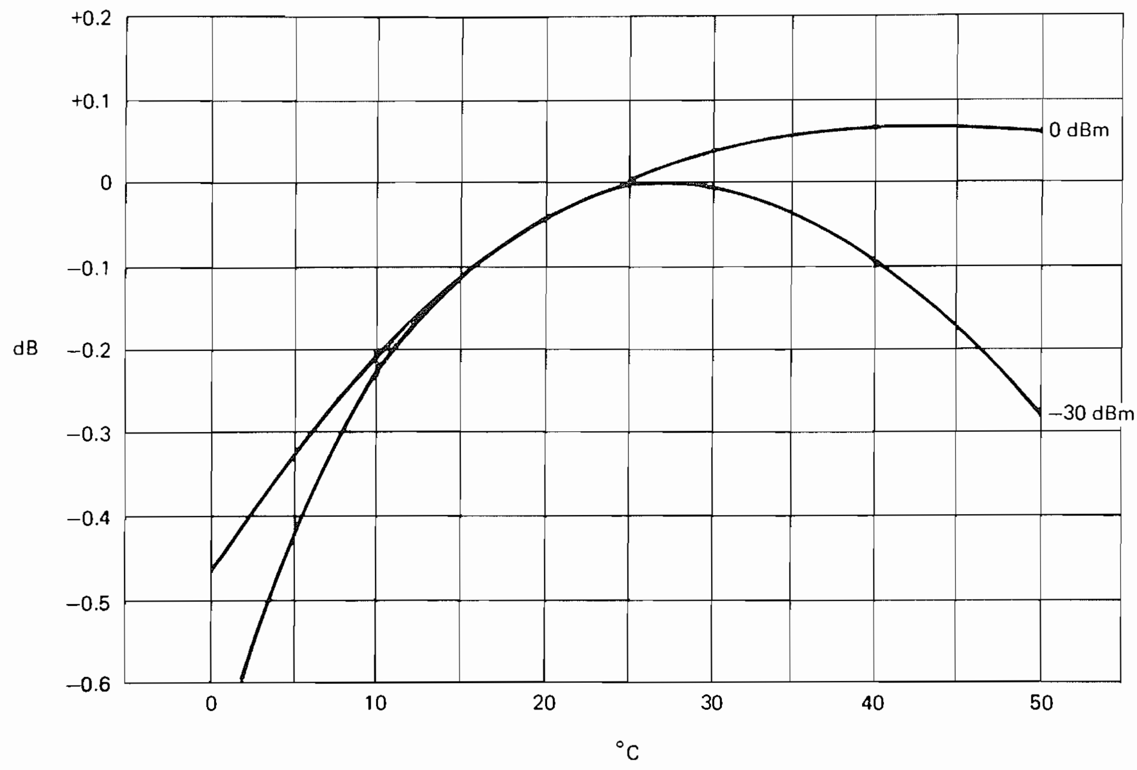


Figure 2-4 Typical Temperature Characteristics of Series 4210 Sensors

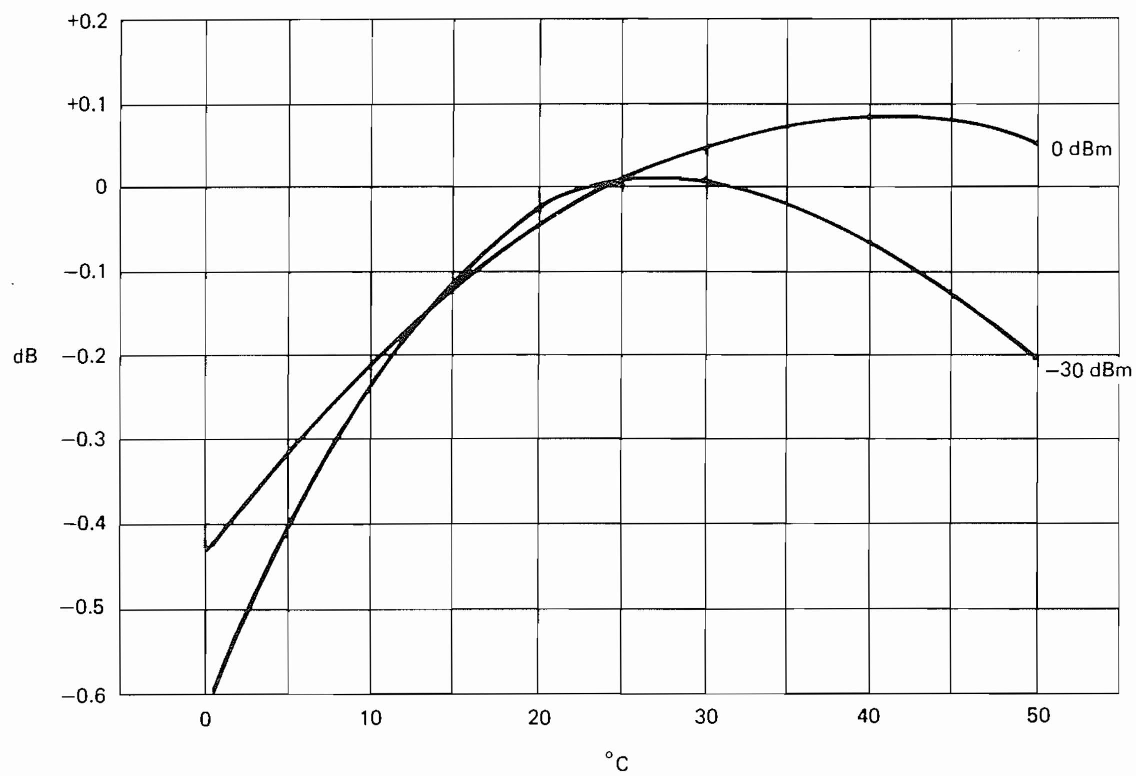


Figure 2-5 Typical Combined Temperature Characteristics of Instrument and Sensor

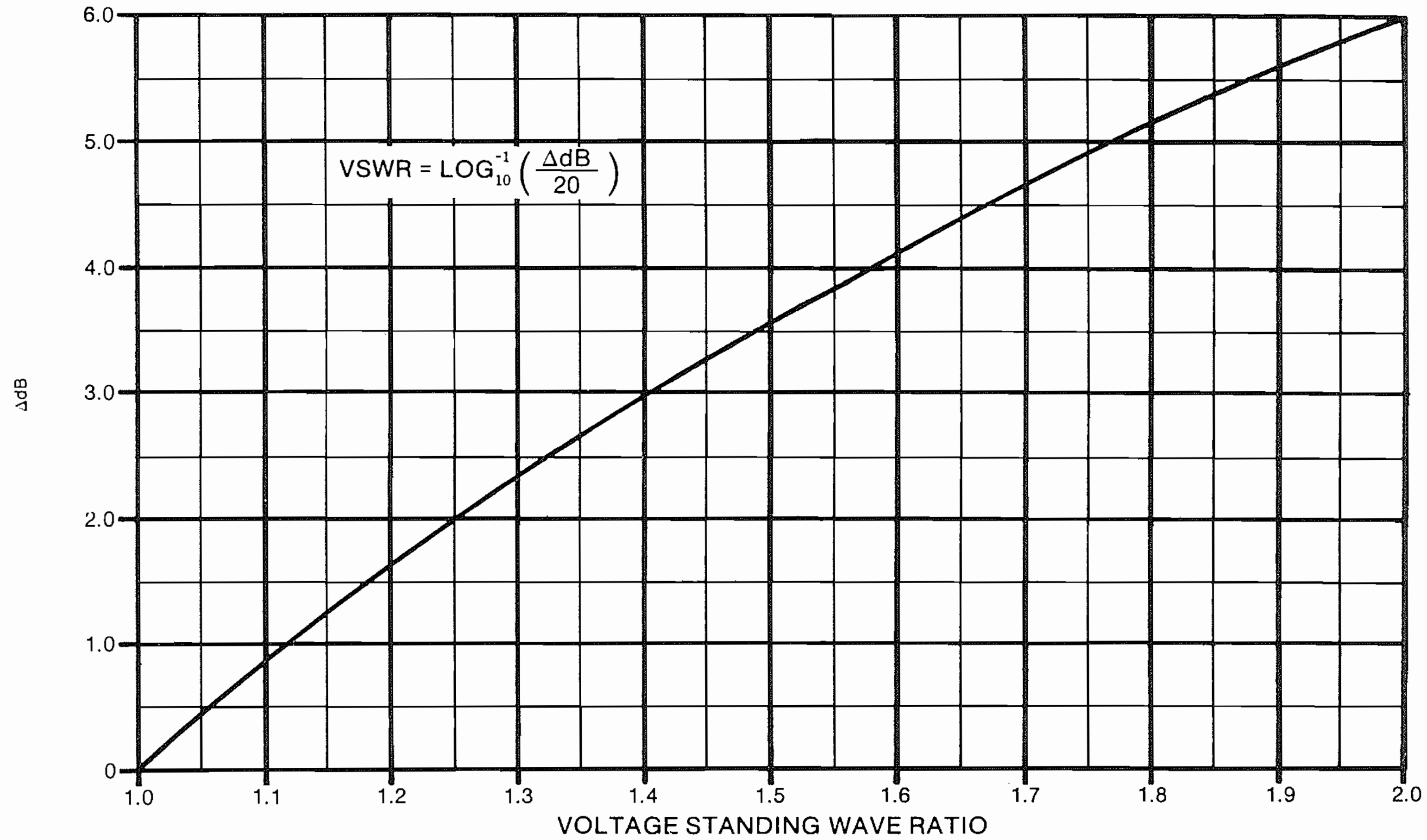


Figure 2-6 dB-SWR Conversion Chart

a. Set the power source to 1 mW.

b. Press the dBm key. The indication should be 00.00 dB ± 0.07 dB (± 0.1 dB with 4210-7E sensor). The power annunciators should be off and the dBm annunciator on.

2-33. Basic Instrument Accuracy Test. To check the basic accuracy of the instrument, proceed as follows:

a. With zero input to the sensor (adjustable power source turned off), zero the instrument by pressing the PWR key, then pressing the ZERO key.

b. Press the dBm key.

c. Set the output level of the adjustable power source to each of the following dBm levels, and check that the display agrees with the output level of the power source within the specified dB limits:

Power Source	4210-4		4210-5		4210-7E	
	+10 to -49 dBm	-50 to -60 dBm	+20 to -39 dBm	-40 to -50 dBm	-10 to -19 dBm	-20 to -30 dBm
F.S.* - 0 dBm	±0.07 dB	±0.15 dB	±0.07 dB	±0.15 dB	±0.07 dB	±0.10 dB
- 1	±0.07	±0.21	±0.07	±0.21	±0.07	±0.20
- 2	±0.08	±0.23	±0.08	±0.23	±0.08	±0.30
- 3	±0.08	±0.33	±0.08	±0.33	±0.08	±0.40
- 4	±0.09	±0.40	±0.09	±0.40	±0.09	±0.50
- 5	±0.09	±0.46	±0.09	±0.46	±0.09	±0.60
- 6	±0.09	±0.52	±0.09	±0.52	±0.09	±0.70
- 7	±0.10	±0.58	±0.10	±0.58	±0.10	±0.80
- 8	±0.10	±0.65	±0.10	±0.65	±0.10	±0.90
- 9	±0.11	±0.75	±0.11	±0.75	±0.11	±1.00
-10	—	±0.77	—	±0.77	—	±1.10

*F.S. Inputs, 4210-4: +10, 0, -10, -20, -30, -40, and -50 dBm
4210-5: +20, +10, 0, -10, -20, -30, and -40 dBm
4210-7E: +10, 0, -10, -20 dBm

2-34. dBr Mode. To check the dBr mode of the instrument, proceed as follows:

a. Set the power source to 100 μW and the instrument to the dBm mode. The indication should be -10.00 dBm ± 0.07 dB.

b. Press the REF key. This stores the dBm display of -10.00 dBm as a reference.

c. Press the dBr key. The display should now indicate 00.00 dBr [-10.00 dBm - (-10.00 dB)] and the dBr annunciator should be on.

2-35. Analog Meter. To check the analog meter display of the instrument, proceed as follows:

a. Set the power source to 10 mW and the instrument to the power mode. The indication of the analog meter should be approximately 85% of full scale.

b. Reduce the power source in steps of 1 dB and note that the analog meter display decreases.

c. Set the power source to 10 mW and then reduce in steps of 10 dB. The analog meter should indicate approximately 85% of full scale in each case.

d. Set the power source to 10 mW (100 mW for the 4210-5 sensor) and press the dBm key of the instrument. The analog meter display should indicate approximately 85% of full scale.

e. Decrease the power source in steps of 10 dB. The analog meter display should decrease in approximately equal steps, approaching zero with zero input.

2-36. Calibration-Factor Test. To check operation of the calibration-factor function, proceed as follows:

a. Set the power source to 1.0 mW, the CAL FACTOR control of the instrument to 0, and press the dBm key. The indication should be 00.00 dBm.

b. Rotate the CAL FACTOR control to +1 dBm. The indication should be +1.00 dBm.

c. Rotate the CAL FACTOR control to -1 dBm. The indication should be -1.00 dBm.

SECTION III
THEORY OF OPERATION

3-1. GENERAL.

3-2. The instrument is a microprocessor-controlled, solid-state unit that measures r.f. power levels from 1 nW (-60 dBm) to 100 mW (+20 dBm) in the frequency range of 0.2 MHz to 18 GHz. A microprocessor is used with a program resident in memory to accomplish automatically most of the measurement tasks, including ranging, scaling, shaping, zero correction, power to dBm conversion, and sensor calibration factor correction. Function selection is accomplished manually through front-panel pushbutton switches. Measured values are displayed on a 4-digit numeric display, and the unit of measurement is indicated by an LED annunciator. An analog meter is also provided for relative power indications for peaking and nulling applications.

3-3. BLOCK DIAGRAM.

3-4. For purposes of this discussion, the circuits of the instrument are grouped by function as shown in Figure 3-1. The r.f. power that is to be measured is applied to a sensor, which converts the r.f. to a d.c. voltage that is some function of the r.f. power level. This d.c. voltage is applied through the sensor cable to a solid-state chopper, which converts the d.c. voltage to a 94-Hz square wave with an amplitude proportional to the d.c. voltage. Drive signals for the chopper are provided from the analog section.

3-5. The analog section also provides amplification, ranging, and demodulation of the 94-Hz square wave signal supplied from the chopper. Ranging is performed automatically using range data supplied from the digital section. The analog section also receives a 752-Hz clock signal from the digital section; the chopper and demodulator drive signals are derived from this clock signal by frequency divider circuits in the analog section. The d.c. output voltage of the analog section is supplied to the digital section.

3-6. The digital section contains the microprocessor with associated memory, I/O, and D/A and A/D converters. Input d.c. from the analog section is converted to a digital form by an A/D converter. This digital data is processed

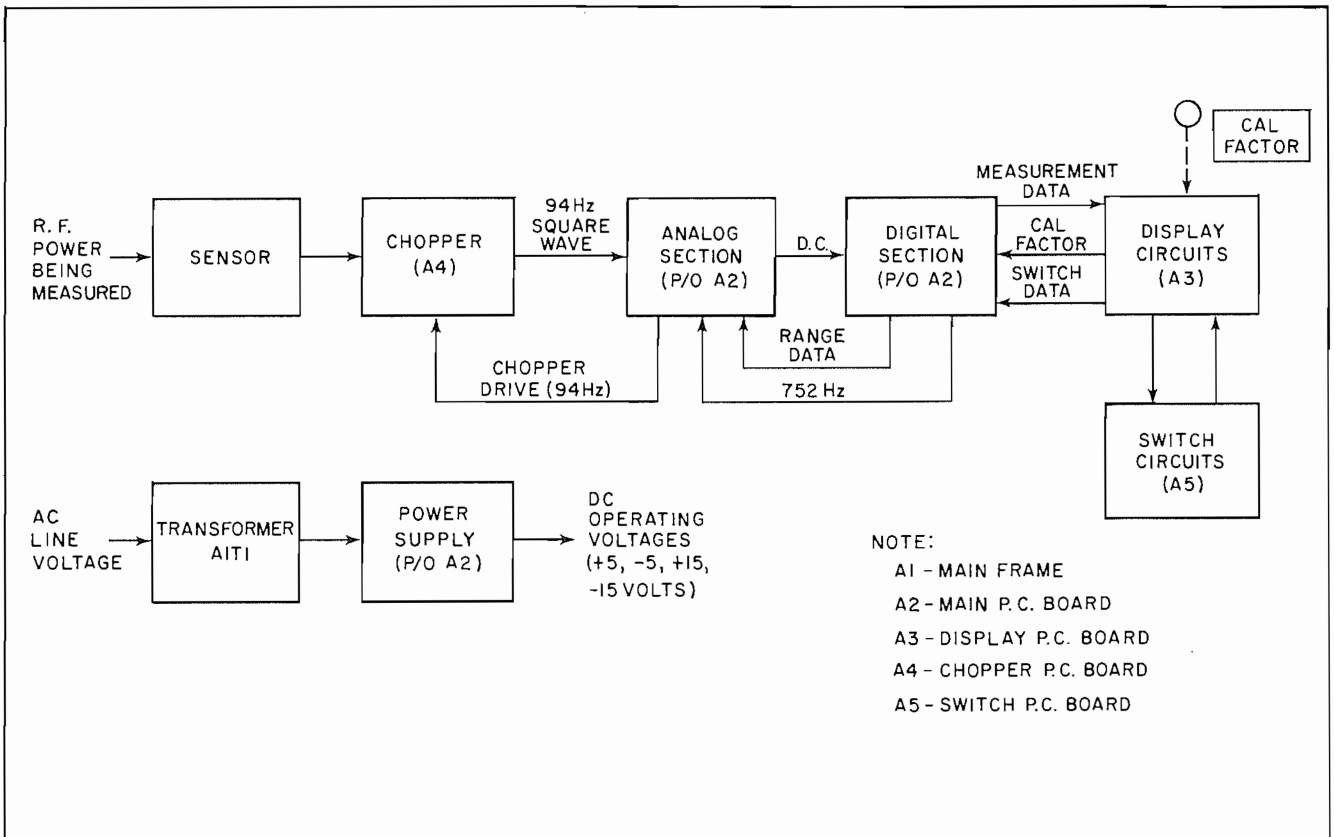


Figure 3-1 Block Diagram

(smoothed, zero corrected, shaped, etc.) by the microprocessor, and it is then supplied to the display circuits through the I/O ports. Switch data, which define the function to be performed, and calibration factor information for the sensor that is being used, are supplied to the microprocessor through the display circuits and the I/O ports in the digital section. The microprocessor reads this data, executes switch commands, and applies calibration factors to the measured values.

3-7. The display circuits contain a 4-digit display, an analog meter, and associated annunciator and control circuits. Digital measurement data from the digital section drives the 4-digit display and annunciators. A D/A converter in the digital section converts measurement data to an analog voltage that drives the analog meter. The CAL FACTOR potentiometer in the display circuits provides a means for entering calibration correction data for the sensor being used with the instrument. The display circuits also route scanning signals from the microprocessor to the switch circuits, which permit operator selection of instrument functions. Switch closure information is routed through the display circuits and the I/O ports in the digital section to the microprocessor.

3-8. Operating power for the instrument circuits is provided by the power supply. Line voltages of 100, 120, 220, or 240 volts ±10% may be applied to power transformer A1T1. Switches on the rear panel of the instrument allow switching of primary winding connections to accommodate the various input voltages. The secondary windings of transformer A1T1 supply power to rectifier-regulator circuits that develop regulated +5 volts, -5 volts, +15 volts, and -15 volts for operation of the other circuits in the instrument.

3-9. DETAILED THEORY OF OPERATION, SENSOR AND ANALOG SECTION.

(See Figure 3-2.)

3-10. The r.f. power that is to be measured is applied to the sensor, which converts r.f. power to a proportional d.c. voltage. The output voltage from the sensor ranges from a fraction of a millivolt to volts, as a function of the input power level to the sensor. To reduce the effects of drift and residuals at very low levels, the d.c. output voltage of the sensor is converted to a.c. by the chopper, and the a.c. is amplified, scaled, and converted back to d.c. by the analog section. The resulting d.c. voltage is supplied to the digital section for additional processing required to develop the final measurement signals used to drive the display circuits.

3-11. The sensor used with the instrument contains a non-inductive load resistor and a pair of selected diodes connected as a full-wave rectifier across the load resistor. The r.f. voltage developed across the load resistor is rectified by the diodes to produce a d.c. voltage which is some function of the applied r.f. power level. At levels up to approximately 10 microwatts, the d.c. voltage is proportional to the input power; at higher levels, the d.c. voltage gradually becomes proportional to the peak value of the r.f. power level.

3-12. The chopper printed-circuit board contains four solid-state switches, which are used to convert input d.c. voltage to a 94-Hz square wave. The switches are controlled by 94-Hz chopper drive signals supplied from a frequency divider chain in the analog section. Potentiometers A4R4 and A4R5 provide means for adjusting the chopper. Use of a solid-state chopper eliminates most of the undesirable characteristics of electromechanical choppers, such as contact wear, bounce, and contamination. The output of the chopper is a balanced 94-Hz square wave that is directly proportional to the d.c. voltage applied from the sensor.

3-13. The balanced 94-Hz square wave signal from the chopper is amplified by operational amplifiers A2U8, A2U10, and A2U12 and associated circuits. The gain of operational amplifiers A2U8 and A2U10 is controlled by the microprocessor through gates A2U11a and A2U11b, multiplexer A2U9, and resistance networks in the feedback paths of the operational amplifiers. Gain is adjusted by adjusting the feedback. Signals R0, R1, and R2 from the digital section, applied through gates A2U11a and A2U11b, control switching of input terminals D1 and D2 of multiplexer A2U9 to two of eight points in the resistance networks, thereby adjusting the feedback and the amplifier gain. The 94-Hz output of operational amplifiers A2U8 and A2U10 is applied to the differential inputs of operational amplifier A2U12, which provides additional amplification and converts the signal to a single-ended signal. This signal is amplified and scaled by operational amplifier A2U13 and associated circuitry. Multiplexer A2U14 adjusts the gain of this operational amplifier in seven steps under control of signals R0, R1, and R2 from the microprocessor, to provide decade ranging in power. The nominal output for a full-scale input on each range is approximately 3.6 volts peak-to-peak. Separate potentiometers are provided for calibration of the instrument on each range.

3-14. A solid-state demodulator, consisting of switches A2U15a and A2U15b, converts the amplified and scaled 94-Hz square wave signal back to a d.c. voltage. The demodulator is driven by a 94-Hz demodulator drive signal, which is synchronized with the 94-Hz chopper drive signal. A synchronous, sampling-type demodulator circuit is used, with the sample being taken at a point well removed from the chopper switching points. The demodulator is followed by high input impedance buffer A2U19 to reduce loading of sampling capacitor A2U24 to negligible propor-

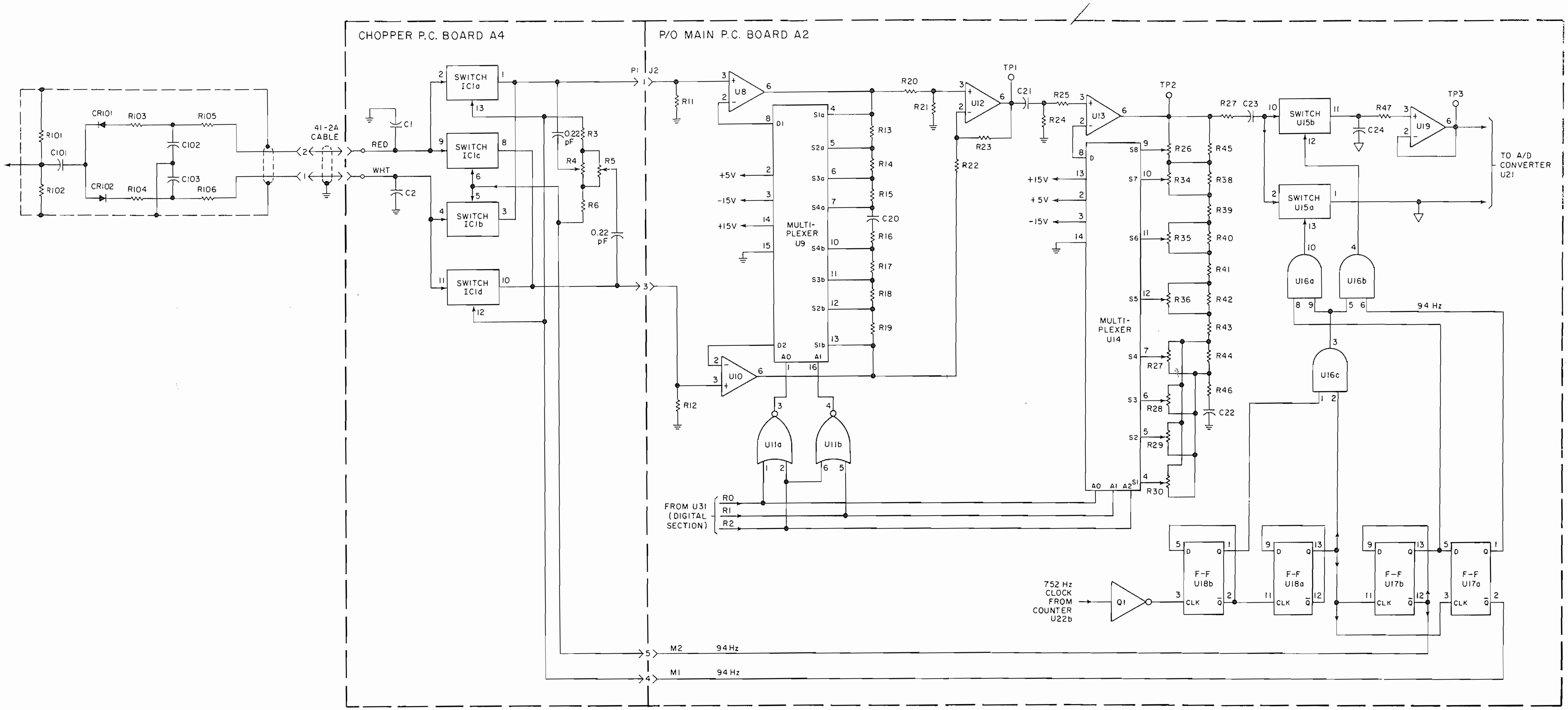


Figure 3-2 Sensor and Analog Section, Detailed Block Diagram

tions. Output d.c. is supplied to A/D converter A2U21 in the digital section.

3-15. Chopper and demodulator drive signals are derived from the 752-Hz clock supplied from the digital section. Flip-flops A2U18b, A2U18a, A2U17b, and A2U17a divide the 752-Hz clock down to 94-Hz, and gates A2U16a, A2U16b, and A2U16c shape the 94-Hz demodulator drive signal. Figure 3-3 shows the derivation of the chopper and demodulator drive signals from the 752-Hz clock signal.

3-16. DETAILED THEORY OF OPERATION, DIGITAL SECTION.

(See Figure 3-4.)

3-17. The digital section contains a microcomputer with related I/O, timing, and D/A and A/D converter circuits. The microcomputer executes a program resident in memory to perform the following functions:

a. Measure, store, and apply zero corrections for each range.

b. Measure and shape, as necessary, the input signal after conversion to digital format.

c. Check switch closures and execute switch commands.

d. Convert measured power level to dBm.

e. Store present dBm level, and apply it as the reference level.

f. Average out noise on low-level signals.

g. Interpret the position of the CAL FACTOR potentiometer and correct power and dBm values accordingly.

h. Range the instrument.

i. Supply analog information to drive the analog meter.

j. Supply digital information to drive the digital display and annunciators.

3-18. The microcomputer consists of CPU A2U28, PROM A2U29, and RAMs A2U30 and A2U32. CPU A2U29 retrieves instructions from the program resident in PROM A2U29 and executes the instructions. RAMs A2U30 and A2U32 are used for temporary storage of variable values. Data exchanges between the CPU, memory, and I/O devices are performed over an 8-bit bidirectional bus. Addresses for memory and I/O device exchanges are provided by a 12-bit address bus.

3-19. When the instrument is turned on, CPU A2U28 is reset through a network consisting of resistor A2R58, capacitor A2C30, and diode A2CR7. RAMs A2U30 and A2U32 are cleared during initialization. When capacitor A2C30 has charged through resistor A2R58, the CPU $\overline{\text{RESET}}$ signal is deactivated, and the CPU begins execution of the stored program. The CPU is clocked at 1.7895 MHz by a clock signal developed by crystal A2Y1, an internal clock circuit in A/D converter A2U21, flip-flop A2U26a, and gate A2U27a. PROM A2U29 is enabled through gate A2U24b by signals $\overline{\text{MRQ}}$ and $\overline{\text{RD}}$ from CPU A2U28, and the instruction stored at the location specified by the address bits is retrieved and sent to the CPU over the data bus. The CPU executes the received instruction.

3-20. After initialization, the microprocessor first performs a display check, whereby the LED display digits, the minus sign, and all annunciators light for 1 second, blank for 0.5 second, and then commence normal indications. Data for this display check is supplied over the data bus to the display printed-circuit board through programmable peripheral interface A2U31. Address bit A2 selects this I/O device; address bit A0 and A1 select the appropriate port of the programmable peripheral interface; and signal $\overline{\text{WR}}$ commands a write function. Data from the data bus is routed through the addressed ports to the display circuits.

3-21. After the display check, the microprocessor executes a measurement routine repeatedly until the instrument is turned off. The steps of the measurement routine are as follows:

a. The microprocessor reads stored front-panel switch commands and executes the switch commands.

b. The microprocessor reads measured data from A/D converter A2U21.

c. The microprocessor checks to see if the instrument is in range; if the instrument is overrange or underrange, the microprocessor supplies suitable ranging signals to the analog section to bring the instrument to the proper range.

d. The microprocessor corrects received measurement data for any zero offset. It calculates power, smooths or averages readings as required, reads and applies the manually entered CAL FACTOR, calculates dBm, and introduces the dB reference.

e. The final results are displayed.

f. The measurement cycle is repeated.

3-22. Front-panel switch commands are supplied from the display circuits to port PC6 of programmable peripheral

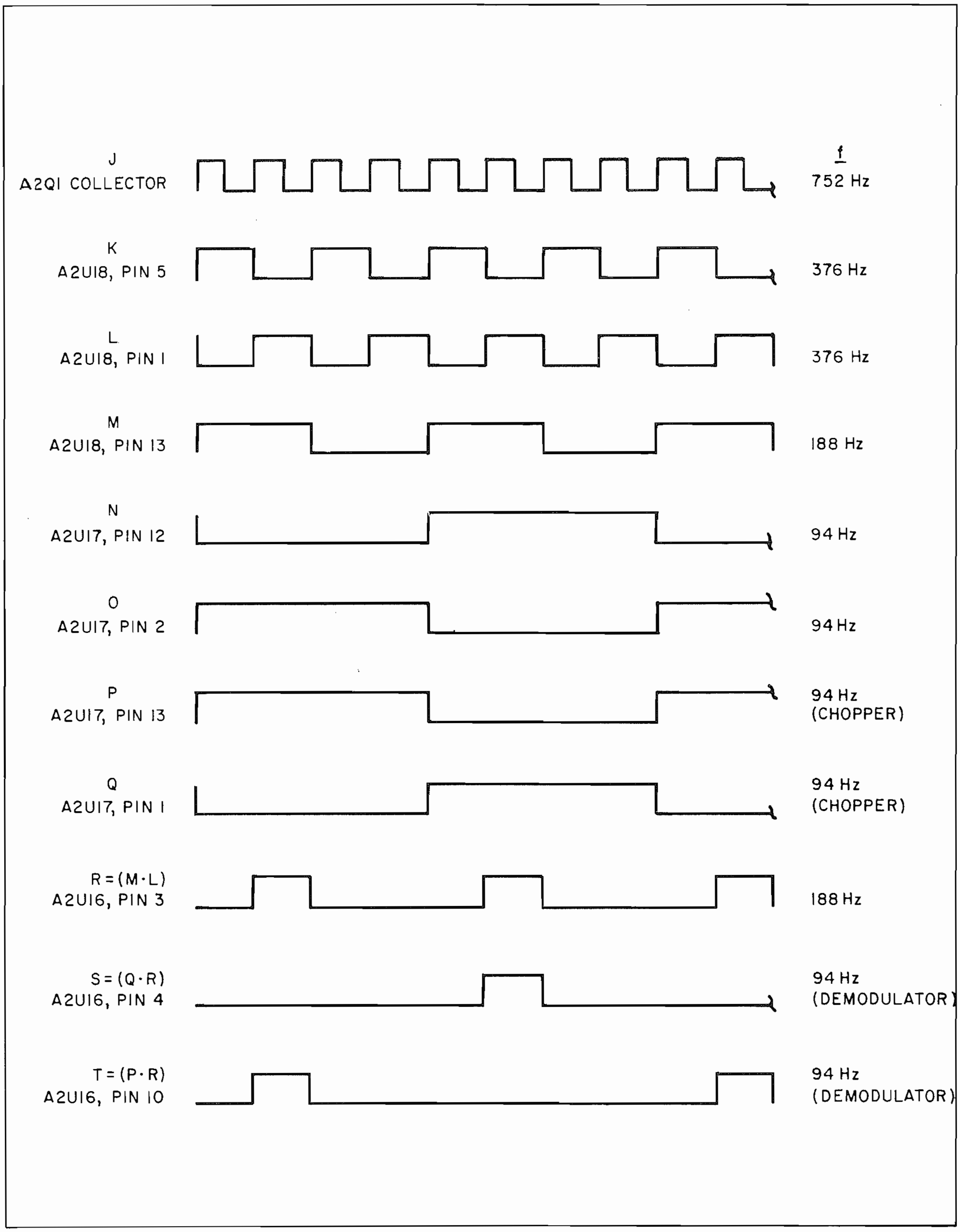


Figure 3-3 Derivation of Chopper and Demodulator Drive Signals

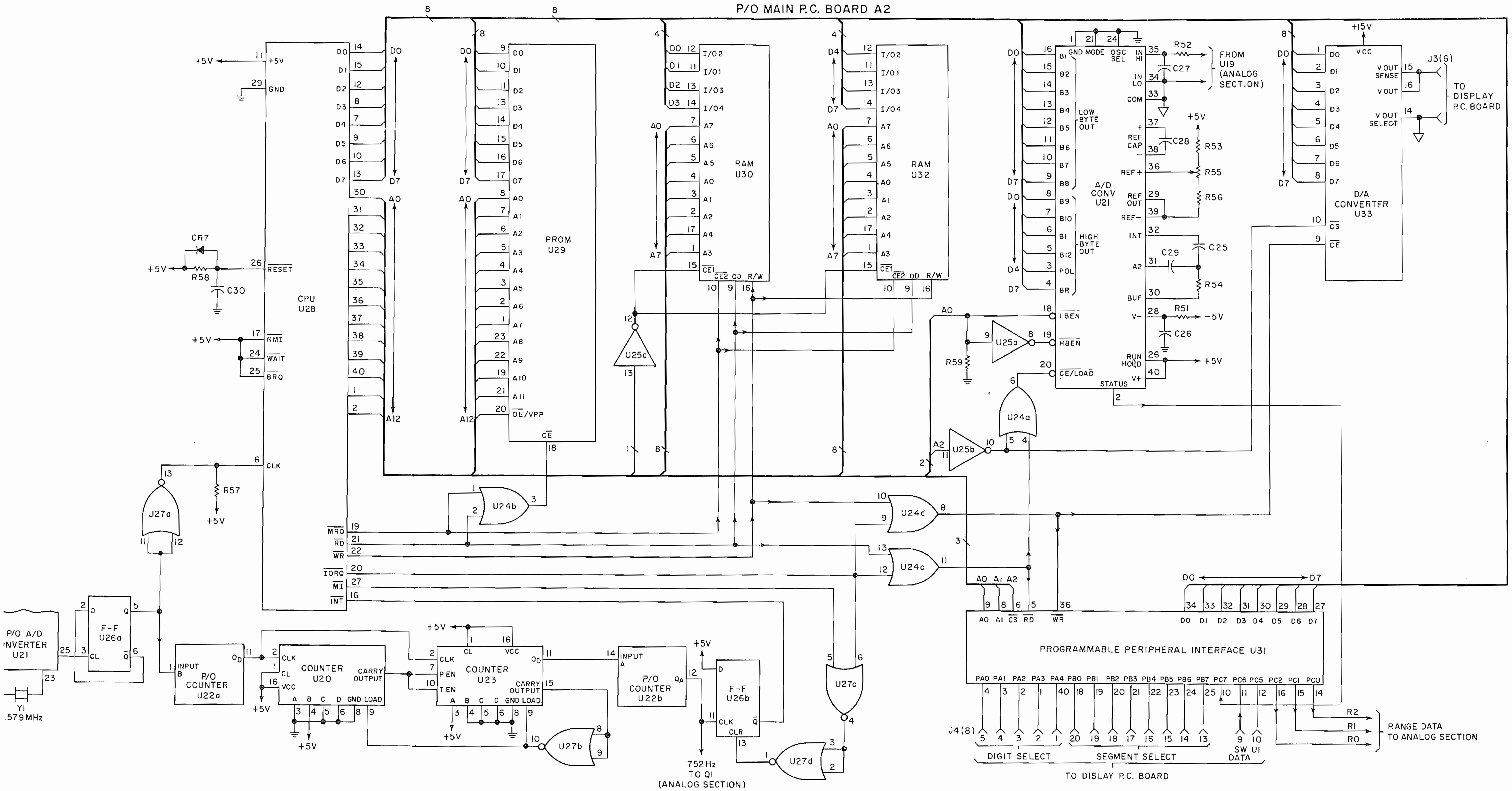


Figure 3-4 Digital Section, Detailed Block Diagram

interface A2U31. Switch data is transferred from the programmable peripheral interface to the data bus under control of the CPU. Device and port selection at the programmable peripheral interface is accomplished by address bits A0 through A2 from the CPU; the $\overline{RD}$ function is activated through gate A2U24c by signals $\overline{RD}$ and $\overline{IORQ}$ from the CPU.

3-23. Measurement data from the analog section is supplied to A/D converter A2U21, which is a dual-slope, automatic zeroing converter. It converts the applied analog measurement data to a 12-bit binary value. An internal clock is generated using a 3.579-MHz crystal oscillator and internal frequency dividers. Under control of this clock, 7.5 conversions per second are performed, thereby providing excellent immunity from 60-Hz line components. The A/D converter operates autonomously; it provides a status signal that indicates to the CPU when it is performing a conversion and when new data is ready. This status signal is supplied to the CPU through port PC7 of programmable peripheral interface A2U31 and the data bus. Converted data is read when signal $\overline{CE/LOAD}$ is activated through gate A2U24a, inverter A2U25b, and gate A2U24c by address bit A2 and signals $\overline{RD}$ and $\overline{IORQ}$ from the CPU and the status bit is low. Since the A/D converter develops a 12-bit output while an 8-bit data bus is used by the microprocessor, binary output data is divided into two bytes, which are transmitted sequentially over the data bus. The low byte output is enabled when address bit A0 is low; the high byte output is enabled through inverter A2U25a when address bit A0 is high.

3-24. Automatic ranging signals are supplied by the microprocessor to the analog section through ports PC0 through PC2 of programmable peripheral interface A2U31. The ranging signals control attenuator circuits in the analog section that perform required scaling of the input signal. Device and port selection for transmission of the automatic ranging signals is accomplished by address bits A0 through A2, and the $\overline{WR}$ function is activated through gate A2U24d by signals $\overline{IORQ}$ and $\overline{WR}$ from the CPU.

3-25. RAMs A2U30 and A2U32 are used for temporary storage of variable values. The RAMs are 4-bit memory devices; therefore, two are used in parallel to accommodate the 8-bit data from the microprocessor. RAM selection and control are exercised by the CPU by means of address bit A12 and signals $\overline{MRQ}$, $\overline{RD}$, and $\overline{WR}$. The RAMs are both written to and read.

3-26. D/A converter A2U33 performs a dual function. During one of every five microprocessor interrupt periods, it is used with circuits on the display printed-circuit board to determine the setting of the front-panel CAL FACTOR potentiometer. For this function, digital data from the microprocessor is converted to an analog voltage by the D/A converter, and this analog voltage is compared in the display circuits with the voltage at the output arm of the CAL FACTOR potentiometer. If the two voltages do not agree, an error signal is supplied to the microprocessor through port PC5 of programmable peripheral interface A2U31, and the microprocessor adjusts the digital input to D/A converter A2U33. This process continues until the error signal is eliminated. The digital signal on the data bus is then a function of the voltage from the CAL FACTOR potentiometer setting. At all other times, D/A converter A2U33 converts the final digital measurement data from the microprocessor to an analog voltage that drives the analog meter in the display circuits. Selection of the D/A converter is achieved through inverter A2U25b by address bit A2 from the CPU; the D/A converter is enabled through gate A2U24d by signals $\overline{IORQ}$ and $\overline{WR}$ from the CPU.

3-27. Final digital measurement values are supplied to the display circuits through the data bus and programmable peripheral interface A2U31 during microprocessor interrupt periods. Data for one digit of the digital display or for the annunciators is routed through port B of the programmable peripheral interface to segment drive lines of the display circuits; the digit-select line for that digit or the annunciators is activated through one of the A ports of the programmable peripheral interface to enable display of the segment data by the selected digit or the annunciators. Device and port selection is accomplished by means of address bits A0 through A2, and the $\overline{WR}$ function is activated through gate A2U24d by the CPU.

3-28. Timing of microprocessor interrupts is controlled by a frequency divider chain that converts the 3.579-MHz clock signal from A/D converter A2U21 to a 752-Hz interrupt signal. The counter chain consists of flip-flop A2U26a, ÷5 counter A2U22a, presettable counters A2U20 and A2U23, ÷2 counter A2U22b, and flip-flop A2U26b. Presettable counters A2U20 and A2U23 are hard-wired to provide the required frequency division; when counter A2U23 times out, the hard-wired count is loaded into the counters by a load command supplied through gate A2U27b. Signal $\overline{INT}$ to the CPU is terminated when flip-flop A2U26b is cleared through gates A2U27c and A2U27d by the CPU. The 752-Hz clock signal is also supplied to the analog section for use in developing the chopper and demodulator drive signals. Each time the CPU receives an interrupt signal, it jumps to a special routine which does the following:

a. Clears the display.

b. Supplies new data to the display.

c. Checks and stores switch closures.

d. Returns to the regular program.

3-29. DETAILED THEORY OF OPERATION, DISPLAY AND SWITCH CIRCUITS.

(See Figure 3-5.)

3-30. The display circuits provide a clear, unambiguous readout of measured r.f. power levels by means of a 4-digit, LED type digital display with decimal point. Five annunciators associated with the digital display indicate the units of measurement, and a sixth annunciator activates the minus sign. The display circuits also provide relative-power indications for peaking and nulling applications by means of an analog meter, and operate with the switch printed-circuit board to supply switch-selected commands to the digital section.

3-31. The digital display consists of four 7-segment LED digits. Five LED unit annunciators and a sixth LED sign annunciator are treated as another digit. Measurement data for these digits are generated and stored in the digital section during each measurement cycle. At each microprocessor interrupt period (approximately every 1.33 milliseconds), one of the five digits is updated and turned on. The digit sequence is: the annunciator digit, the least significant digit of the digital display, and the remaining digits of the digital display, in succession, to the most significant digit. Each digit is on for 20 percent of the time, and each digit is updated every 6.65 milliseconds.

3-32. Selection of the digit to be updated is controlled by digit-drive signals supplied by the microprocessor through programmable peripheral interface A2U31 in the digital section. Each digit-drive signal controls a separate digit through a digit driver (A3Q3 through A3Q7). Only one digit-drive signal is activated during a microprocessor interrupt, and the active digit-drive signal enables updating of the digit that it controls. Measurement data for that digit is supplied, in the form of segment-drive signals, from the microprocessor through programmable peripheral interface A2U31. Segment-drive signals are applied through gates A3U2a through A3U2d and A3U3a through A3U3d and resistive network A3R15 to the segment inputs of all digits in parallel; however, only that digit whose digit-drive signal is active at that time will be updated by the segment-drive data.

3-33. Digit-drive signals from digit drivers A3Q3 through A3Q7 are also supplied to switch printed-circuit board A5. Front-panel switches on the switch printed-circuit board are scanned sequentially during successive microprocessor interrupts. Closure of any switch produces a positive pulse across resistor A3R7 when that switch is scanned. The resulting pulse is transferred to the microprocessor circuits through programmable peripheral interface A2U31 in the display section, where it is stored for execution in the main program after completion of the interrupt routine. The digit-drive signal that is active at the time the switch pulse is activated signifies which of the five switches has been pressed.

3-34. Comparator A3U1 functions with D/A converter A2U33 in the digital section to provide selected CAL FACTOR potentiometer information to the digital section. At the high frequencies (2 GHz to 18 GHz), calibration correction factors supplied with each sensor are introduced by means of front panel CAL FACTOR potentiometer A3R3. During an interrupt period, the output analog voltage from D/A converter A2U33 in the digital section is compared with the voltage supplied from the CAL FACTOR potentiometer by comparator A3U1. If the two voltages are not equal, an error signal is supplied from the comparator to the microprocessor circuits through programmable peripheral interface A2U31 in the digital section, and the microprocessor adjusts the digital input to D/A converter A2U33 until the error signal is eliminated. The digital data at the input of the D/A converter then are proportional to the setting of the CAL FACTOR potentiometer. This digital value is processed to provide the proper correction to measurement values in both the power and dB modes of operation.

3-35. At all other times, D/A converter A2U33 in the digital section supplies analog data to the front-panel analog meter. The meter circuit is turned off through transistors A3Q2 and A3Q1 during those interrupt periods when the CAL FACTOR potentiometer setting is being determined by the microprocessor. Potentiometer A3R5 provides a means for adjusting the analog meter.

3-36. DETAILED THEORY OF OPERATION, POWER SUPPLY CIRCUITS.

(See Figure 3-6.)

3-37. The power supply circuits provide d.c. operating power for all other circuits of the instrument. Regulated output voltages of +15 volts, -15 volts, +5 volts, and -5 volts are supplied. Line voltages of 100 volts, 120 volts, 220 volts, and 240 volts a.c. can be accommodated. The applied a.c. line voltage may depart as much as 10 percent from the nominal value with no degradation in instrument performance.

3-38. A.C. power is applied to the primary windings of power transformer A1T1 through LINE switch A1S2 and line-voltage switch A1S1. The two-section line-voltage switch changes transformer primary winding connections as required to accommodate the available a.c. line voltage. Fuse A1F1 protects the power supply circuits against overload. The a.c. voltages developed in the secondary windings of power transformer A1T1 are applied to three rectifier-regulator circuits on main printed-circuit board A2.

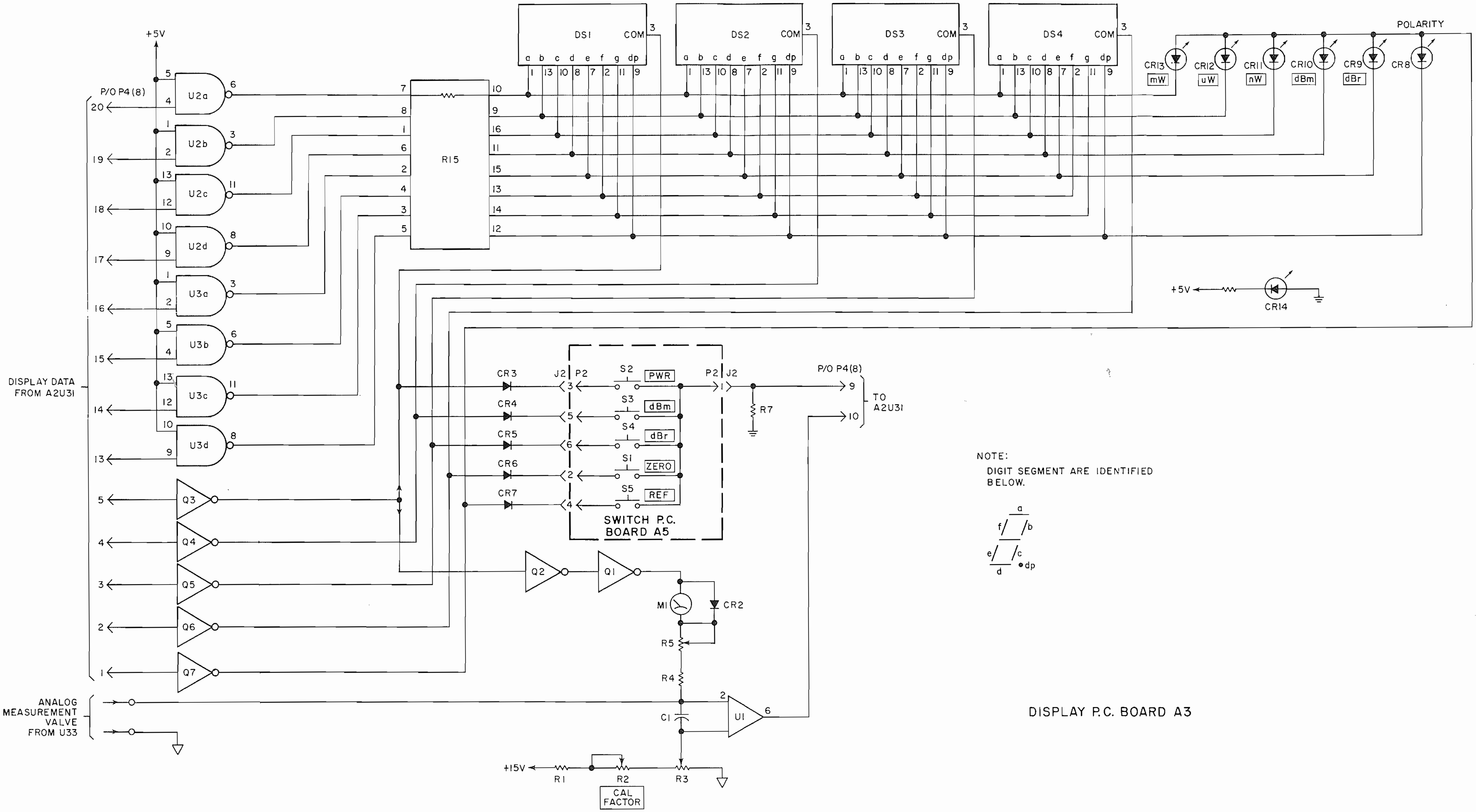


Figure 3-5 Display and Switch Circuits,
Detailed Block Diagram

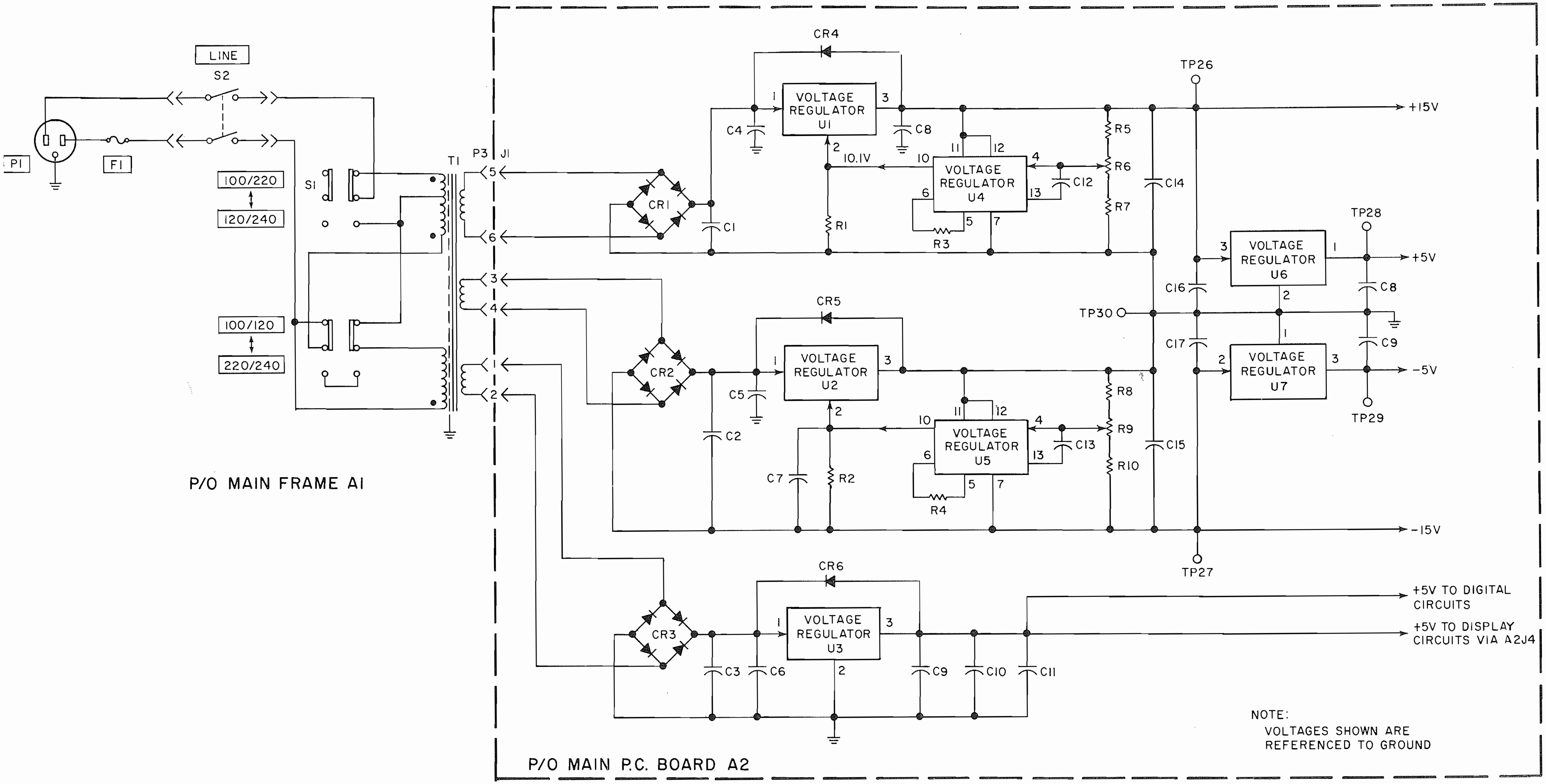


Figure 3-6 Power Supply Circuits, Detailed Block Diagram

3-39. The +15 volt and -15 volt supplies are similar. Input to each supply consists of 20 volts a.c., supplied by a separate secondary winding of power transformer A1T1. In each supply, the applied a.c. voltage is rectified by a bridge rectifier, filtered, and then regulated. Potentiometers A2R6 and A2R9 provide means for adjusting the output voltages of the +15 volt and -15 volt supplies, respectively. Regulated +5 volt and -5 volt operating supplies for the most sensitive circuits (the chopper and analog circuits) of the instrument derive power from the regulated +15 volt and -15 volt supplies using voltage regulators A2U6 and A2U7; these supplies are thereby extra-regulated.

3-40. Regulated +5 volts for the digital and display circuits is provided by a separate 5-volt d.c. supply, powered by the third secondary winding of power transformer A1T1. The applied a.c. voltage is rectified by bridge rectifier A2CR3 to develop 11 volts d.c., and this filtered d.c. is converted to +5 volts by voltage regulator A2U3.

SECTION IV
MAINTENANCE

4-1. GENERAL.

4-2. This section contains maintenance and calibration instructions for the instrument. Included are a list of test equipment required for maintenance, symptomatic and systematic troubleshooting procedures designed to localize a malfunction to an individual subassembly or circuit, and adjustment instructions for restoring the instrument to proper operating condition after repairs have been completed.

NOTE

For minimum-performance tests of the instrument refer to Section II of this manual.

4-3. TEST EQUIPMENT REQUIRED.

4-4. Test equipment required for maintenance is listed below. Equipment of equivalent characteristics may be substituted for any item listed.

NOTE

It is recommended that Section III of this manual, Theory of Operation, be read for a basic understanding of how the instrument operates before attempting any maintenance procedures.

a. Digital Multimeter, Data Precision Model 1450

b. Adjustable Power Source, Boonton Model 25A

c. Signature Analyzer, Hewlett-Packard Model 5004A

d. Oscilloscope

e. Variable-Voltage Transformer, GenRad Variac (required for Line-Influence check in Table 4-1).

f. 30 MHz Power Source, capable of 100 mW output

NOTE

A 1-MHz adjustable power source, such as the Boonton Model 25A, is sufficient for instruments equipped with all Boonton sensors except the Model 4210-7E sensor. For this sensor, an equivalent 50-MHz source is required.

4-5. TROUBLESHOOTING CONCEPT.

4-6. This instrument uses both analog and microprocessor-based digital circuity. D.C. and a.c. measuring instruments, such as voltmeters and oscilloscopes, have been the traditional test instruments for electronic instrument maintenance. Although these instruments are still required for some tests, they are not sufficient for a microprocessor-based instrument. A new technique, signature analysis, has been devised that offers many advantages over the older methods. A complete discussion of signature analysis is beyond the scope of this manual; however, a brief description of the method may be helpful.

Long and complex data streams are present in microprocessor systems. In signature analysis, with the system operating at normal speed, these data streams can be compressed into concise, easy-to-interpret readouts (signatures) at pertinent circuit nodes by choosing appropriate measurement periods or gates. By choosing particular nodes and gates, these signatures become unique; one, and only one, signature occurs at a given node if operation is normal. Signature analysis checks are of two basic types: free-running and stimulated. In the case of the 4210, only free-running signature analysis is used.

4-7. PRELIMINARY INSPECTION.

4-8. Initial Check. If equipment malfunction occurs, some attempt should be made to categorize the malfunction. Examples are: incorrect indication on the 100 μW range; or analog meter indicating zero at all times; or display blanked, etc. This procedure will frequently isolate the problem to a given area, or even to the component level.

4-9. Visual Check. Disconnect the power cord from the instrument and remove the top instrument cover (secured with four screws through the bottom cover.) Inspect the instrument for signs of damage caused by excessive shock or vibration; look for things such as broken leadwires, loose hardware, and unseated IC's. Then check for signs of overheating, which may be caused by electrical short-circuits, faulty components, or accumulation of dirt and other foreign matter. Correct any problems discovered through the visual check.

4-10. Display Check. Each time the instrument is turned on, the following occurs: all digit segments, decimal points, the minus sign, and all LED annunciators light for approximately 1 second, blank for approximately 0.5 second, and then commence normal indications.

If the above sequence occurs, it indicates that all display components are capable of being turned on and off; that in all probability the display section of the instrument is normal, and, at least, that part of the operating program is being executed correctly. Correct any problems discovered through the display check. If trouble persists, proceed with the electrical checks.

4-11. Power-Supply Check. Improper operation of the instrument may be caused by incorrect d.c. operating voltages. Before proceeding with any other electrical checks, perform the power-supply checks in accordance with Table 4-1. The location of all internal instrument adjustments and test points are shown in Figure 4-1 and the printed-circuit board layouts appear on the aprons of the schematic diagrams.

WARNING

Voltages up to 240 volts a.c. may be encountered in the power-supply circuits. To protect against electrical shock, observe suitable precautions when connecting and disconnecting test equipment, and when making voltage measurements.

If any voltage appears to be incorrect, or unadjustable, check that portion of the circuit for defective components. An abnormal load, of course, can lead to an abnormal voltage. All IC's are socketed, making their replacement simple. Correct any abnormal supply voltage before proceeding with any further troubleshooting procedures.

TABLE 4-1 POWER SUPPLY CHECK

Test Point	Normal Voltage	Adjustment	Line Influence, ±10%
TP25	4.8 to 5.2V	—	<±0.1 V
26	15 ±0.1 V	A2R6	<±0.01 V
27	-15 ±0.1 V	A2R9	<±0.01 V
28	4.75 to 5.25 V	—	0 V
29	-4.75 to -5.25 V	—	0 V

4-12. Analog-Section Checks. To check the analog section of the instrument, proceed as follows:

a. Connect the proper sensor to the instrument and turn the instrument on.

b. Connect the sensor to the adjustable power source, Model 25A, and turn it on.

c. Set the adjustable power source to an output of 1 mW.

d. Connect an oscilloscope, in turn, to the test points A through T of the divider chain and check the resulting waveforms against those shown on the schematic diagrams. Note that the test points are arranged in descending frequency (A = 3.5795 MHz, T = 94 Hz). The first departure, if any, from the correct waveform will point to the IC immediately before the test point as the most probable cause for malfunction. All IC's are socketed, making their replacement easy. If all the waveforms appear correct, proceed to step (e).

e. Connect an oscilloscope, in turn, to the test points 1 through 23 and check the waveforms against those shown on the schematic diagrams. Again, at the first departure from a normal waveform, the IC's and components most intimately associated with that test point should be investigated as the probable source of the malfunction.

4-13. Signature-Analysis Checks. To check the digital section of the instrument using signature analysis, proceed as follows:

a. Disconnect the a.c. power cord to the instrument and remove the Z80 microprocessor, V28. Connect the microprocessor to the signature-analysis adapter (Boonton P/N950028), and connect the adapter to the microprocessor socket in the instrument.

b. Turn the instrument on. The adapter disconnects the Z80 data lines from the instrument and forces an NOP operation on the Z80. The microprocessor will now run through its address field and repeat continuously.

c. Connect the signature analyzer, in turn, to each of the nodes shown in Tables 4-2 through 4-9. Any signature which does not agree with that shown in the tables indicates a problem with the IC's or components tied to that node.

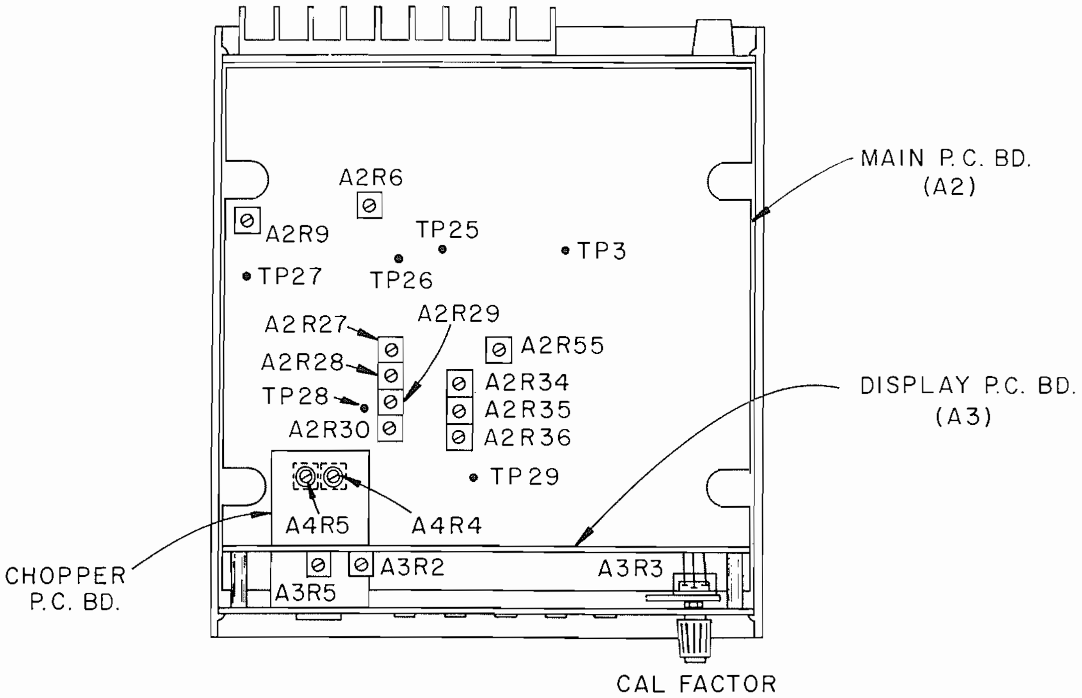
4-14. ADJUSTMENT PROCEDURES.

4-15. General. Paragraphs 4-16 through 4-20 provide instructions for all adjustments required. Adjustment is not a substitute for troubleshooting. Make certain that all other possible causes of instrument malfunction have been eliminated before undertaking adjustment. See Figure 4-1 and the printed-circuit board layouts on the aprons of the schematic diagrams for the location of adjustment controls.

4-16. Power-Supply Adjustments. To adjust the power supply, perform the steps shown in Table 4-10.

4-17. Chopper Adjustments. These adjustments require that the instrument and sensor be turned on, and that they be in an ambient temperature of 21°C (70°F) to 25°C (77°F) for not less than one hour. To adjust the chopper, proceed as follows:

a. Connect the sensor to the adjustable power source (Model 25A) and set the source to ZERO.



REF. SYMBOL	r. f. INPUT	ADJUST
A2 R6	—	+ 15.00 ± .02 Vdc AT TP 26
A2 R9	—	− 15.00 ± .02 Vdc AT TP 27
A4 R4	0	0.00 INDICATION (1)
A4 R5	0	0.00 INDICATION (1)
A3 R3	—	CAL FACTOR ; 0 dB
A2 R30	(100 nW) 10 nW	(100.0 nW) 10.00 nW INDICATION
A2 R29	(1 μW) 100 nW	(1.000 μW) 100.0 nW INDICATION
A2 R28	(10 μW) 1 μW	(10.00 μW) 1.000 μW INDICATION
A2 R27	(100 μW) 10 μW	(100.0 μW) 10.00 μW INDICATION
A2 R36	(1 mW) 100 μW	(1.000 mW) 100.0 μW INDICATION
A2 R35	(10 mW) 1 mW	(10.00 mW) 1.000 mW INDICATION
A2 R34	(100 mW) 10 mW	(100.0 mW) 10.00 mW INDICATION
A2 R55	—	ANALOG/DIGITAL CONVERTER SENSITIVITY (2)
A3 R2	(10 mW) 1 mW	CAL FACTOR Linearity
A3 R5	1 mW	Analog Meter; 85% f.s.

(1) BALANCED CIRCUIT, ADJUST EACH POT ABOUT ONE HALF TOTAL.
(2) ADJUST IF OTHER RANGES WILL NOT CALIBRATE.
NUMBERS IN PARENTHESIS APPLY TO 4200-5 SERIES. 831249

Figure 4-1. Parts Location

TABLE 4-2. SIGNATURE ANALYSIS TEST - CPU ADDRESS FIELD

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 7	U28	Z80	PIN 11	+5 V	0000
STOP		TP 7	U28	Z80	PIN 29	COM	755U
CLK		TP 8	U28	Z80	PIN 30	A_0	H335
			U28	Z80	PIN 31	A_1	C113
			U28	Z80	PIN 32	A_2	7050
			U28	Z80	PIN 33	A_3	0772
			U28	Z80	PIN 34	A_4	C4C3
			U28	Z80	PIN 35	A_5	AA08
			U28	Z80	PIN 36	A_6	7211
			U28	Z80	PIN 37	A_7	A3C1
			U28	Z80	PIN 38	A_8	7707
			U28	Z80	PIN 39	A_9	577A
			U28	Z80	PIN 40	A_{10}	HH86
			U28	Z80	PIN 1	A_{11}	89F1
			U28	Z80	PIN 2	A_{12}	AC99
			U28	Z80	PIN 3	A_{13}	PCF3
			U28	Z80	PIN 4	A_{14}	1180
			U28	Z80	PIN 5	A_{15}	755U

TABLE 4-3. SIGNATURE ANALYSIS TEST - PROM CONTENT
J0Aa 4210-4 SERIES SENSOR

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 9	U29	2732	PIN 24	+5 V	826P
STOP		TP 9	U29	2732	PIN 12	COM	0000
CLK		TP 8	U29	2732	PIN 9	D_0	6243
			U29	2732	PIN 10	D_1	H952
			U29	2732	PIN 11	D_2	PH2H
			U29	2732	PIN 13	D_3	7493
			U29	2732	PIN 14	D_4	3361
			U29	2732	PIN 15	D_5	AU6P
			U29	2732	PIN 16	D_6	82C7
			U29	2732	PIN 17	D_7	CA4P

TABLE 4-4. SIGNATURE ANALYSIS TEST - PROM CONTENT J0Ba 4210-5 SERIES SENSOR

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 9	U29	2732	PIN 24	+5 V	826P
STOP		TP 9	U29	2732	PIN 12	COM	0000
CLK		TP 8	U29	2732	PIN 9	D_0	14F3
			U29	2732	PIN 10	D_1	UP59
			U29	2732	PIN 11	D_2	2CF3
			U29	2732	PIN 13	D_3	C1F0
			U29	2732	PIN 14	D_4	7964
			U29	2732	PIN 15	D_5	H6U3
			U29	2732	PIN 16	D_6	82C7
			U29	2732	PIN 17	D_7	CA4P

TABLE 4-5. SIGNATURE ANALYSIS TEST - PROM CONTENT J0Ca 4210-7E SERIES SENSOR

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 9	U29	2732	PIN 24	+5 V	826P
STOP		TP 9	U29	2732	PIN 12	COM	0000
CLK		TP 8	U29	2732	PIN 9	D_0	AFC2
			U29	2732	PIN 10	D_1	1A6C
			U29	2732	PIN 11	D_2	C831
			U29	2732	PIN 13	D_3	1876
			U29	2732	PIN 14	D_4	7896
			U29	2732	PIN 15	D_5	65P2
			U29	2732	PIN 16	D_6	9618
			U29	2732	PIN 17	D_7	1C2U

TABLE 4-6. SIGNATURE ANALYSIS TEST - RAM ADDRESS LINES

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 7	U30	2111	PIN 18	+5 V	755U
STOP		TP 7	U32		PIN 8	COM	0000
CLK		TP 8			PIN 1	A_3	A3C1
					PIN 2	A_2	AA08
					PIN 3	A_1	C4C3
					PIN 4	A_0	0772
					PIN 5	A_5	7050
					PIN 6	A_6	C113
					PIN 7	A_7	H335
					PIN 15	CE1	HPF6
					PIN 17	A_4	7211

TABLE 4-7. SIGNATURE ANALYSIS TEST - INVERTER

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 7	U25	74L504	PIN 14	+5 V	755U
STOP		TP 7	U25	74L504	PIN 7	COM	0000
CLK		TP 8	U25	74L504	PIN 1		755U
			U25	74L504	PIN 2		0000
			U25	74L504	PIN 3		755U
			U25	74L504	PIN 4		0000
			U25	74L504	PIN 5		0000
			U25	74L504	PIN 6		0000
			U25	74L504	PIN 8		A66A
			U25	74L504	PIN 9		H335
			U25	74L504	PIN 10		050U
			U25	74L504	PIN 11		7050
			U25	74L504	PIN 12		HPF6
			U25	74L504	PIN 13		AC99

TABLE 4-8. SIGNATURE ANALYSIS TEST - GATE CHECK

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 7	U27	74L502	PIN 14	+5 V	755U
STOP		TP 7	U27	74L502	PIN 7	COM	0000
CLK		TP 8	U27	74L502	PIN 1		0000
			U27	74L502	PIN 2		755U or 0000
			U27	74L502	PIN 3		755U
			U27	74L502	PIN 4		755U
			U27	74L502	PIN 5		050U
			U27	74L502	PIN 6		755U
			U27	74L502	PIN 8		755U
			U27	74L502	PIN 9		755U
			U27	74L502	PIN 10		755U
			U27	74L502	PIN 11		755U
			U27	74L502	PIN 12		755U
			U27	74L502	PIN 13		755U or 0000

TABLE 4-9. SIGNATURE ANALYSIS TEST - A/D CONVERTER

SA	ACTIVE	POINT	SA PROBE				SIGNATURE
START		TP 7	U21	7109	PIN 40	+5 V	755U
STOP		TP 7			PIN 1, 21, 24	COM	0000
CLK		TP 9			PIN 18		H335
					PIN 19		A66A
					PIN 26		755U

TABLE 4-10. POWER SUPPLY ADJUSTMENTS

TEST POINT	ADJUST	VALUE
TP 26	A2R6	15 ±0.1V
TP 27	A2R9	-15 ±0.1V

b. Set the two chopper adjustments, A4R4 and A4R5, to their physical midpoints.

c. Connect the digital multimeter to TP3 and note the indication.

d. Adjust A4R4 to decrease the indication to one-half of that in step (c).

e. Adjust A4R5 to bring the indication to zero. There will be some fluctuation of the indication, and mental averaging will be required.

4-18. Range Adjustments. To adjust the power ranges of the instrument, proceed as follows:

a. Using the digital multimeter, check the voltage across the CAL FACTOR control, A3R3. It should be 10.0 volts. If it is not, adjust A3R2 for an indication of 10.0 volts.

b. Check the voltage at the slider of the CAL FACTOR control, A3R3. It should be approximately 5 volts. If it is not, check the position of the knob on the shaft and reset the knob, if necessary, so that the knob indicates 0 when the voltage at the slider is 5 volts.

c. Set A2R55 to its physical mid-position.

d. Set the adjustable power source (Model 25A) to ZERO. Press the ZERO key of the instrument and note the indication. A good zero is indicated when the positive and negative excursions are equal, and the minus sign flashes on and off. Repeat the zero procedure, if necessary, to obtain a good zero.

e. Release the ZERO key of the adjustable power source and set the output, in turn, to each of the levels shown in Table 4-9. On the most-sensitive ranges of the instrument there will be some fluctuation of indications, and mental averaging will be required. If it is impossible to adjust any range, or if any adjustment control is near to its end-stop, readjust A2R55 and repeat the range adjustments of Table 4-11.

TABLE 4-11. RANGE ADJUSTMENTS

Input (See Note)	Adjustment with Sensor				4210
	4210-4	4210-5	4210-7E	4210-8E	Indication
10 nW	A1R30				10.00 nW
100 nW	R29	A1R30			100.0 nW
1 μW	R28	R29			1.000 μW
10 μW	R27	R28	A1R30		10.00 μW
100 μW	R36	R27	R29	A1R30	100.0 μW
1 mW	R35	R36	R28	R29	1.000 mW
10 mW	R39	R35	R27	R28	10.0 mW
100 mW		R34		R27	100 mW

NOTE: Range adjustments for the 4210-8E, *and for the 4210-7E as well*, should be made at 30 MHz—which is not possible using the Model 25A. For these two sensors, substitute a 30 MHz power source (30 - 50 MHz is acceptable), with an output of at least 100 mW.

4-19. Analog-Meter Adjustments. To adjust the analog meter of the instrument, proceed as follows:

a. With no a.c. power applied to the instrument, check the zero indication of the analog meter. Adjust it to zero, if necessary, by means of the meter screw located behind the front-panel access hole below the meter window.

b. With the instrument turned on and an output level of 1.0 mW from the adjustable power source, note the indication of the analog meter. The indication should be approximately 85% of full scale (i.e., in the Power Mode only); if it is not, adjust A3R5 for this indication.

4-20. CAL FACTOR Adjustment. Because the adjustment of the CAL FACTOR control affects range accuracy, this adjustment was previously covered in paragraphs 4-18(a) and 4-18(b).

4-21. DETERMINATION OF CALIBRATION FACTORS AND EFFECTIVE EFFICIENCY.

4-22. General. The high-frequency calibration factors are provided on a chart on the barrel of the sensor. It is not normally necessary to compute new calibration factors unless the sensor is repaired or the data are suspect.

4-23. Standard Calibration Factor Computation Method.

a. Connect the test equipment as shown in detail A, Figure 4-2.

b. Adjust the signal generator to the desired test frequency, and adjust its output level to a level sufficient to provide a stable indication on the **monitor** meter.

c. Adjust the double-stub tuner as required to obtain a peak indication on the **monitor** meter.

d. Connect the equipment as shown in detail B, Figure 4-2.

e. At the same test frequency as used in step b, adjust the signal generator output level to provide a convenient indication on the standard power meter. Record the indicated power on the **monitor** meter, and the power indication (P_S) on the standard power meter.

f. Connect the equipment as shown in detail C, Figure 4-2.

g. At the same test frequency as used in steps b and e, adjust the signal generator output level as required to obtain the same power indication on the **monitor** meter as recorded in step e. Record the indicated power (P) on the Model 4210 that is being calibrated.

h. Compute the calibration factor for the test frequency from the relationship:

$$k = \frac{\text{indicated power}}{\text{incident power}} = k_S \frac{(1 - e)P}{(1 - e_S)P_S}$$

Where:
k_S = calibration factor of standard power meter
e_S = instrumentation error of standard power meter for range used
P_S = indicated power on standard power meter
e = instrumentation error of Model 4210 for range used
P = indicated power on Model 4210

NOTE

It is important that the instrumentation error (e_S) of the standard power meter be known. This error can be determined by methods described by the manufacturer. In most cases, the uncertainty of the instrumentation error can be reduced by operating at higher power levels.

i. Repeat steps a through h for each of the other test frequencies of interest.

4-24. Measurement of Effective Efficiency.

a. Connect the equipment as shown in Figure 4-3.

b. Set the signal generator to the test frequency of interest and adjust its output level as required to provide a convenient indication on the Model 4210 that is to be calibrated and a sufficient indication of reflected power on the monitor meter.

c. Record the incident and reflected power indications on the two monitor instruments as value P_i and P_r, respectively. When recording these values, correct the indicated values to acount for the two 6-dB attenuators.

d. Calculate the square of reflection coefficient $|\rho_\ell|^2$ of the Model 4210 being calibrated from the relationship:

$$|\rho_\ell|^2 = P_r/P_i$$

e. Calculate the effective efficiency from the relationship:

$$\eta = \frac{k}{1 - |\rho_\ell|^2} = \frac{\text{indicated power}}{\text{dissipated power}}$$

Where: k = calibration factor determined in paragraph 4-23.

4-25. Improved Calibration Factor Accuracy. The derivations for the equations relating to diode-type sensors are based on the premise that the full-wave rectifying circuit in the sensor is responsive to the total input voltage that appears across the internal impedance of the sensor. The extent that it fails to do so is accounted for in the calibration factor. The calibration factor for a power sensor should be determined using as nearly perfect a power source as possible, that is, one that generates a pure sine wave behind an impedance of Z_O, where Z_O is resistive and equal to the characteristic impedance of the measurement system (generally 50 ohms). With the use of leveling, the source impedance can be brought sufficiently

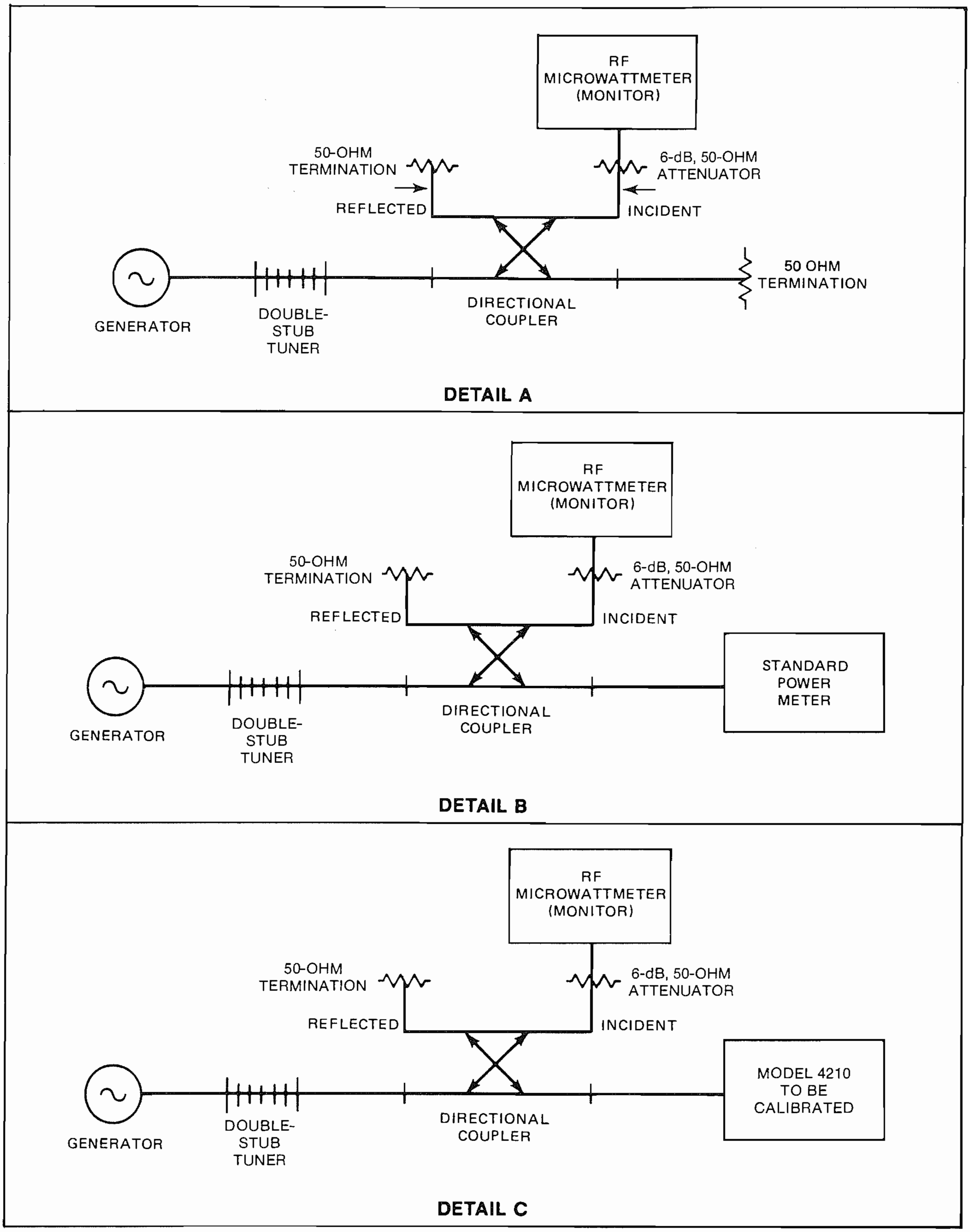


Figure 4-2. Calibration Factor Measurements, Test Setups

close to the ideal to hold the degree of measurement uncertainty within acceptable limits. This uncertainty contributes, in part, to the specified accuracy of the Model 4210.

4-26. The accuracy of the calibration factor and effective efficiency can be improved if the complex reflection coefficients of the source and the power sensors are known. The values of indicated power for both the standard power meter and the Model 4210 to be calibrated are obtained with measurements described in paragraph 4-23.

4-27. Terms used in the following calculations are defined as follows:

$Z_o = R_o + j0$ ohms
ρ_g = complex reflection coefficient of source
ρ_s = complex reflection coefficient of standard sensor
ρ_ℓ = complex reflection coefficient of test sensor
P_s = indicated power on standard power meter
P_{ds} = power dissipated in standard sensor
P_d = power dissipated in test sensor
P_i = incident power (from Z_o source)
P_o = power dissipated in a sensor of Z_o ohms
P = indicated power on meter to be calibrated
e_s = instrument error factor of standard meter
e = instrument error factor of test meter
k_s = calibration factor of standard sensor
k = calibration factor of test sensor
η_s = effective efficiency of standard sensor
η = effective efficiency of test sensor

4-28. If we let m equal the ratio of power dissipated in a sensor of Z_o ohms to the power measured with a diode-type power sensor, when each is connected, in turn, to a source with a reflection coefficient ρ_g, it can be shown that:

$$m = P_o/P_m = \frac{(1 + \rho_g\rho_\ell^2 - \rho_g\rho_\ell - \rho_\ell)^2}{(1 - \rho_\ell)^2} \qquad (1)$$

By definition,

$$k = P/P_i = \frac{\text{indicated power}}{\text{incident power}} = \text{calibration factor}$$

This relationship is correct provided that measurements are made with a Z_o source. The power obtained by dividing the indicated power by the calibration factor, when the Model 4210 is connected to an imperfect source, should be referred to as measured power P_m, where:

$$P_m = P/k \qquad (2)$$

Also, by definition:

$$\eta = P/P_d = \frac{\text{indicated power}}{\text{dissipated power}} = \text{effective efficiency}$$

$$k/\eta = P_d/P_i = \frac{\text{dissipated power}}{\text{incident power}} = (1 - |\rho_\ell|^2)$$

P_o is designated as the power that would be dissipated in a sensor of Z_o ohms if it were connected to a power source having a reflection coefficient of ρ_g. This power is related to the actual power dissipated in the standard sensor by:

$$P_o = P_{ds}\frac{|1 - \rho_g\rho_s|^2}{(1 - |\rho_s|^2)} \qquad (3)$$

Rearranging equation (2) to solve for k, and substituting for P_m with (1), yields:

$$k = m\,(P/P_o) \qquad (4)$$

4-29. Typical Example.

a. Using source number 1 of Figure 4-4, the following measurements obtain for the two power sensors shown:

1. **Standard Power Sensor.**
   P_s = indicated power = 49 μW
   P_i = incident power = 50 μW
   P_{ds} = dissipated power = $P_i(1 - |\rho_s|^2)$
   = 50 μW X 0.99
   = 49.5 μW

From this,

k = 49 μW/50 μW = 0.98

and,

η = 49 μW/49.5 μW = 0.99

2. **Diode-Type Power Sensor.**
   P = indicated power = 48 W
   P_i = incident power = 50 W
   P_d = dissipated power = $P_i(1 - |\rho_\ell|^2)$
   = 50 μW X 0.974
   = 48.7 μW
   k = 48 μW/50 μW = 0.96
   η = 48 μW/48.7 μW = 0.986

b. Using source number 2 of Figure 4-4, the following measurements obtain for the two power sensors shown:

1. **Standard Power Sensor.**
   P_s = 55.9 μW
   $P_{ds} = P_s/\eta$
   = 55.9 μW/0.99
   = 56.5 μW
2. **Diode-Type Power Sensor.**
   P = 55.6 μW

c. Assuming for convenience that the instrument errors are zero, the calibration factor of the test instrument would be computed from paragraph 4-23 to be:

k = 0.98(55.6 μW/55.9 μW) = 0.975

This is 1.6% higher than the actual value of k. When the complex reflection coefficients are known, however, using equations (1), (3), and (4), we find:

$$m = [1 + (0.106\ \lfloor\underline{122^\circ})(0.16\ \lfloor\underline{-96^\circ})^2 - (0.106\ \lfloor\underline{122^\circ})(0.16\ \lfloor\underline{-96^\circ}) - (0.16\ \lfloor\underline{-96^\circ})]^2 \Big/ (1 - 0.16\ \lfloor\underline{-96^\circ})^2 \qquad (1)$$

$$m = 0.97$$

$$P_o = 56.5\ \mu W\ \frac{|1 - (0.106\ \lfloor\underline{122^\circ})(0.099\ \lfloor\underline{-78.6^\circ}\,|^2}{(1 - 0.099^2)} \qquad (3)$$

$$P_o = 56.5 \times 0.9946$$

$$P_o = 56.2\ \mu W$$

From this,

$$k = 0.97 \frac{55.6}{56.2} = 0.96 \qquad (4)$$

This is the correct calibration factor determined in step a.2 using an ideal 50-ohm source.

4-30. HIGH FREQUENCY ACCURACY.

4-31. General. Power measurements, particularly at high frequencies, are fraught with a number of uncertainties. These include: what power is measured, what power it is desired to measure, and how the indicated power is converted to the needed power. If all power sources and power meters had impedances that were resistive and equal to Z_O (the characteristic impedance of the measuring system), most problems would disappear. The incident, dissipated, and maximum available powers would all be equal, and the indicated power would differ only by the inefficiency of the power sensor in converting all of the dissipated power to indicated power. This inefficiency is called the effective efficiency and, for a power sensor whose input impedance is resistive and equal to Z_O, it also defines the calibration factor. Unfortunately, perfect impedances are seldom the case and the source impedance of power sources can depart substantially from Z_O. The use of attenuator pads can mask this departure, as can the use of a directional coupler to level the source and reduce its reflection coefficient to a value equal to the directivity factor of the coupler. No such control over the input impedance of a power sensor is possible without the use of attenuator pads which sacrifice sensitivity and introduce other uncertainties.

4-32. Mismatch Error Correction Using Complex Reflection Coefficients. When the complex reflection coefficients of both an imperfect source and the power detector are known, a correction factor can be calculated and applied to the measured power, P_m, to obtain the power that would be dissipated in an ideal power sensor of impedance Z_O. The correction factor, m, equals:

$$m = \frac{P_d}{P_m} = \frac{1 + \rho_g \rho_\ell^2 - \rho_g \rho_\ell - \rho_\ell}{1 - \rho_\ell^2} \qquad (1)$$

$$P_m = \frac{P_{ind}}{K} = \text{measured power}$$

where
P_d = dissipated power
P_{ind} = indicated power
K = calibration factor
ρ_g = complex reflection coefficient of the power source
ρ_ℓ = complex reflection coefficient of the power detector

The maximum power available from this source is:

$$P_a = \frac{P_d}{1 - |\rho_g|^2} \qquad (2)$$

4-33. Assume that the complex reflection coefficients are known to be $P_g = 0.0909 \angle 20°$ and $P_\ell = 0.111 \angle -35°$. The calibration factor for this power meter at the operating frequency is 1.138 (as determined from the incident power of a 50-ohm source). When the power meter and source are connected, the indicated power is 55.2 μW. Applying the calibration factor, $P_m = 55.2/1.138 = 48.5\ \mu W$. The correction factor calculated from equation (1) for the reflection coefficients given is 0.99; thus the power that would be dissipated in an ideal power meter would be 0.99 X 48.5 μW, or 48.0 μW. The maximum available power from this source, from equation (2), is $48.0/[1 - |0.0909|^2] = 48.4/\mu W$.

4-34. Mismatch Uncertainties Where Only SWR Is Known. When the complex coefficients of both an imperfect source and a power sensor are not known, and only the maximum or actual SWR of both are known, the maximum positive and negative uncertainties of the measured power, P_m, can be determined from Figure 4-5. In the example above, the SWR of the source is known to be 1.2 and the SWR of the power sensor is 1.25. From Figure 4-5, the power measured by an ideal power meter connected to the same source may differ by +2% from the power measured by the imperfect meter, from 47.5 μW to 49.5 μW. The maximum power available from this source is:

$$P_a = \frac{47.5}{0.99} = 47.9\ \mu W \text{ to } \frac{49.5}{0.99} = 49.9\ \mu W.$$

4-35. Where Neither Reflection Coefficients Nor SWR Are Known. When neither the complex reflection coefficients nor SWR of both an imperfect source and a power sensor are known, the measured power cannot be defined as anything except the indicated power. If, however, the power source impedance is Z_O, the calibration factor can be applied to yield the incident power. In the case of series 4210 power sensors, the calibration factor versus input frequency in GHz is shown on a decal on the power sensor.

4-36. POWER SENSOR REPAIR

4-37. Repair and adjustment of a Power Sensor is a difficult operation requiring a high degree of skill. If the user elects to make such a repair, it must be understood that the repaired Sensor may not meet the swr and response characteristics as specified in this manual.

4-38. Before attempting a repair of the Power Sensor check all possible sources of trouble, such as the instrument itself, the probe cable, connectors, the RF power source, etc. If the defect cannot be located, and the symptoms

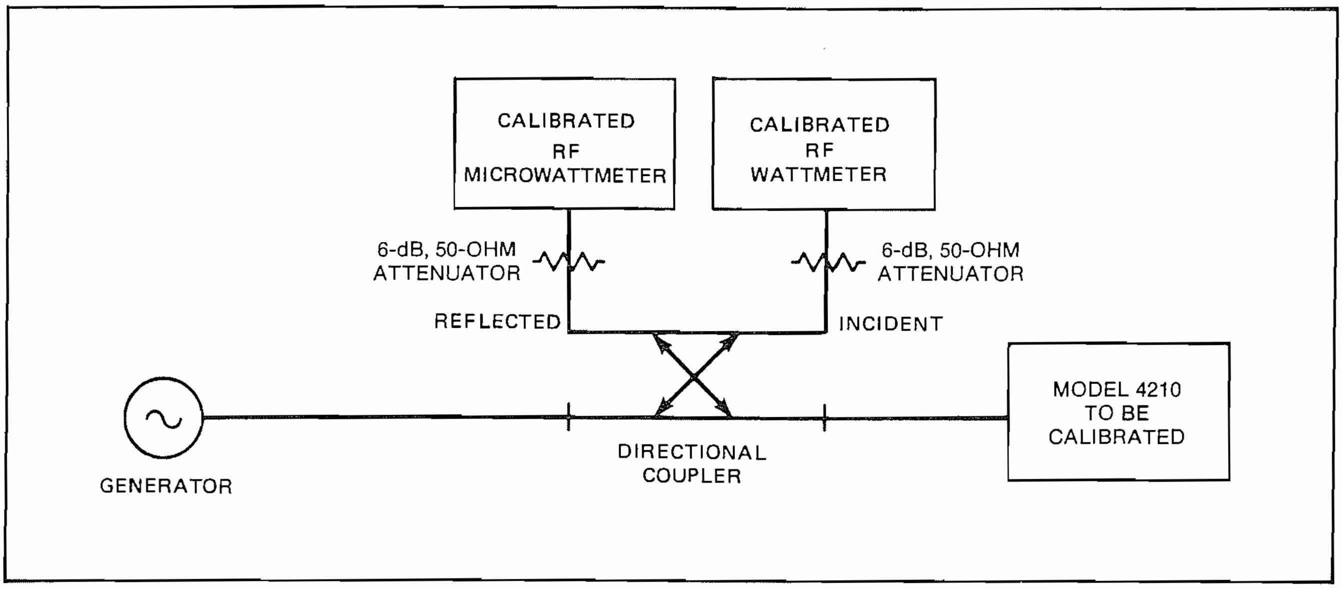


Figure 4-3. Effective Efficiency Measurement, Test Setup

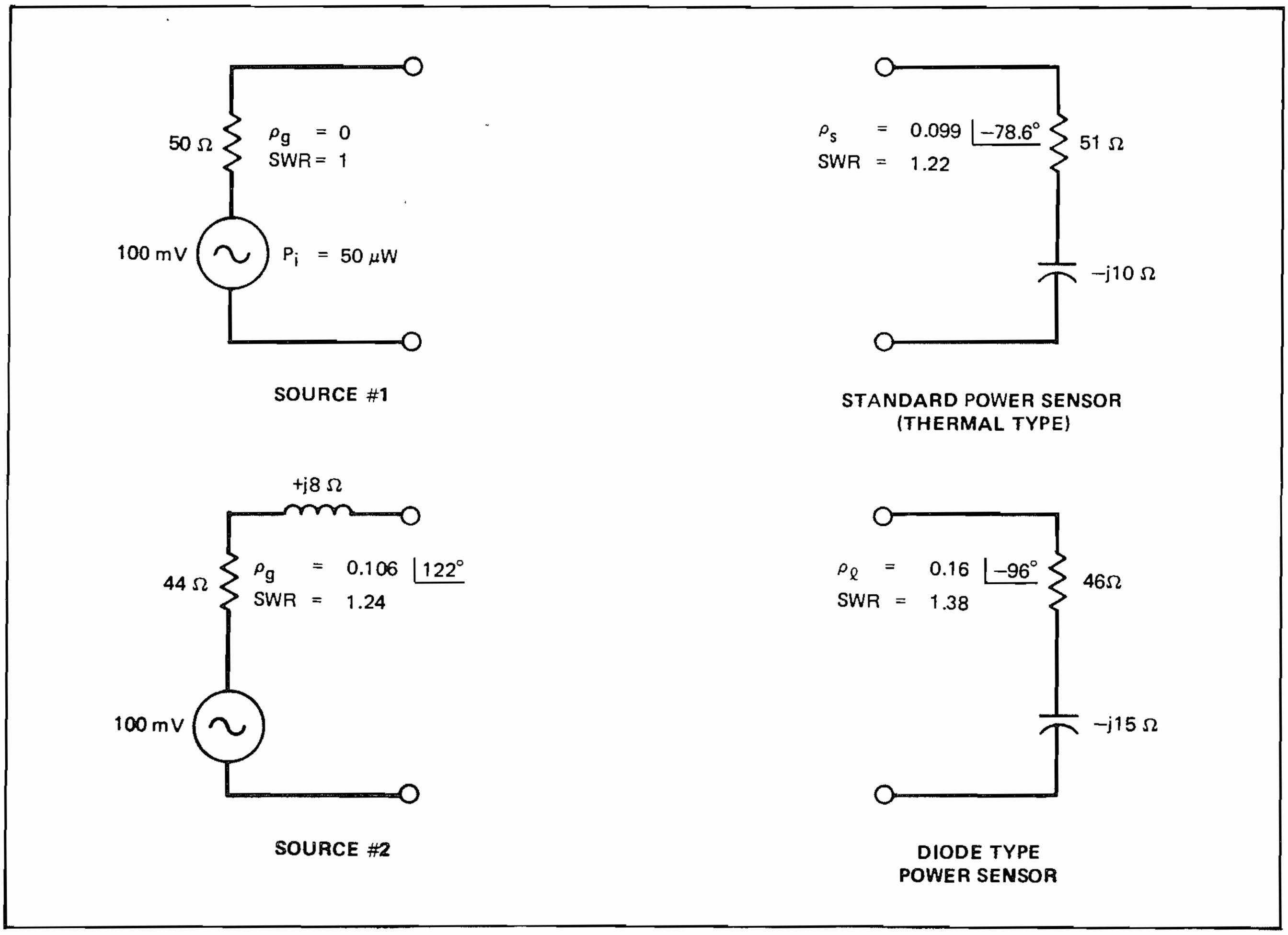


Figure 4-4. Source and Sensor Examples for Calibration Factor Measurements

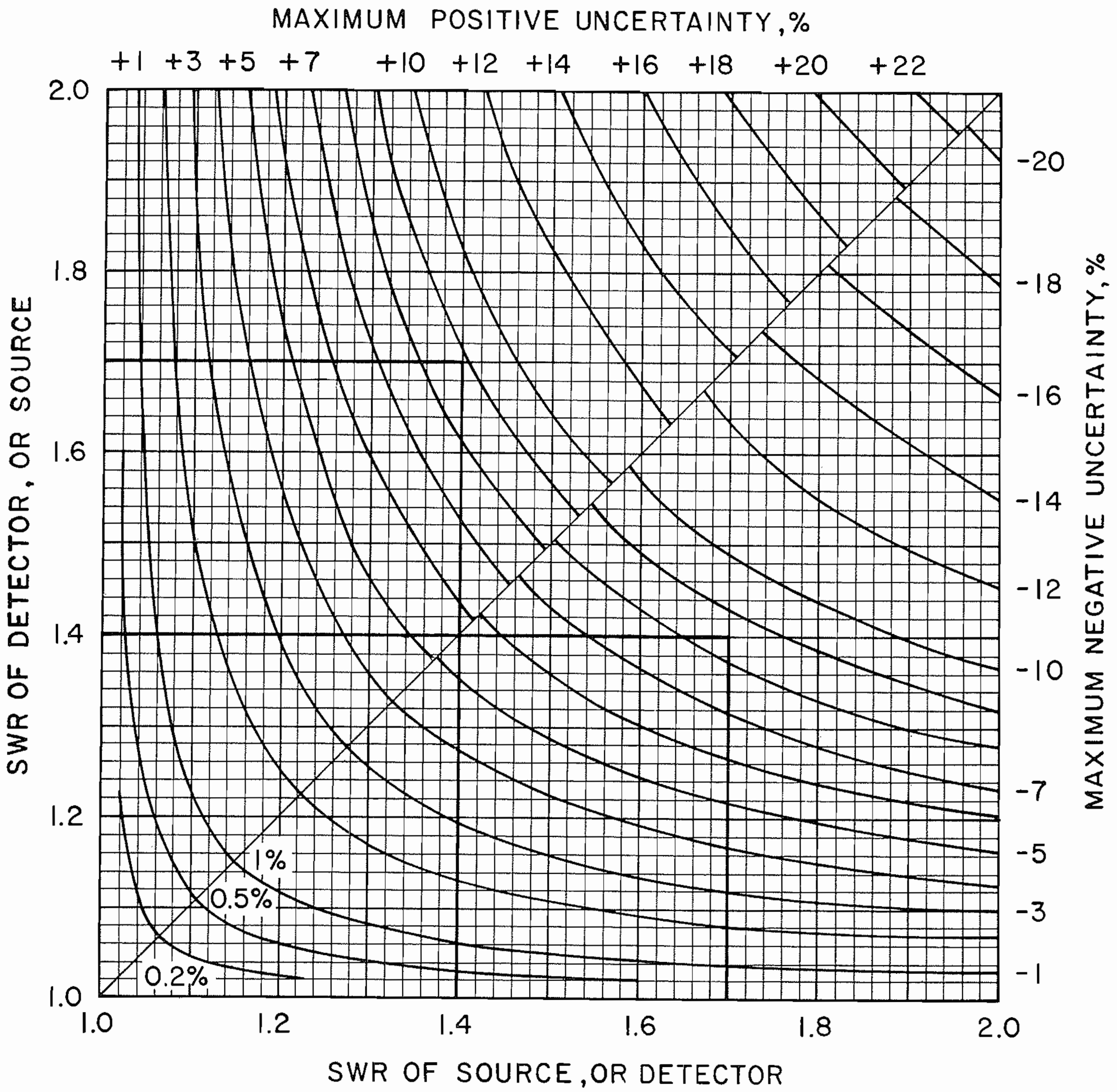


Figure 4-5. Mismatch Uncertainties Chart

indicate a faulty Power Sensor, make the external resistance measurements outlined below to localize the trouble before opening the Sensor housing. (A Simpson Model 260 is recommended for most of these measurements.)

a. Measure the resistance of the RF input connector from the center conductor to ground shell. This should be 50, ±1 Ω. (For this measurement, a more accurate instrument than the Model 260 should be used.)

b. Inspect the rear connector for possible damage. Measure the resistance from pins 1 and 2 to ground. This should measure >10 MΩ.

c. With the Model 260 on the 10 kΩ range, measure the resistance from pin 1 (negative lead of the 260) to pin 2 (positive lead). This should be less than 3 kΩ.

d. With the Model 260 on the 10 kΩ range, measure the resistance from pin 1 (positive lead of the 260) to pin 2 (negative lead). This should be greater than 400 kΩ.

e. Remove the three 2-56 screws holding the outer shield. Slide the shield forward over the RF input connector.

f. Look for broken wires at this point. If any are found, repair them and retest the unit before proceeding.

g. The rear connector may be replaced, if necessary, by removing the set-screw at the side of the rear disc (the red mark on the side of the housing polarizes pin 1).

h. Remove the four 2-56 screws holding the inner shield. Slide the shield backwards from the main housing. Unsolder the wires at the Teflon™ terminals, if necessary.

If the Power Sensor failed the insulation test in (b), look for a short to ground from the 1000 pF capacitors C102 and C103, or an internal short in one of the capacitors. These capacitors may be removed by taking out the two 0-80 screws on the side of the bracket. Tilt the housing to the side so the bracket will fall away when a soldering iron is touched to the joint. The capacitor may then easily be replaced remote from the housing. Screw the bracket to the housing before soldering.

CAUTION:

Always ground the soldering iron tip when soldering the probe housing to avoid damaging the diodes.

If the Power Sensor failed the tests of (c) or (d), measure the resistance of the diodes CR101 and CR102 with the Model 260 on the 10 kΩ range. The forward resistance of each diode should measure about 500 ohms, and the backward resistance should be greater than 50 kΩ. If the back resistance of a diode measures appreciably less than 50 kΩ, replace it, using the following technique:

NOTE

Before attempting to replace the diode network in either the -4E or the -5E, C102 and C103 must be removed as described above.

i. While grasping the diode with tweezers, and applying a light upward pull, touch the center post with a small, high-temperature iron. The diode will lift when the solder melts. Now unsolder the far end of the series resistor and lift out the diode-resistor combination (-4A, -4B, -5B, and -4C only).

j. At this point, test the terminating resistors as in (a). If R101 or R102 tests faulty, replace it as follows:

Remove the four 2-56 screws that hold the 100 Ω resistors in place. Unsolder from the center post by pulling the resistor from the rear while heating the center post. (Overheating can cause distortion of the Teflon™ spacer supporting the center conductor.) Replace the new resistor in the reverse order.

k. Replace the diode/resistor networks by soldering the resistor ends first, and then touching the center post as quickly as possible with the iron to solder the diode lead.

4-39. After any critical parts (diodes or terminating resistors) have been replaced, it will be necessary to check the input swr and calibration factor over the frequency range. A swept reflectometer system is recommended for these tests because of the interaction of the adjustments.

CLAMPS: Located on top of the housing and used to vary lead lengths of R101 and R102. Adjust for minimum swr and optimum flatness across the band.

ANGLE: The diodes are normally mounted parallel to the bottom of the channels on top of the housing. Lowering the diodes will improve swr between 8 - 12 GHz.

TAPE: A small strip of copper tape on the diode body will improve rectification efficiency at 18 GHz. Secure with Q MAX or other varnish with a low dielectric constant.

4-40. Calibrate calibration factor using good microwave techniques such as those found in Paragraph 4-21 of the instruction manual.

4-41. After repair, if proper adjustment of the Power Sensor is found difficult, return it to the factory. In a covering letter, be sure to include details of all work performed on the Sensor and parts replaced. This information will help our Service Department to return the Sensor to you in the shortest possible time.

SECTION V
PARTS LIST

5-1. Introduction.
Table 5-2. Replaceable Parts, list all the replaceable parts and includes; the reference symbol, description, Mfr., Mfr's Part No., and the BEC Part No. Table 5-1. Manufacturer's Federal Supply Code Numbers, list the manufacturer's federal supply numbers.

TABLE 5-1. Manufacturer's Federal Supply Code Numbers.

NUMBER	NAME	NUMBER	NAME
01121	Allen Bradley	31313	Components Corp.
01139	General Electric	31918	ITT Schadow, Inc.
01295	Texas Instruments	32293	Intersil, Inc.
02735	RCA Solid State Division	32575	AMP
04222	AVX Ceramics Company	34335	Advanced Micro Devices
04713	Motorola Semiconductor	34649	Intel Corp.
04901	Boonton Electronics	51640	Analog Devices, Inc.
06383	Panduit Corp.	54426	Buss Fuses
06776	Robinson Nugent, Inc.	56289	Sprague Electric Company
07263	Fairchild Semiconductor	56708	Zilog, Inc.
13812	Dialco Div. of Amperex	57582	Kahgan Electronics Corp. iv.
16482	Belden	73138	Beckman Instr., Helipot D
17801	Panel Corp. (Schurter)	91506	Augat
19701	Mepco Electra	95402	Electro Dynamics
20307	Arco – Micronics	98291	Sealectro Corp.
27264	Molex, Inc.	99942	Centralab
27735	F-Dyne Electronics	S4217	United Chemicon, Inc.
28480	Hewlett-Packard Corp.		

5-2. Replacement Parts

Replaceable Parts List for PWA Main Final — PL 042242-00C

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
C1	Capacitor EL 2200 µF -10%/+50% 35V	57582	KSMM-2200-35	283351-000
C2	Capacitor EL 2200 µF -10%/+50% 35V	57582	KSMM-2200-35	283351-000
C3	Capacitor EL 4700 µF -10%/+50% 16V	57582	KSMM-4700-16	283352-000
C4	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C5	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C6	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C10	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C11	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C16	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C17	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C18	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C19	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C20	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C21	Capacitor PE 0.1 µF 10% 200V	56289	192P10492	234005-000
C22	Capacitor EL 100 µF 20% 25V	S4217	SM-25-VB-100-M	283334-000
C23	Capacitor PE 0.1 µF 10% 200V	56289	192P10492	234005-000
C24	Capacitor PP 0.1 µF 10% 100V	27735	PP11-.1-100-10	234148-000
C25	Capacitor MPC .15 µF 10% 100V	19701	719B1CA154PK101SA	234163-000
C26	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C27	Capacitor Cer 0.01 µF 10% 100V	04222	SR201C103KAA	224269-000
C28	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C29	Capacitor MPC .33 µF 10% 100V	19701	719B1GD334PK101SB	234162-000
C31	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
C32	Capacitor Mica 50pF 5% 500V	20307	DM15-500J	200058-000
C33	Capacitor Mica 50pF 5% 500V	20307	DM15-500J	200058-000
CR1	Diode Bridge KBP-02	20307	KBP-02	532013-000
CR3	Diode Bridge KBP-02	20307	KBP-02	532013-000
CR4	Diode 1N4001	04713	1N4001	530151-000
CR5	Diode 1N4001	04713	1N4001	530151-000
CR6	Diode 1N4001	04713	1N4001	530151-000
CR7	Diode 1N914	01295	1N914	530058-000
J2	Socket Pin Spring	32575	1-332070-7	479333-000
J1(5)	Header 5 Circuit	06383	HPSS-156-5-C	477345-000
J4(8)	Connector 22 Circuit	27264	22-02-2225	479428-000
Q1	Transistor PNP 2N3906	04713	2N3906	528076-000

5-2. Replacement Parts (Continued)

Replaceable Parts List for PWA Main Final PL 042242-00C

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
R1	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R2	Resistor MF 4.99k ohm 1%	---	RN55D-4991-F	341367-000
R3	Resistor MF 2.21k ohm 1%	---	RN55D-2211-F	341333-000
R4	Resistor MF 12.7k ohm 1%	---	RN55D-1272-F	341410-000
R11	Resistor Comp 12M ohm 5%	01121	CB	343708-000
R12	Resistor Comp 12M ohm 5%	01121	CB	343708-000
R13	Resistor MF 100k ohm 1%	---	RN55D-1003-F	341500-000
R14	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R15	Resistor MF 1.00k ohm 1%	---	RN55D-1001-F	341300-000
R16	Resistor MF 221 ohm 1%	---	RN55D-2210-F	341233-000
R17	Resistor MF 1.00k ohm 1%	---	RN55D-1001-F	341300-000
R18	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R19	Resistor MF 100k ohm 1%	---	RN55D-1003-F	341500-000
R20	Resistor MF 8.25k ohm 1%	---	RN55D-8251-F	341388-000
R21	Resistor MF 1.82k ohm 1%	---	RN55D-1821-F	341325-000
R22	Resistor MF 8.25k ohm 1%	---	RN55D-8251-F	341388-000
R23	Resistor MF 1.82k ohm 1%	---	RN55D-1821-F	341325-000
R24	Resistor Comp 1.0M ohm 5%	01121	CB	343600-000
R25	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R27	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R28	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R29	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R30	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R34	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R35	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R36	Resistor Var 25k ohm 10% 0.5W	73138	72PR25K	311400-000
R37	Resistor MF 51.1k ohm 1%	---	RN55D-5112-F	341468-000
R38	Resistor MF 2.26k ohm 1%	---	RN55D-2261-F	341334-000
R39	Resistor MF 14.0k ohm 1%	---	RN55D-1402-F	341414-000
R40	Resistor MF 590 ohm 1%	---	RN55D-5900-F	341274-000
R41	Resistor MF 4.12k ohm 1%	---	RN55D-4121-F	341359-000
R42	Resistor MF 127 ohm 1%	---	RN55D-1270-F	341210-000
R43	Resistor MF 976 ohm 1%	---	RN55D-9760-F	341295-000
R44	Resistor MF 47.5 ohm 1%	---	RN55D-47R5-F	341165-000
R45	Resistor MF 78.7k ohm 1%	---	RN55D-7872-F	341486-000
R46	Resistor MF 165 ohm 1%	---	RN55D-1650-F	341221-000
R47	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R48	Resistor Comp 5.6k ohm 5%	01121	CB	343372-000
R49	Resistor Comp 3.3k ohm 5%	01121	CB	343350-000
R50	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R51	Resistor Comp 100 ohm 5%	01121	CB	343200-000
R52	Resistor Comp 1.0M ohm 5%	01121	CB	343600-000
R53	Resistor MF 1.65k ohm 1%	---	RN55D-1651-F	341321-000
R54	Resistor Comp 200k ohm 5%	01121	CB	343529-000
R55	Resistor Var 2k ohm 10% 0.5W	73138	72PR2K	311343-000
R56	Resistor MF 7.50k ohm 1%	---	RN55D-7501-F	341384-000
R57	Resistor MF 681 ohm 1%	---	RN55D-6810-F	341280-000
R59	Resistor Comp 4.7k ohm 5%	01121	CB	343365-000
R60	Resistor MF 100k ohm 1%	---	RN55D-1003-F	341500-000
TP1	Terminal (Test Point)	31313	TP-101-10	483258-000
TP2	Terminal (Test Point)	31313	TP-101-10	483258-000
TP3	Terminal (Test Point)	31313	TP-101-10	483258-000
TP6	Terminal (Test Point)	31313	TP-101-10	483258-000
TP7	Terminal (Test Point)	31313	TP-101-10	483258-000
TP8	Terminal (Test Point)	31313	TP-101-10	483258-000
TP9	Terminal (Test Point)	31313	TP-101-10	483258-000
TP25	Terminal (Test Point)	31313	TP-101-10	483258-000
TP26	Terminal (Test Point)	31313	TP-101-10	483258-000
TP27	Terminal (Test Point)	31313	TP-101-10	483258-000
TP28	Terminal (Test Point)	31313	TP-101-10	483258-000
TP29	Terminal (Test Point)	31313	TP-101-10	483258-000
TP30	Terminal (Test Point)	31313	TP-101-10	483258-000
TP31	Terminal (Test Point)	31313	TP-101-10	483258-000
TPI	Terminal (Test Point)	31313	TP-101-10	483258-000
TPN	Terminal (Test Point)	31313	TP-101-10	483258-000
U6	IC 78L05AWC Regulator	07263	78L05AWC	535044-000
U7	IC 79L05ACP Regulator	04713	MC79L05ACP	535090-000
U8	IC LF356 Op Amp IT/F 535052000	04901	BEC	535062-000
U9	IC IH6208CPE	32293	IH6208CPE	534266-000
U10	IC LF356 Op Amp IT/F 535052000	04901	BEC	535062-000
U11	IC CD4001AE	02735	CD4001AE	534023-000
U12	IC LF356P Op Amp	01295	LF356P/883B-00	535040-000
U13	IC LF356P Op Amp	01295	LF356P/883B-00	535040-000
U14	IC IH6108CPE	32293	IH6108CPE	534265-000
U15	IC CD4066AE	02735	CD4066AE	534078-000
U16	IC CD4081BE	02735	CD4081BE	534142-000
U17	IC CD4013BE (only)	02735	CD4013BE	534205-000
U18	IC CD4013BE (only)	02735	CD4013BE	534205-000
U19	IC LF356P Op Amp	01295	LF356P/883B-00	535040-000

5-2. Replacement Parts (Continued)

Replaceable Parts List for PWA Main Final — PL 042242-00C

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
U20	IC 74LS163AN Sync Preset Binary Counter	01295	SN74LS163AN	534279-000
U21	IC ICL7901CPL A/D Converter	32293	IC7109CPL	535089-000
U22	IC SN74LS90N	01295	SN74LS90	534233-000
U23	IC 74LS163AN Sync Preset Binary Counter	01295	SN74LS163AN	534279-000
U24	IC 74LS32N Quad 2 Input OR	01295	SN74LS32N	534168-000
U25	IC 74LS04N Hex Inverter	01295	SN74LS04N	534155-000
U26	IC SN74LS74N	01295	SN74LS74N	534157-000
U27	IC 74LS02N Quad 2 Input NOR	01295	SN74LS02N	534154-000
U28	IC Z80-CPU-PS	56708	Z80-CPU-PS	534159-000
U29	IC 2732 Eprom M/F 534268 'A' SHAPING	04901	BEC	534276-000
U30	IC P2111A-4	34649	P2111A-4	534162-000
U31	IC Am8255APC Interface	34335	AM 8255 APC	534171-000
U32	IC P2111A-4	34649	P2111A-4	534162-000
U33	IC AD558JD D/A Converter	51640	AD558JD	534267-000
XU1	Socket IC 15 Pin M/F 473048	04901	BEC	473067-00B
XU2	Socket IC 15 Pin M/F 473048	04901	BEC	473067-00B
XU3	Socket IC 15 Pin M/F 473048	04901	BEC	473067-00B
XU8	Socket IC 8 Pin	06776	ICN-083-S3-G	473041-000
XU9	Socket IC 16 Pin	06776	ICN-163-S3-G	473042-000
XU10	Socket IC 8 Pin	06776	ICN-083-S3-G	473041-000
XU11	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XU14	Socket IC 16 Pin	06776	ICN-163-S3-G	473042-000
XU15	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XU16	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XU17	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XU18	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XU21	Socket IC 40 Pin	06776	ICN-406-S4-G	473052-000
XU28	Socket IC 40 Pin	06776	ICN-406-S4-G	473052-000
XU29	Socket IC 24 Pin	06776	ICN-246-S4-G	473043-000
XU30	Socket IC 18 Pin	06776	ICN-183-S3-G	473045-000
XU31	Socket IC 40 Pin	06776	ICN-406-S4-G	473052-000
XU32	Socket IC 18 Pin	06776	ICN-183-S3-G	473045-000
XU33	Socket IC 16 Pin	06776	ICN-163-S3-G	473042-000
Y1	Crystal 3.579545 MHz	95402	Holder HC-18/U Tol. ±0.003%	547035-000

Replaceable Parts List for Rear Panel Assembly for 4210 — PL 042246-00A

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
F1	Fuse 0.3 A	54426	MDL 0.3	545507-000
FH1	Fuse Carrier (Gray)	17801	FEX 031.1666s	482114-000
P3	Connector 5 Circuit	06383	CE156F24-5-C	479394-000
T1	Transformer Power	04901	BEC	446093-00A

Replaceable Parts List for Chopper Assembly — PL 042161-00G

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
C1	Capacitor PP 0.1 µF 10% 100V	27735	PP11-.1-100-10	234148-000
C2	Capacitor PP 0.1 µF 10% 100V	27735	PP11-.1-100-10	234148-000
IC1	IC CD4016BE (only) IT/F 534354 PED4200-3	04901	BEC	534223-000
P1	Terminal	98291	229-1071-23	510038-000
R3	Resistor MF 51.1k ohm 1%	---	RN55D-5112-F	341468-000
R4	Resistor Var 20k ohm 10% 0.5W	73138	72PR20K	311354-000
R5	Resistor Var 20k ohm 10% 0.5W	73138	72PR20K	311354-000
R6	Resistor MF 51.1k ohm 1%	---	RN55D-5112-F	341468-000
XIC1	Socket IC 14 Pin	91506	508-AG7D	473056-000

Replaceable Parts List for Front Panel Assembly for 4210 — PL 042243-00A

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
R3	Resistor Var 5k ohm 10% 1W	99942	BA-0251-0001	311407-000

Replaceable Parts List for Switch/Cable Unit — PL 465290-00A

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
P2	Connector Housing 4 Pin Male	27264	03-06-2043 Model 2004	477306-000
S2	Switch Power	13812	572-2121-0103-010	465286-000

5-2. Replacement Parts (Continued)

Replaceable Parts List for PWA Display Final — PL 042244-00C

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
C1	Capacitor Cer 150 pF 10% 1 kV	99942	CE-151	224314-000
C2	Capacitor Cer 150 pF 10% 1 kV	99942	CE-151	224314-000
C3	Capacitor EL 10 µF 20% 25V	S4217	SM-25-VB-10-M	283336-000
CR1	Diode 1N914	01295	1N914	530058-000
CR3	Diode 1N914	01295	1N914	530058-000
CR4	Diode 1N914	01295	1N914	530058-000
CR5	Diode 1N914	01295	1N914	530058-000
CR6	Diode 1N914	01295	1N914	530058-000
CR7	Diode 1N914	01295	1N914	530058-000
CR8	LED 5082-4650 Red Diffused	28480	HP5082-4650	536014-000
CR9	LED 5082-4684 Red Diffused	28480	HLMP-1301 (5082-4684)	536024-000
CR10	LED 5082-4684 Red Diffused	28480	HLMP-1301 (5082-4684)	536024-000
CR11	LED 5082-4684 Red Diffused	28480	HLMP-1301 (5082-4684)	536024-000
CR12	LED 5082-4684 Red Diffused	28480	HLMP-1301 (5082-4684)	536024-000
CR13	LED 5082-4684 Red Diffused	28480	HLMP-1301 (5082-4684)	536024-000
CR14	LED 5082-4684 Red Diffused	28480	HLMP-1301 (5082-4684)	536024-000
DS1	Display Numeric 5082-7651 (C or D Only)	28480	5082-7651	536811-000
DS2	Display Numeric 5082-7651 (C or D Only)	28480	5082-7651	536811-000
DS3	Display Numeric 5082-7651 (C or D Only)	28480	5082-7651	536811-000
DS4	Display Numeric 5082-7651 (C or D Only)	28480	5082-7651	536811-000
M1	Meter Marked	04901	BEC	554335-000
M1	Meter Marked	04901	BEC	554335-00A
P4(8)	Connector 22 Circuit	27264	22-05-2221	477372-000
Q3	Transistor PNP D39C2	01139	D39C2	528048-000
Q4	Transistor PNP D39C2	01139	D39C2	528048-000
Q5	Transistor PNP D39C2	01139	D39C2	528048-000
Q6	Transistor PNP D39C2	01139	D39C2	528048-000
Q7	Transistor PNP D39C2	01139	D39C2	528048-000
R1	Resistor MF 1.50k ohm 1%	---	RN55D-1501-F	341317-000
R2	Resistor Var 2K ohm 10% 0.5W	73138	72XWR2K	311347-000
R4	Resistor Comp 7.5k ohm 5%	01121	CB	343384-000
R5	Resistor Var 2K ohm 10% 0.5W	73138	72XWR2K	311347-000
R7	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R10	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R11	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R12	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R13	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
R14	Resistor Comp 330 ohm 5%	01121	CB	343250-000
R15	Resistor Network 51 ohms 2%	73138	898-3-R51	345036-000
R16	Resistor MF 10.0k ohm 1%	---	RN55D-1002-F	341400-000
S1	Switch Pushbutton	31918	220075 Type D7	465287-000
S2	Switch Pushbutton	31918	220075 Type D7	465287-000
S3	Switch Pushbutton	31918	220075 Type D7	465287-000
S4	Switch Pushbutton	31918	220075 Type D7	465287-000
S5	Switch Pushbutton	31918	220075 Type D7	465287-000
U1	IC CA3140AE Op Amp	02735	CA3140AE	535050-000
U2	IC 7438N Quad 2 Input Nand Buffer	01295	SN7438N	534108-000
U3	IC 7438N Quad 2 Input Nand Buffer	01295	SN7438N	534108-000
XDS1	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XDS2	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XDS3	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000
XDS4	Socket IC 14 Pin	06776	ICN-143-S3-G	473019-000

Replaceable Parts List for Heatsink Assembly for 4210 — PL 042247-00A

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
U1	IC 78MGU1C Regulator	07263	78MGU1C	535042-000
U2	IC 79MGU1C Regulator	07263	µ79MGU1C	535097-00A
U3	IC µA7805UC Regulator & Hardware	07263	µA7805UC	535011-00A

Replaceable Parts List for Button Up Assembly 4210 — PL 940017-00A

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
LC1	Line Cord	16482	CH9461	568106-000

Replaceable Parts List for Fuse Kit for 220V at 0.2A — PL 960003-01A

Reference Symbol	Description	Mfr.	Mfr's Part No.	BEC Part No.
F1	Fuse 0.2 A	54426	MDL 0.2	545508-000
FH1	Fuse Carrier (Black)(Foreign only)	17801	FEK 031.1663s	482115-000

SECTION VI
SCHEMATIC DIAGRAMS

NOTE

Internal drawing number 831170, Sheet 1 of 3 is referenced on various schematic diagrams in this section. This number corresponds to Figure 6-1.

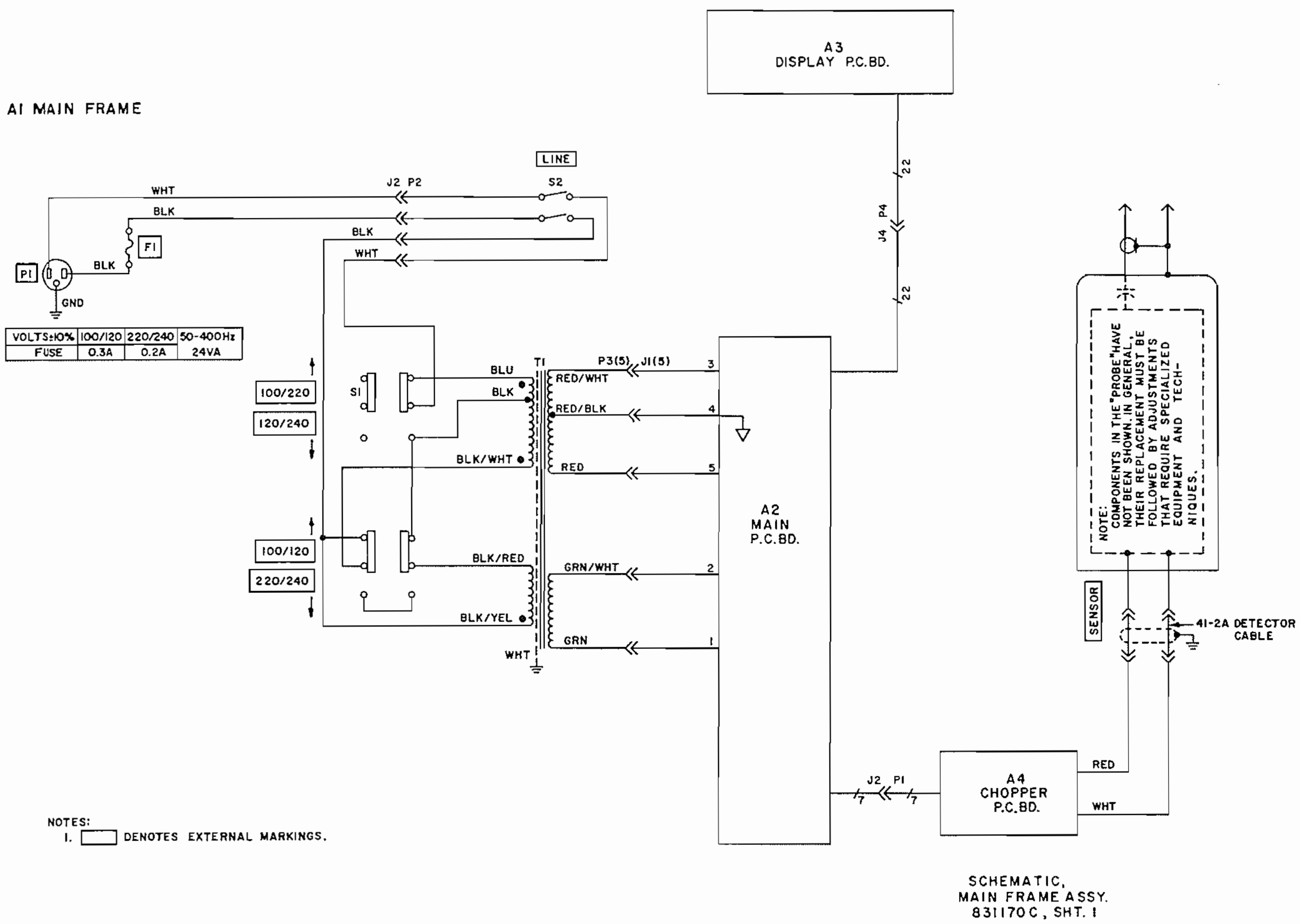
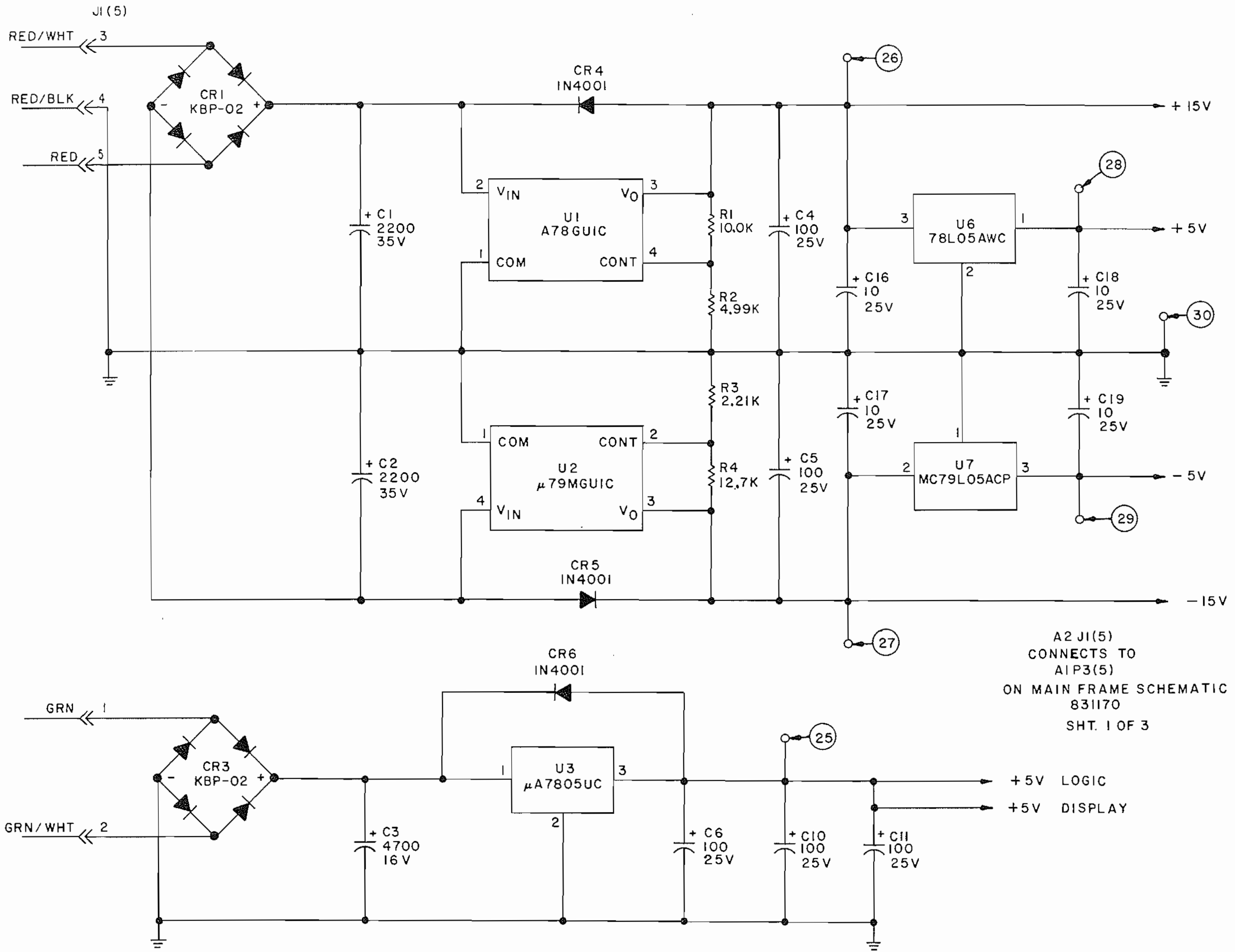


Figure 6-1 Main Frame A1, Schematic Diagram

A2 MAIN P.C. BD.



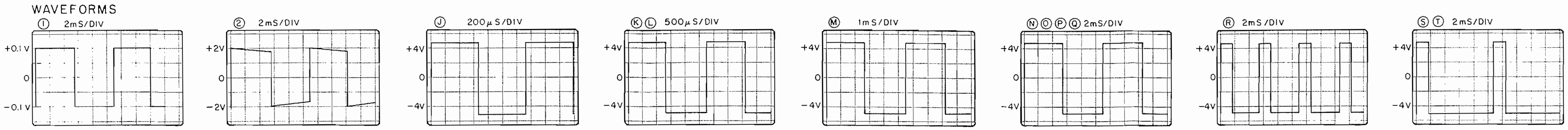
NOTES:

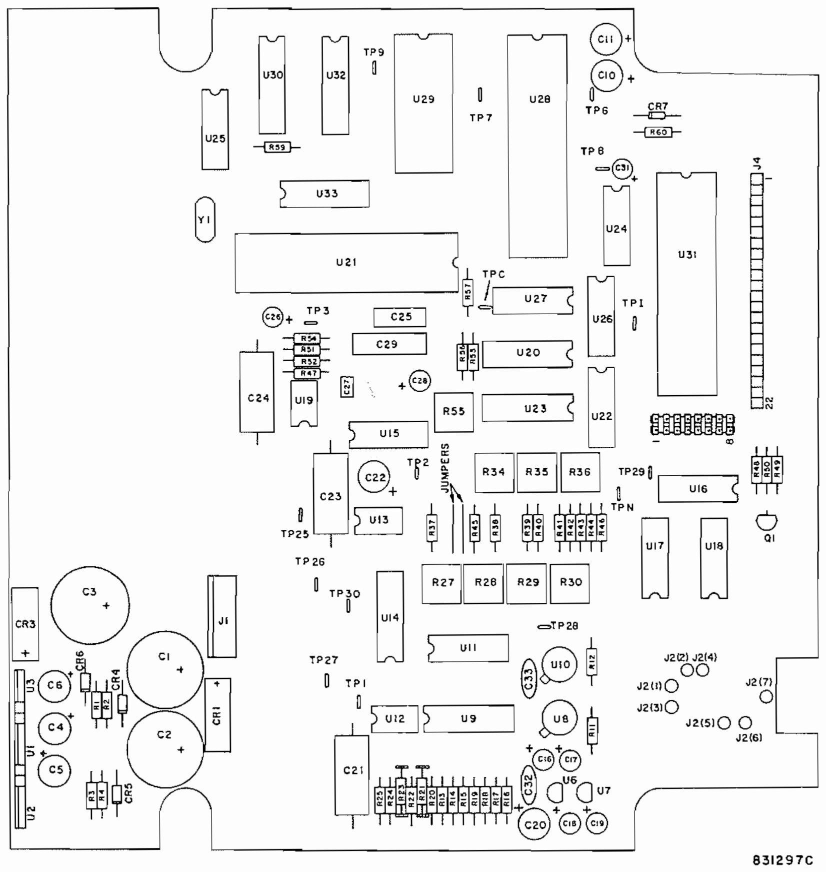
1. CAPACITANCE VALUES IN μF UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS.
3. [dashed box] USED FOR 4210-7E SENSORS.
4. ADDRESS & DATA LINES NOT IN SEQUENCE.
5. LAST NUMBERS USED:
   R60, C33, CR7, U33
6. NUMBERS NOT USED:
   R5,6,7,8,9,10,26,31,32,33,58 CR2
   C7,8,9,12,13,14,15,30 J3
7. ⊛ SELECTED VALUES.
8. TEST CONDITIONS:
   a. 1 mW 0 dBm 4200-4 SERIES.
   b. 10 mW+ 10 dBm 4200-5 SERIES.
9. [dotted box] USED FOR 4210-8E SENSORS.

SCHEMATIC,
MAIN P.C. BD. (POWER SUPPLY SECT.)
D83117CG, SHT. 2a of 3

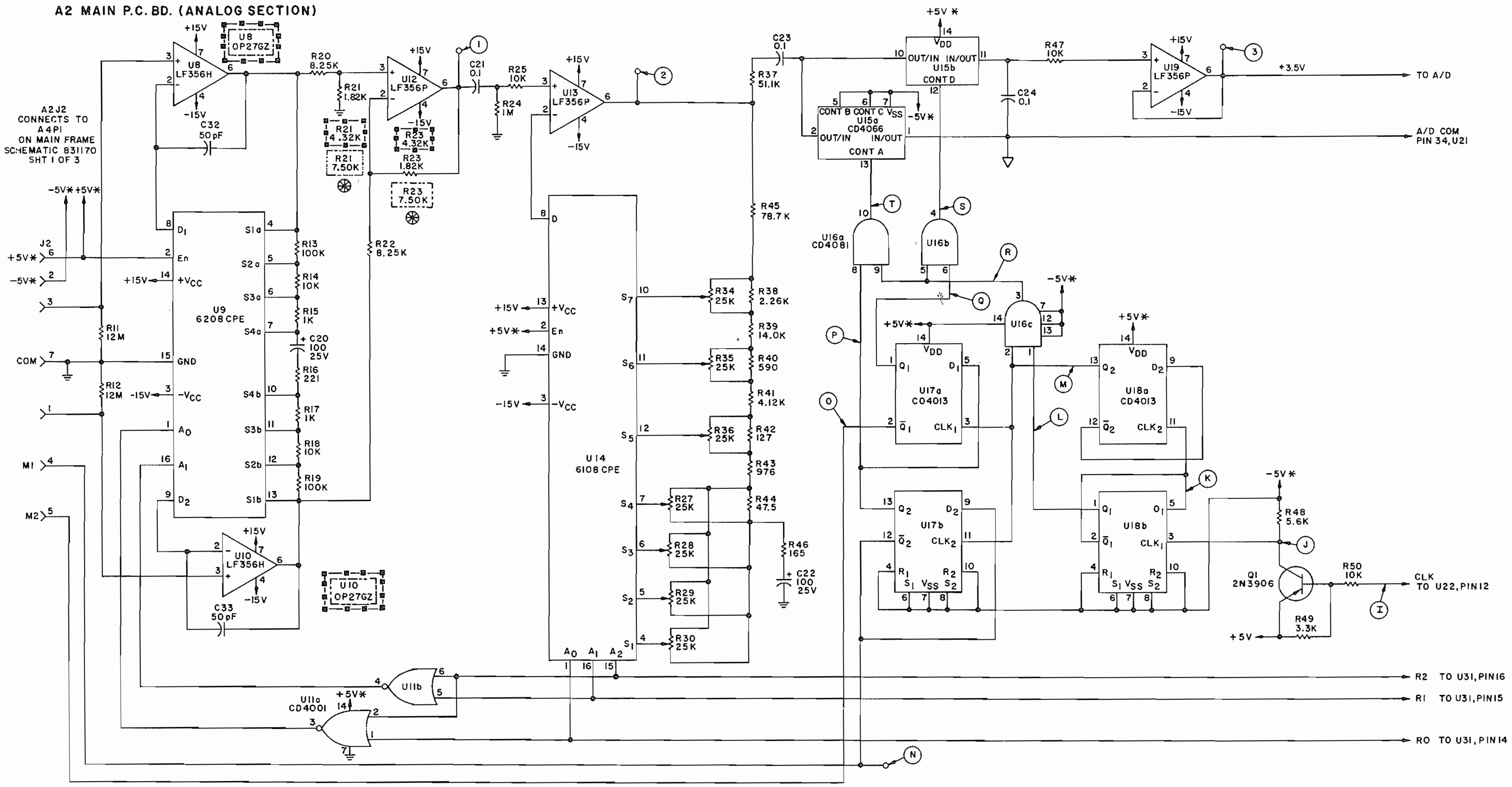
Figure 6-2 Power Supply A2, Schematic Diagram

WAVEFORMS





A2 MAIN P.C. BD. (ANALOG SECTION)



SCHEMATIC, MAIN P.C. BD. (ANALOG SECTION)
E831170F, SHT. 2b OF 3

Figure 6-3 Analog Section A2, Schematic Diagram

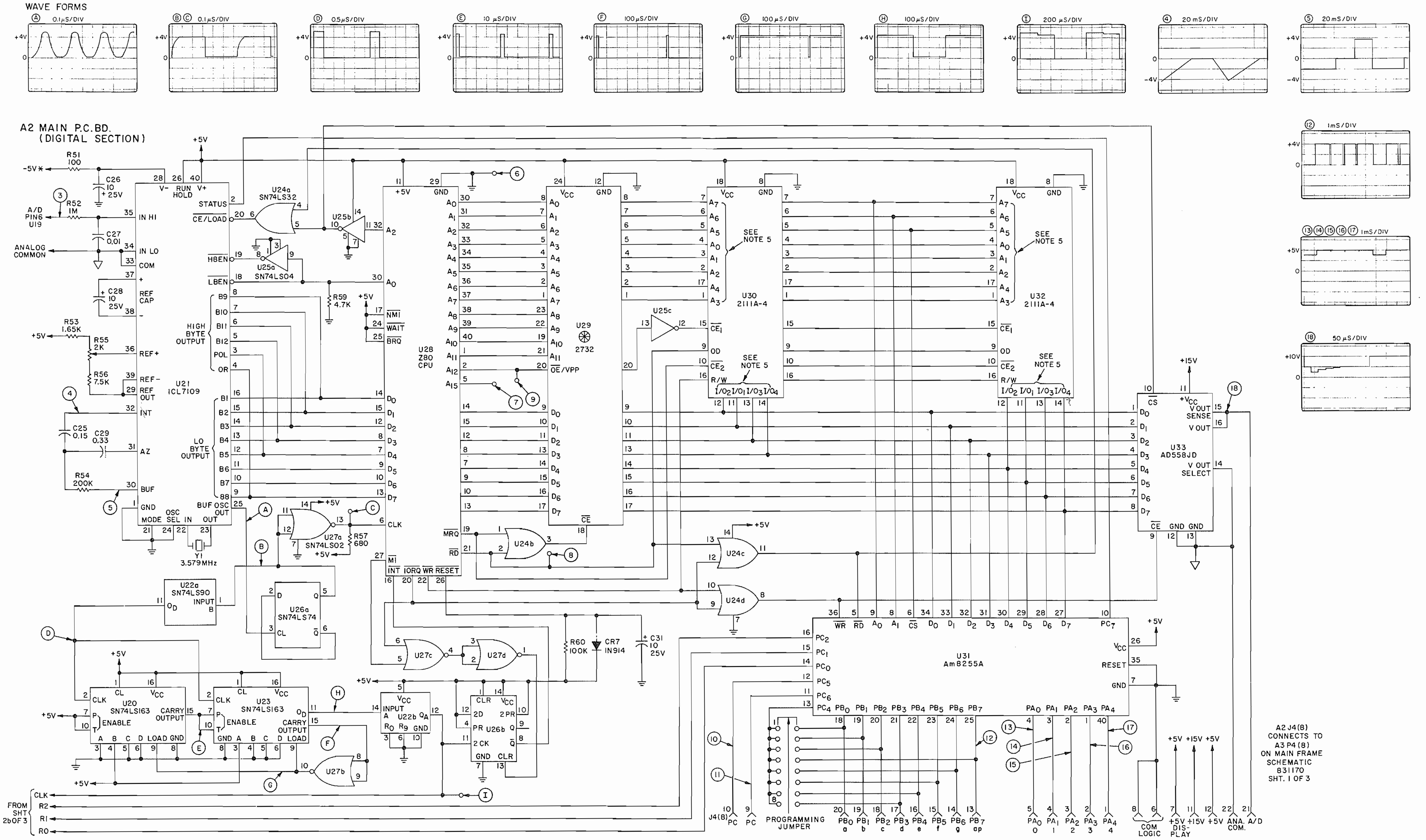
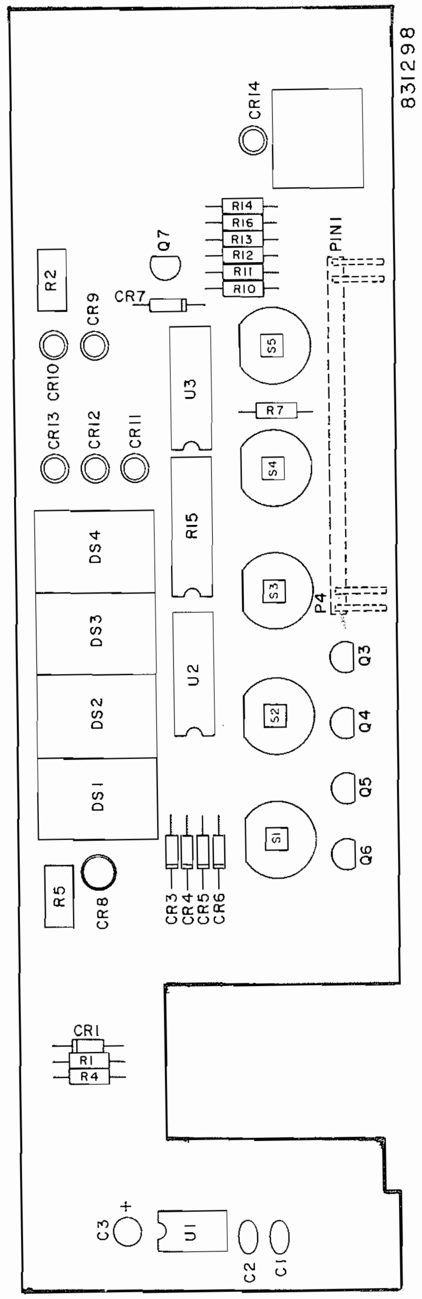
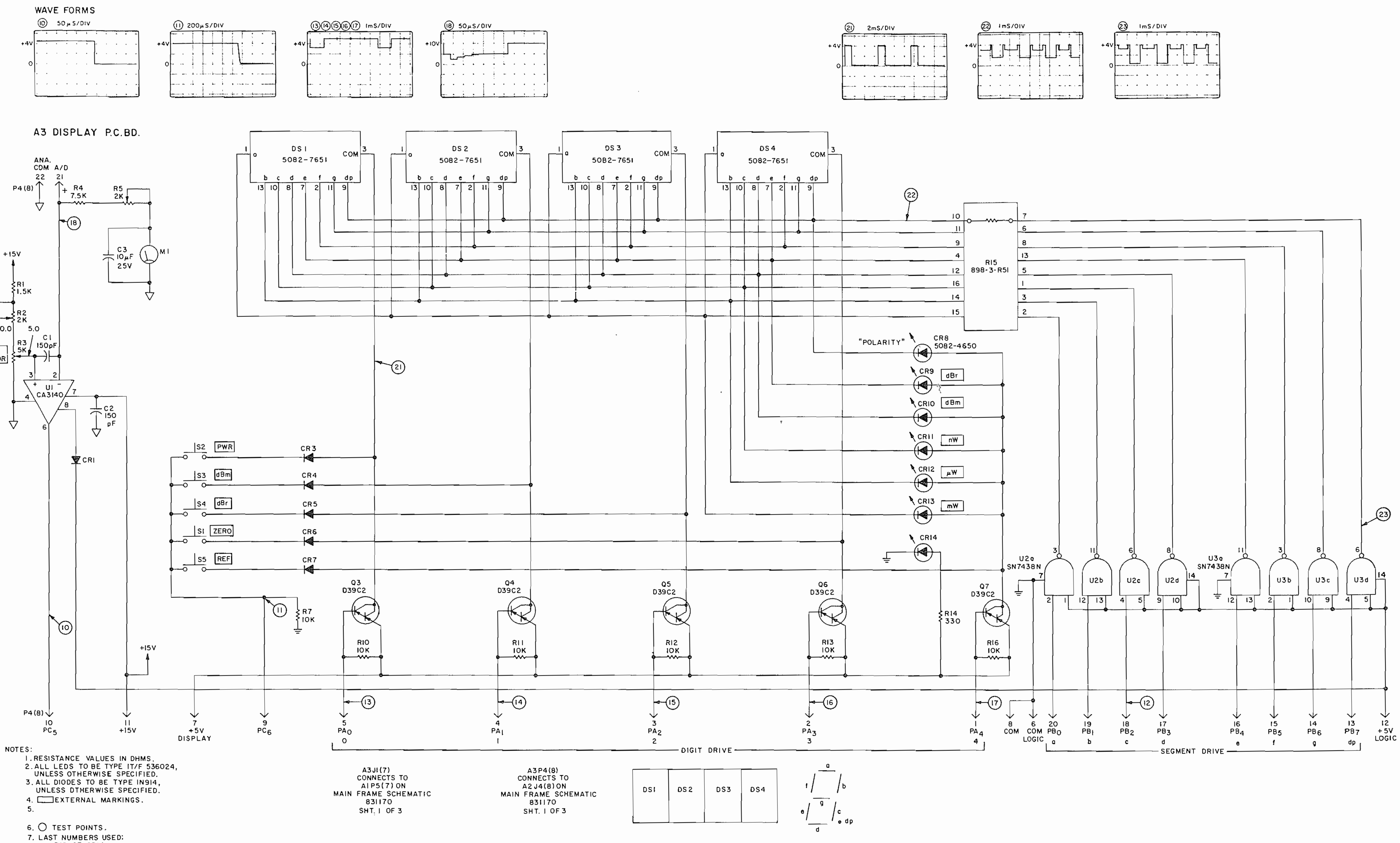


Figure 6-4 Digital Section A2, Schematic Diagram

SCHEMATIC, MAIN P.C.BD.
(DIGITAL SECTION)
E831170G SHT. 2c OF 3

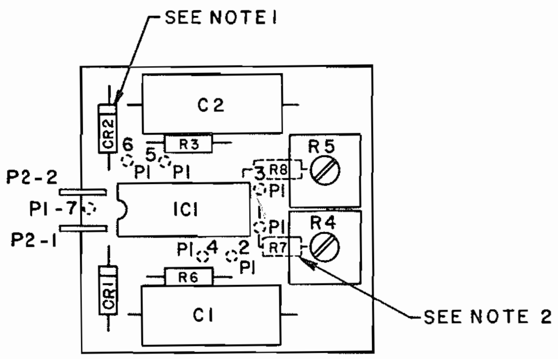




NOTES:
1. RESISTANCE VALUES IN OHMS.
2. ALL LEDS TO BE TYPE IT/F 536024, UNLESS OTHERWISE SPECIFIED.
3. ALL DIODES TO BE TYPE IN914, UNLESS OTHERWISE SPECIFIED.
4. ▭ EXTERNAL MARKINGS.
5.
6. ○ TEST POINTS.
7. LAST NUMBERS USED: R16 Q7 CR14
8. NUMBERS NOT USED: P1,2,3,TP24, CR2, R6,R8,R9,Q1,Q2,TP20

SCHEMATIC, DISPLAY P.C.BD
831170 C SHT. 3 OF 3

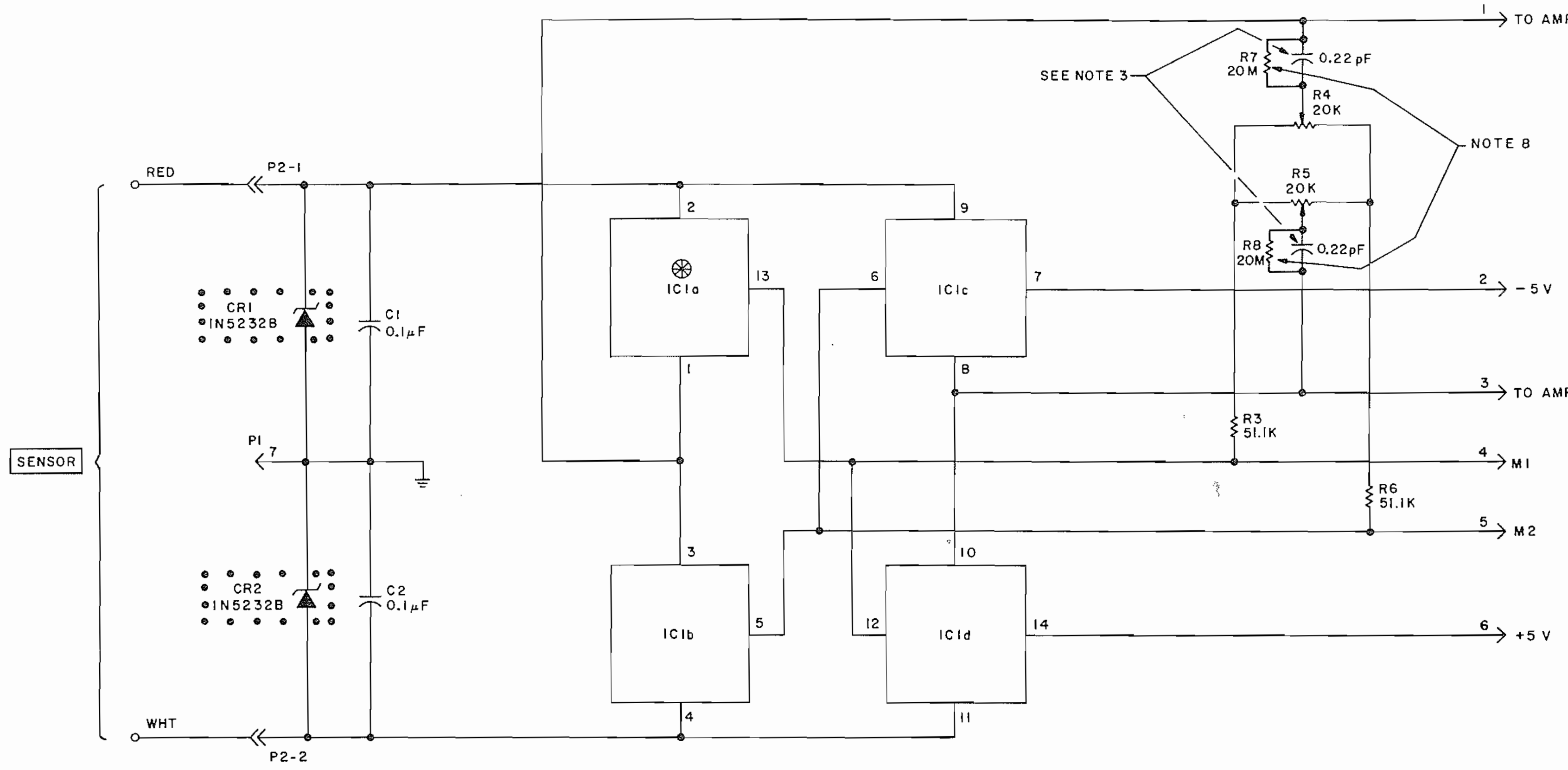
Figure 6-5 Display PCB A3, Schematic Diagram



831045G

NOTE
1. CR1 AND CR2 USED ON 92E-S5 ONLY.
2. R7 AND R8 USED WITH 4210-7E AND 4210-8E ONLY.

A4 CHOPPER P.C. BD.



P1
CONNECTS TO
A6J1
ON FRAME SCHEMATIC
831271
SHT. 1 OF 7
AND
A6 J1
ON OPTION FRAME
SCHEMATIC
831099
AND
A2 J2
ON FRAME SCHEMATIC
831170
SHT. 1 OF 3

NOTES:

1. RESISTANCE VALUES IN OHMS.
2. ⊛ SELECTED VALUE.
3. CAPACITANCE IS PART OF P.C. BD. CIRCUITRY.
4. ▭ EXTERNAL MARKING.
5. LAST NUMBERS USED: R8
6. NUMBERS NOT USED: R1, R2
7. ⁘ USED ON 92E-S5 ONLY.
8. RES R7, R8 USED ONLY WITH 4210-7E AND 4210-8E SENSORS.

SCHEMATIC,CHOPPER P.C.BD.
D831271D SHT. 4 OF 7

Figure 6-6 Chopper PCB A4, Schematic Diagram