Model 124A

Lock-In Amplifier

Instruction Manual

215298-A-MNL-B

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Table of Contents

Safety Notice 1
A. INTRODUCTION 1
B. INSPECTION 1
C. SAFETY MECHANISM 1
D. POWER VOLTAGE SELECTION 1
E. LINE FUSE 1
F. VENTILATION 1
G. DEFECTS AND ABNORMAL STRESSES 1

Chapter 1, Characteristics 3
1.1 INTRODUCTION 3
1.2 SPECIFICATIONS 5
1.2A SIGNAL CHANNEL SPECIFICATIONS 5
1.2B REFERENCE CHANNEL SPECIFICATIONS 5
1.2C DEMODULATOR CHARACTERISTICS 5
1.2D OUTPUTS 6
1.2E DYNAMIC RANGE SPECIFICATIONS 6
1.2F OTHER CHARACTERISTICS 6

Chapter 2, Initial Checks 9
2.1 INTRODUCTION 9
2.2 EQUIPMENT NEEDED 9
2.3 PROCEDURE 9

Chapter 3, Operating Instructions 11
3.1 BLOCK DIAGRAM DISCUSSION 11
3.1A INTRODUCTION 11
3.1B SIGNAL CHANNEL 11
Preamplifier 11
Selective Amplifier 11
Intermediate Amplifier 11
3.1C REFERENCE CHANNEL 11
Voltage-Controlled Oscillator 11
Phase Controls 11
3.1D SYNCHRONOUS DETECTOR 11
3.2 SIGNAL CHANNEL OPERATION 12
3.2A INTRODUCTION 12
3.2B PREAMPLIFIER CHOICE 12
3.2C GROUNDING 13
3.2D REMOTE PREAMPLIFIER ADAPTER 13
3.2E SINGLE-ENDED, DIFFERENTIAL, AND TRANSFORMER INPUTS 14
3.2F COMMON-MODE REJECTION 14
3.2G NOISE AND SOURCE RESISTANCE 14
3.2H SELECTIVE AMPLIFIER 19
3.21 DYNAMIC RANGE 23
3.2J DYNAMIC OVER-RIDE 24
3.2K OVERLOAD 25
3.2L OFFSET DUE TO NOISE 26
3.2M OVERLOAD RECOVERY 27
3.2N SIGNAL MONITOR 28
3.3 REFERENCE CHANNEL OPERATION 28

3.3A SYNC INPUT/OUTPUT 28
3.3B PHASE CONTROLS 29
3.4 OUTPUT CHANNEL OPERATION 29
3.4A FILTER TIME CONSTANT 29
3.4B OFFSET CONTROLS 31
3.5 HARMONIC RESPONSE 31
3.6 SENSITIVITY AND NOTCH CALIBRATION 32
3.7 AC VOLTMETER OPERATION 33
3.8 DIGITAL PANEL METER MODIFICATION (1241/98) 34
3.9 PHASE MEASUREMENTS 37
3.10 REAR PANEL CONNECTORS 38
3.10A INTERFACE CONNECTOR (J9) 38
3.10B EXT. TIME CONSTANT 39
3.11 BATTERY OPERATION 39
3.12 PHASE METER MODIFICATION (1241/85) 39
3.13 MIXER MONITOR MODIFICATION (1241/92) 39
3.14 REMOTE PROGRAMMING OPTION MODIFICATION (1241/83) 40
3.15 SELECTIVE EXTERNAL REFERENCE MODIFICATION (1241/77) 41

Chapter 4, Alignment Procedure 43
4.1 INTRODUCTION 43
4.2 EQUIPMENT NEEDED 43
4.3 PROCEDURE 43
4.3A PRELIMINARY STEPS 43
4.3B ±24 V ADJUSTMENTS (R6028 and R6010) - POWER SUPPLY BOARD 43
4.3C INITIAL REFERENCE OSCILLATOR BOARD ADJUSTMENTS 44
4.3D AUXILIARY REFERENCE BOARD ADJUSTMENTS 45
4.3E MIXER BOARD ADJUSTMENTS 45
4.3F INTERMEDIATE AMPLIFIER BOARD ADJUSTMENTS 46
4.3G FINAL REFERENCE OSCILLATOR BOARD ADJUSTMENTS 47
4.3H SIGNAL BOARD ADJUSTMENTS 47
4.31 FINAL ADJUSTMENTS 48
4.3J PHASE METER OPTION ALIGNMENT 48
4.4 MODEL 116, 117,OR 119 PREAMPLIFIER ALIGNMENT 49
4.4A PRELIMINARY STEPS 49
4.4B PROCEDURE 49
4.5 MODEL 118 PREAMPLIFIER ALIGNMENT 50
4.5A PRELIMINARY STEPS 50
4.5B PROCEDURE 50

Chapter 5, Troubleshooting 51
5.1 INTRODUCTION 51
5.2 EQUIPMENT REQUIRED 51
5.3 INITIAL STEPS 51
5.4 POWER SUPPLY 51
5.5 REFERENCE CHECKS 51
5.6 SIGNAL CHANNEL 53
5.6A PREAMPLIFIER 53
5.6B SIGNAL AMPLIFIER 53
5.6C INTERMEDIATE AMPLIFIER 55
5.6D MIXER BOARD AC GAIN 55
5.6E MIXER SCHMITT TRIGGERS 56
5.6F MIXER CIRCUIT 56
5.6G DC AMPLIFIERS 56
5.7 NOISE CHECKS 56

Chapter 6, Schematics 59

Figures

Figure 1. POWER CORD PLUG 1

Figure 1-1. FRONT & BACK PANELS 4

Figure 1-2. SYNC. SIGNAL SLEWING RATE 5

Figure 1-3. TYPICAL CALIBRATOR ACCURACY 6

Figure 3-1. MODEL 124A FUNCTIONAL BLOCK DIAGRAM 12

Figure 3-2. OPTIMUM PREAMP PERFORMANCE REGIONS 13

Figure 3-3. MODEL 118 FREQUENCY VS DISTORTION 13

Figure 3-4. GROUND-LOOP VOLTAGE REJECTION BY USING DIFFERENTIAL INPUTS 13

Figure 3-5. TYPICAL COMMON-MODE REJECTION 14

Figure 3-6. TYPICAL NOISE-FIGURE CONTOURS FOR MODEL 117, MODEL 116 (DIRECT) & MODEL 119 (DIRECT) 16

Figure 3-7. TYPICAL NOISE FIGURE AND AMPLITUDE TRANSFER CURVES FOR MODEL 116 OPERATING IN TRANSFORMER MODE 17

Figure 3-8. TYPICAL NOISE FIGURE CONTOURS AND AMPLITUDE TRANSFER CURVES FOR MODEL 119 OPERATING IN TRANSFORMER MODE 18

Figure 3-9. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 118 19

Figure 3-10. MODEL 1900 CHARACTERISTICS & WIRING DIAGRAM 20

Figure 3-11. B-H CURVES AND WAVEFORMS 21

Figure 3-12. DEGAUSSING WAVEFORMS 21

Figure 3-13. 124A BANDPASS CHARACTERISTICS 22

Figure 3-14. 124A NOTCH CHARACTERISTICS 22

Figure 3-15. 124A LOW-PASS CHARACTERISTICS 22

Figure 3-16. 124A HIGH-PASS CHARACTERISTICS 22

Figure 3-17. MODEL 124A DYNAMIC RANGE CHARACTERISTICS 24

Figure 3-18. TYPICAL OUTPUT OFFSET AS A FUNCTION OF INPUT NOISE 27

Figure 3-19. TYPICAL REFERENCE OSCILLATOR SLEWING RATE 28

Figure 3-20. NET PHASE DIFFERENCE BETWEEN SIGNAL AND REFERENCE CHANNELS AS A FUNCTION OF FREQUENCY 29

Figure 3-21. OUTPUT FILTER TRANSFER FUNCTIONS 30

Figure 3-22. TYPICAL CALIBRATION ACCURACY 32

Figure 3-23. MIXER OUTPUT FOR IN-PHASE AND QUADRATURE SIGNALS 40

Figure 4-1. 124A ADJUSTMENTS AND TEST POINTS 44

Tables

Table 1-1. PREAMPLIFIER SPECIFICATIONS 3

Tale 3-1. STABILITY AND OUTPUT NOISE AS A FUNCTION OF OPERATING DYNAMIC TRADEOFF 25

Table 3-2. MAXIMUM RMS INPUT LEVELS FOR MIXER AND TUNED AMPLIFIER OVERLOAD AS A FUNCTION OF SENSITIVITY AND OPERATING DYNAMIC RANGE 26

Table 3-3. MAXIMUM FREQUENCY ACQUISITION TIMES OF OSCILLATOR 28

Table 3-4. TYPICAL HARMONIC RESPONSE OPERATING IN FLAT MODE 32

Table 3-5. TYPICAL HARMONIC RESPONSE OPERATING IN BANDPASS MODE WITH Q = 10 32

Table 3-6A. DIGITAL OUTPUT PIN ASSIGNMENTS 35

Table 3-6B. DIGITAL OUTPUT FORMAT AND EXPONENT TABLE 36

Table 3-7. INTERFACE CONNECTOR SIGNALS AND PINS 38

Table 3-8. EXTERNAL TIME CONSTANT CONNECTOR SIGNALS AND PINS 39

Table 3-9. REMOTE PROGRAMMING CONNECTOR PIN ASSIGNMENTS 40

Table 5-1. GAIN AND RELAY SWITCHING FOR THE MODEL 124A 54

Safety Notice

A. INTRODUCTION

The Model 124A to which this instruction manual applies has been supplied in a safe condition. This manual contains some information and warnings that have to be followed by the user to ensure safe operation and to retain the instrument in a safe condition.

Note that the 124A has been designed for indoor use.

B. INSPECTION

Newly received apparatus should be inspected for shipping damage. If any is noted, notify EG&G PARC and file a claim with the carrier. Be sure to save the shipping container for inspection by the carrier.

WARNING! The protective grounding could be rendered ineffective in damaged apparatus. Damaged apparatus should not be operated until its safety has been verified by qualified service personnel. Damaged apparatus waiting for safety verification should be tagged to indicate to a potential user that it may be unsafe and that it should not be operated.

C. SAFETY MECHANISM

As defined in IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, the Model 124A is Class I apparatus, that is, apparatus that depends on connection to a protective conductor to earth ground for equipment and operator safety. Before any other connection is made to the apparatus, the protective connection is made via the earth ground prong of the power cord plug. The power cord plug shall only be inserted into a socket outlet provided with the required earth ground contact. The protective action must not be negated by the use of an extension cord without a protective conductor, by use of an "adapter" that doesn't maintain earth ground continuity, or by any other means.

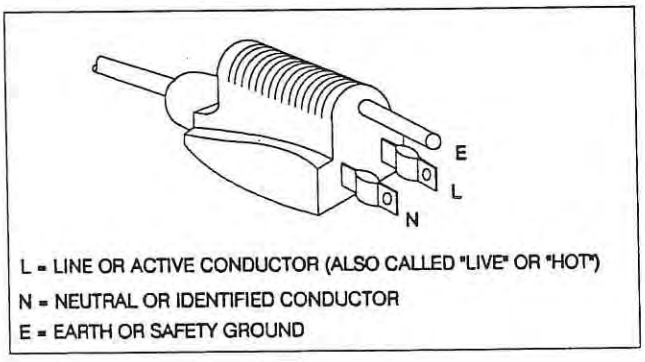


Figure 1. POWER CORD PLUG

WARNING! Any interruption of the protective conductor inside or outside the apparatus or disconnection of the protective earth terminal may make the apparatus dangerous. Intentional interruption is prohibited.

The power cord plug provided is of the type illustrated in Figure 1. If the provided plug is not compatible with the available power sockets, the plug or power cord should be replaced with an approved type of compatible design.

WARNING! If it is necessary to replace the power cord or the power cord plug, the replacement cord or plug must have the same polarity as the original. Otherwise a safety hazard from electrical shock, which could result in injury or death, might results.

D. POWER VOLTAGE SELECTION

Before plugging in the power cord, make sure that the instrument is set for operation from the voltage of the ac power supply.

CAUTION! The apparatus described in this manual may be damaged if it is set for operation from 110 V ac and turned on with 220 V ac applied to the power input connector.

The line voltage is selected by means of a rear-panel switch. Depending on the switch position, either "115" or "230" (both are printed on the switch) will be visible to the operator. For operation from a line voltage of nominally 115 V, position the switch so that "115" shows. For operation from a line voltage of nominally 230 V, position the switch so that "230" shows.

E. LINE FUSE

The ac line-fuse holder is located at the rear panel near the line cord. For operation from a line voltage of nominally 115 V, the fuse should be a slow-blow type rated at ½ A. For operation from a line voltage of nominally 230 V, the fuse should be a slow-blow type rated at ¼ A. The voltage rating of the fuse should be 125 V or higher for 115 V operation and 250 V or higher for 230 V operation. Only a LITTELFUSE type 3AG fuse or equivalent should be used.

WARNING! To avoid the possibility of a safety hazard from electrical shock which could result in injury or death, disconnect the power cord before removing or installing a fuse. Fuses should only be changed by qualified service personnel who are aware of the hazard involved.

F. VENTILATION

The Model 124A does not have any special ventilation requirements. It can be operated on a bench or in a rack, the only constraint being that the ambient temperature be in the range of 15°C to 45°C.

G. DEFECTS AND ABNORMAL STRESSES

Whenever it is likely that the protection provided by the connection to earth ground has been impaired, the

apparatus shall be made inoperative and secured against any unintended operation. The protection is likely to be impaired if, for example, the apparatus:

1. Shows visible damage,
2. Fails to perform the intended measurements,
3. Has been subjected to prolonged storage under unfavorable conditions,
4. Has been subjected to severe transport stresses.

Such apparatus should not be used until its safety has been verified by qualified service personnel.

Chapter 1
Characteristics

1.1 INTRODUCTION

The Model 124A Lock-In Amplifier accurately measures the rms amplitude and phase of weak signals buried in noise. Signals in the range of picovolts up to 500 mV at frequencies from 0.2 Hz to 210 kHz can be measured quickly and precisely. Meter and voltage outputs are provided for the amplitude, and the phase of the signal may be read from a dial. These measurements are with reference to a synchronizing signal supplied to, or supplied by, the Model 124A. In either the External or External f/2 mode of operation, the instrument will accept any reference waveform that crosses its mean twice each cycle, and will lock to and track that signal over a 100:1 frequency range. In the Internal mode, the frequency is determined by front-panel dials or by an externally derived voltage.

A selection of plug-in preamplifiers is available for providing optimum low-noise performance over a wide range of input frequencies and source resistances. After preamplification, noise and harmonics accompanying the signal are attenuated in the Signal Channel by filtering out all frequencies except the band in which the signal lies. Flat, band pass, band reject, high pass, and low pass filtering modes may be selected. The remaining band of frequencies is converted to an equivalent bandwidth about dc by a synchronous detector, which is locked to the synchronizing signal. A low-pass filter eliminates frequency components above dc, so that the detector output is a dc voltage proportional to the in-phase component of the fundamental signal. Proper selection of signal channel and output channel filtering parameters can render the final noise bandwidth extremely narrow. The rms value of the fundamental signal is indicated on the panel meter when the synchronous detection phase is adjusted for maximum detector output.

A switch is provided that allows drift to be traded for dynamic reserve. In addition, an output dc offset feature is provided to allow higher sensitivity settings for relatively steady signals. These features permit selection of the optimum operating mode for each experimental situation.

Other design features include selection of output filter time constants to 300 s, optional digital panel meter with BCD output, a built-in calibrator, and independent use of the phase-lockable oscillator and tuned amplifier for general-purpose laboratory work. The Model 124A may also be used as a conventional wideband laboratory voltmeter.

Accessories include an ac zero offset, several light choppers, a computer interface system, and a wide assortment of low-noise preamplifiers.

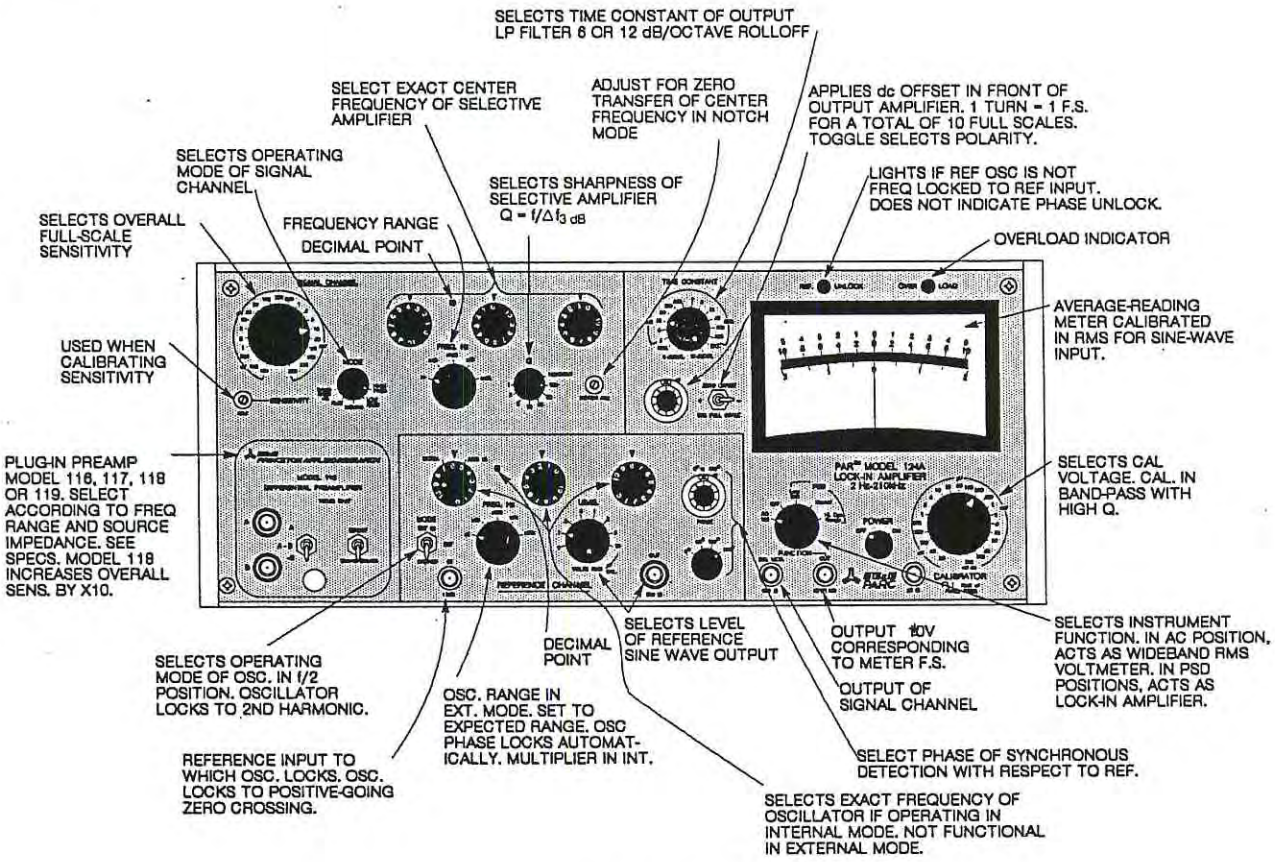
Specification	Model 116	Model 117	Model 118	Model 119
Input Z	Selected by front-panel switch: Direct: 100 MΩ SE/DE Transformer[b]: Low Z SE/DE	100 MΩ SE/DE	10 kΩ SE/DE	Selected by front panel switch: Direct: 100 MΩ SE/DE Transformer: Low Z SE/DE
Bandwidth	Direct: 0.2 Hz-210 kHz Transformer[c]: 1.5 Hz-10 kHz	0.2 Hz-210 kHz	0.2 Hz-210 kHz	Direct: 0.2 Hz-210 kHz Transformer[c]: 1 kHz-210 kHz
Common Mode Rejection Ratio	Direct: 120 dB at 60 Hz Transformer: 140 dB at 60 Hz	120 dB at 60 Hz	110 dB at 60 Hz	Direct: 120 dB at 60 Hz Transformer: 120 dB at 60 Hz
Full Scale Sensitivity	Direct: 100 nV Transformer: 1 nV[b]	100 nV	10 nV	Direct: 100 nV Transformer: 1 nV
Maximum Input Voltage	Direct: ±200 V dc Transformer: 10 mV rms sine wave	±200 V dc	±5 V	Direct: ±200 V dc Transformer: 10 mV rms sine wave

[b]Maybe wired for 1:50 to 1:350 turns ratio. Standard is 1:100

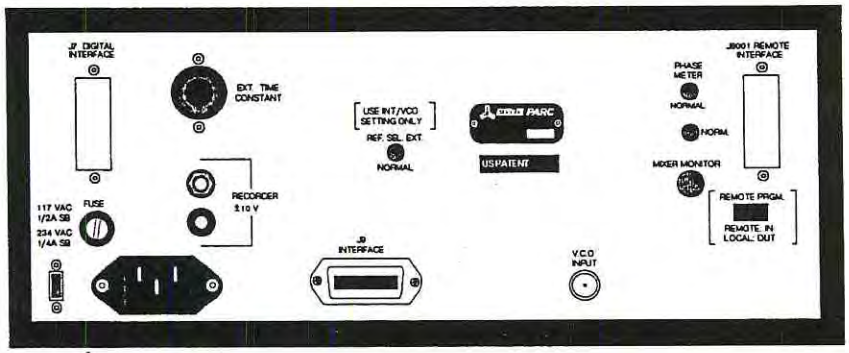
[c]Varies with source impedance.

Note: A current-sensitive preamplifier, the Model 184, is also available.

Table 1-1. PREAMPLIFIER SPECIFICATIONS



FRONT PANEL



BACK PANEL

Figure 1-1. FRONT & BACK PANELS

1.2 SPECIFICATIONS

1.2A SIGNAL CHANNEL SPECIFICATIONS

Frequency Range
Model 124A: 2 Hz - 210 kHz
Model 124AL: 0.2 Hz - 210 kH2 *(Model 124AL has significantly longer severe-overload recovery time - 80 s vs 30 s with 5000 times full-scale overload for one minute).*

Sensitivity: 21 full-scale ranges in 1-2-5 sequence. Full-scale voltages are determined by the choice of preamplifier. Sensitivity and all other preamplifier determined specifications are given in Table 1-1. *(Two additional preamplifiers, the Model 184 and the Model 185, are available. For information, contact the factory or the factory representative in your area).*

Signal Channel Modes of Operation

1. **FLAT:** Flat response within ±1% from 10 Hz to 110 kHz, ±2% from from 110 kHz to 210 kHz, and ±10% below 10 Hz.

2. **BANDPASS:** Provides a tunable bandpass response with the center frequency set by front-panel digital dials over a range of 2 Hz to 110 kHz. Setting accuracy is within ±2% or 0.05 Hz, whichever is greater. Bandwidth is adjustable over a range of 1% to 100% (at 3 dB points), corresponding to a range of Q between 100 and 1, by means of the front-panel Q control.

3. **NOTCH:** Essentially the same as the Flat mode, but with the addition of a tunable notch that provides up to 80 dB of attenuation at any specific frequency. The notch is tuned with the same controls as set the bandpass frequency.

4. **LOW PASS:** Essentially the same as the Flat mode, but with the addition of a low pass filter that provides 12 dB per octave rolloff above the set frequency.

5. **HIGH PASS:** Essentially the same as the Low Pass mode, but with the substitution of a high pass filter in place of the low pass filter.

1.2B REFERENCE CHANNEL SPECIFICATIONS

Modes

1. **INTERNAL:** Frequency of the internal reference oscillator is set by means of front-panel digital dials and/or rear-panel VCO control voltage. Setting accuracy is within ±2% or 0.05 Hz, whichever is greater. VCO control voltage of 0 to ±10 V corresponds to the full frequency range on all bands. VCO Input impedance is 10 kΩ. The amplitude stability is typically 0.01%. The frequency stability is typically 0.05% of the set frequency.

2. **EXTERNAL:** The internal reference oscillator will lock in both frequency and phase to virtually any externally generated signal crossing its mean only twice each cycle. Maximum input voltage is ±20 V dc. Minimum time required on either side of the mean is 100 ns. Amplitude excursion must be at least 50 mV above and below the mean. Input impedance is 1 MΩ.

   When locked on, the reference oscillator will track the external signal over a frequency range of 100:1 within the range of the set band of frequencies. Maximum frequency acquisition (lock-on) times for each frequency band are given in the following table.

Band	Frequency Range	Maximum Time
X1	0.2 Hz to 21 Hz	15 minutes
X10	2 Hz to 210 Hz	2 minutes
X100	20 Hz to 2.1 kH2	10 seconds
X1K	200 Hz to 21 kHz	2 seconds
X10K	2.1 kHz to 210 kHz	2 seconds

Note: Time to lock can be shortened appreciably by momentarily switching to Internal Mode and manually setting the oscillator to the proper frequency.

Once the frequency has locked, the phase will track at the rate shown in Figure 1-2.

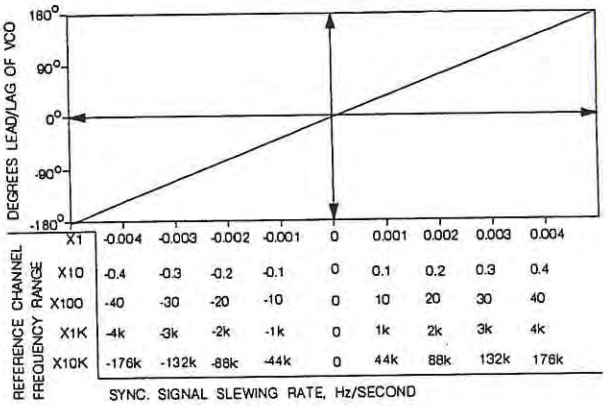


Figure 1-2. SYNC. SIGNAL SLEWING RATE

Phase Adjustment: Calibrated 10 turn potentiometer provides 0-100° phase shift. Linearity of phase setting is within ±2° from 2 Hz to 21 kHz, and within ±5° from 21 Hz to 210 kHz. Resolution is 0.1°. A four-position quadrant switch provides 90° phase-shift increments.

1.2C DEMODULATOR CHARACTERISTICS

ACVM: An ACVM position on the function switch permits the Model 124A to be used as a conventional or frequency selective dc voltmeter. Accuracy is within ±1% from 2 Hz to 20 kHz, increasing to ±10% at 210 kHz.

Dc Output Stability and Noise: Dependent on the operating mode selected by the front-panel Function switch, as shown in the Stability & Noise Table (next

page).

Function	Output Stability	Output Noise
LOW DRIFT	<150 μV/°C	<100 μV rms
NORMAL	<1 mV/°C	<1 mV rms
HIGHDYN RANGE	<10 mV/°C	<10 mV rms

Demodulator Overload Limits: Dependent on Function switch setting as follows (see Section 3.2I for over-ride considerations).

LOWDRIFT ..... 10 x full scale
NORMAL ..... 100 x full scale
HIGH DYN RANGE ..... 1000 x full scale

This limit is defined as the ratio, at the input, of the maximum pk-pk voltage of a non-coherent signal, before overload, to the pk-pk voltage of a full-scale coherent sinewave. Note that, in terms of pk-pk noise to rms signal, the instrument will accept, without overload, interfering signals having an amplitude up to 3000 times the sensitivity setting. (See discussion in Section 3.2I.)

Filter Time Constants: 1 ms to 300 s in 1-3-10 sequence, and a minimum time constant position having a time constant of less than 1 ms (determined by internal stray capacitance). The External position allows capacitance to be added via a rear-panel connector to obtain special values of time constant. Either 6 or 12 dB/octave rolloff as selected by means of front-panel switch is provided.

Equivalent Noise Bandwidth: 416 μHz minimum (300 s time constant with 12 dB/octave rolloff).

Zero Suppress: Calibrated control permits off-setting zero(by ±1000% of full scale on Normal and High Dynamic Range only.

System Gain Stability: 100 ppm/°C; 100 ppm/24 Hr in the Flat mode and with Function switch set to NORMAL.

1.2D OUTPUTS

Meter Reading: Choice of either center-zero or lefthand-zero Panel meter of taut-band construction, providing 0.5% linearity.

Optional Digital Readout: The Model 124A may be ordered with an optional digital readout in place of the standard panel meter. The readout is a 3½ digit display with a linearity of 0.05% of the reading, ±1 count. In addition, a BCD output is provided at the rear panel. The output levels are DTL/TTL compatible: Logic 0 = +0.2 V ±0.2 V, 5 mA maximum sinking current; Logic 1 = +3.5 V ±1.0 V, 100 μA maximum sourcing current.

Function Out: A dc signal corresponding to the panel-meter reading. An output of 10 V corresponds to full-scale deflection. The output impedance is 1 kΩ.

Signal Monitor: Enables continuous monitoring of the signal channel output ahead of the demodulator. In LO DRIFT operation, a full scale rms input sinewave gives a 100 mV rms sinewave at the Signal Monitor jack. In NORMAL operation, the signal monitor output with a full-scale input is 10 mV, and in HI, it is 1 mV. Dynamic Over-ride considerations apply as explained in Section 3.21. Output impedance is 600 Ω.

Internal line frequency pickup is less than 20 nV rms (referred to the Direct inputs of a Type 116 Preamplifier) in any Signal Channel mode except Bandpass and Notch, where the level may rise to 500 nV at highest Q settings.

Reference Channel: A sinewave output at the reference oscillator frequency. Amplitude is continuously adjustable by means of the front-panel Level control over a range of 0 V to 10 V rms with less than 2% distortion. Output impedance is 600 Ω.

1.2E DYNAMIC RANGE SPECIFICATIONS

Vary as a function of the operating Dynamic Range Tradeoff as indicated in the table above.

1.2F OTHER CHARACTERISTICS

Overload: Front-panel light indicates overload at critical circuits.

Reference Unlock: Front-panel light indicates that the reference oscillator has not completed frequency lock.

Internal Calibrator: Square-wave calibrator signal supplied. Rms amplitude of fundamental frequency component adjustable from 20 nV to 100 mV in 1-2-5 sequence. Typical accuracy indicated in Figure 1-3.

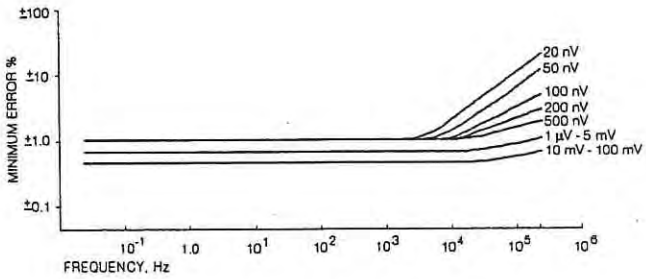


Figure 1-3. TYPICAL CALIBRATOR ACCURACY

Ambient Temperature Range: Unit can be operated at ambient temperatures ranging from 15°C to 45°C.

Auxiliary Power Output: Regulated ±24 V at up to 100 mA is available at rear-panel connector.

Power Requirements: 105-125 or 210-250 V; 50-60 Hz; unit can also be powered from batteries by supplying ±31 V to rear panel connector. Batteries must be able to supply at least 400 mA at +31 V and 360 mA at -31 V.

NOTE: These are maximum values and do not apply for all positions of she Sensitivity switch. See Section 3.2I, *DYNAMIC RANGE,* for additional information.

Size: 17⅛" W x 7" H x 18¼" D (43.6 cm W x 17.8 cm H x 46.5 cm D).

Weight: 34 lbs (15.5 kg).

Accessories: Model 123 AC Zero Offset provides a square wave at the reference frequency which can be used to suppress signals at the input of the Model 124A. Other accessories include a computer interface system, fixed and variable speed light choppers, and a broad selection of special purpose preamplifiers. The AM-1, AM-2, and 190 input transformers allow better noise performance to be achieved when using a high-input impedance preamplifier to process a signal arising in a low source impedance.

The Model 184 Current-Sensitive Preamplifier is also available. This preamplifier, which plugs in like the Models 116, 117, 118, and 119 Preamplifiers, provides 1 V out for input currents ranging from 1 nA to 100 mA as selected by a front-panel Range switch. Frequency range varies with sensitivity, being 2 Hz to 3 kHz on the 1 nA range and 2 Hz to 200 kHz on the 10 μA range.

Chapter 2
Initial Checks

2.1 INTRODUCTION

The following procedure is provided to facilitate initial performance checking of the Model 124A. In general, the procedure should be performed after inspecting the instrument for shipping damage (any noted to be reported to the carrier and to Princeton Applied Research Corporation), but before using it experimentally. *In the case of units having a digital panel meter, it is important that the phrase* **"meter full scale"** *be properly interpreted. Read the paragraph beginning with* **"in reading the display---"** *in Section 3.8 of Chapter 3 before proceeding with the initial checks.* Should any difficulty be encountered in carrying out these checks, contact EG&G PARC or the authorized representative in your area.

2.2 EQUIPMENT NEEDED

(1) General-purpose oscilloscope.

(2) Oscillator, having any 1 kHz repetitive waveshape that crosses its mean exactly twice each cycle and having a pk-pk voltage anywhere between 100 mV and 3 V.

(3) Assorted BNC cables.

2.3 PROCEDURE (for digital units, see Section 3.8 before proceeding)

Note: This procedure must be performed in sequence.

(1) Install a preamplifier if not already installed.

(2) Check the rear-panel 115/230 switch. Make sure the number showing in the window corresponds to the line voltage to be used.

(3) Turn the front-panel Power switch OFF.

(4) Plug the line cord into the rear panel and wall receptacles.

(5) Set the front-panel controls as follows.

Meter: Check mechanical zero. Adjust if necessary.
Preamplifier Input: DIRECT (if applicable)
Sensitivity switch: 1 mV (if using a Model 118 Preamplifier, set the Sensitivity switch to 10 mV)
Signal Channel Mode: FLAT
Signal Frequency dials: 4.05
Signal Frequency range: X100
Q switch: 100
Time Constant: 300 ms
Zero Offset potentiometers: fully counterclockwise
10 X Full Scale switch: OFF (center position)
Preamplifier Mode: A
Reference Frequency dials: Red, NORMAL, Digits, 4.05
Reference Frequency range: X100
Reference Mode: INTERNAL
Reference Level: 10 (cal.)
Phase potentiometer: 90 (9 full turns)
Phase switch: 180°
Function switch: ACVM
Calibrator switch: 1 mV

(6) Connect a cable between the Calibrator BNC jack and the preamplifier's A input.

(7) Turn the Power on and wait five minutes for warmup. **Note:** In an actual measurement application, allow one hour warmup for optimum performance.

(8) The Meter should read to the right.

(9) Set the Signal Mode switch to BANDPASS.

(10) Adjust the right-most Signal Channel frequency dial for a peak on the meter (approximately full scale).

(11) Switch the Q switch back and forth between 100 and 10% ENBW positions, and adjust the Notch (front-panel screwdriver adjustment) for minimum change between the two positions (less than 1% of f.s. change). After adjusting, leave the Q at 100.

(12) Set the Sensitivity ADJ. potentiometer (front-panel screwdriver adjustment) for exactly full scale meter indication.

(13) Set the Signal Mode switch to NOTCH. The meter should now indicate 40% ±15% of positive full scale.

(14) Set the Signal Mode switch to LOW PASS. The meter should now indicate 90% ±10% of positive full scale.

(15) Set the Signal Mode switch to HIGH PASS. The meter should continue to indicate 90% ±10% of positive full scale.

(16) Set the Signal Mode switch to BANDPASS.

This completes the Signal Channel checks. The Phase and Function checks follow.

(17) Set the Function switch to LO DRIFT.

(18) Set the Q Selector to 10% ENBW. Then adjust the Phase potentiometer for zero on the meter. Lock the potentiometer.

(19) Set the Phase switch to 270°. Adjust, if needed, the Sensitivity screwdriver control for plus full-scale meter indication.

(20) Set the Phase switch to 90°. The meter should indicate minus full-scale ±2%.

(21) Set the Phase switch to 0°. The meter should indicate zero ±2% of full scale.

(22) Set the Phase switch back to 270°. (The meter should indicate positive full scale ±1%).

(23) Set the Function switch to NORMAL. The meter should remain at positive full scale (±1%).

(24) Set the Function switch to HI DYN RANGE. The meter should continue to indicate positive full scale (±1%).

This completes the Phase and Function checks. The Reference Channel checks follow.

(25) Connect the Signal Generator to the Reference Channel's In jack. The pk-pk voltage can be anywhere between 100 mV and 3 V. Set the signal generator's frequency to approximately 1 kHz.

(26) Monitor the Reference Channel's Out jack with the oscilloscope. The waveform should be a 28 V (±2 V) pk-pk sinewave.

(27) Set the Frequency Mode switch to EXT. The Ref. Unlock light should come on. Observe the frequency of the oscilloscope waveform. It should have begun increasing as soon as the Mode switch was set to EXT. After several seconds, it should stop increasing. When it stops, the Ref Unlock light should go out. (The meter will go to Zero also.)

(28) Note the frequency of the oscilloscope waveform. Then place the Reference Mode switch to f/2; the frequency should double.

This completes the Reference Channel checks. The Sensitivity Range checks follow.

(29) Set the Reference Mode switch back to INT.

(30) Set both the Signal Channel Sensitivity and the Calibrator output to 100 mV. The meter should remain at full scale ±1%. **Note:** Calibrator to 10 mV with Model 118 Preamplifier.

(31) Progressively rotate the Sensitivity and Calibrator switches one position at a time, in a counter-clockwise direction. The meter should remain at full scale ±2% if the two switches are in corresponding positions. If the meter wavers too much in the low nV settings, increase the Time Constant to 10 seconds. (If using the Model 118 Preamplifier, remember that the instrument is ten times more sensitive than is marked on the Sensitivity switch, and set the switches accordingly. Just be sure to check all sensitivities for which Calibrator voltages are available.)

This completes the Sensitivity Range checks. The Output Offset and Overload checks follow.

(32) Remove the Input signal to the Preamplifier.

(33) Set the Time Constant switch to 300 ms.

(34) Set the Sensitivity switch to 1 mV.

(35) Set the 10 X Full Scale switch to "-".

(36) Adjust the Offset potentiometer for exactly one turn clockwise. The meter should indicate positive full scale ±2%.

(37) Place the 10 X Full Scale switch in "+". The meter should now indicate negative full scale ±2%.

(38) Increase the Offset potentiometer setting to 1.6 turns. The Overload light should come on.

(39) Return the 10 X Full Scale switch to its neutral off position. The Overload light will go out.

This completes the Initial Checks. If the instrument performed as indicated, one can be reasonably sure that it is operating properly.

Chapter 3
Operating Instructions

3.1 BLOCK DIAGRAM DISCUSSION

3.1A INTRODUCTION

Before discussing the actual operation of the Model 124A, let us examine a functional block diagram to better understand what each adjustment does, and how the various adjustments relate to or influence one another. The functional block diagram is located on the following page. Schematics and a chassis wiring diagram are included at the back of this manual.

The Synchronous Detector is the heart of the instrument, around which are situated the Signal Channel, the Reference Channel, and the Output Amplifier. The Signal Channel amplifies and filters the signal, cleaning it up as much as possible before passing it along to the Synchronous Detector. The Reference Channel controls synchronization.

3.1B SIGNAL CHANNEL

Preamplifier

Four models of plug-in preamplifier are available: the Model 116, the Model 117, the Model 118, and the Model 119. Together they cover the whole frequency spectrum from near dc to 210 kHz, each model having the best kind of input circuit for optimum low-noise performance in its frequency range. The Model 116 may be considered the general-purpose choice, performing well in most situations. Specific data for the four preamplifier models is given in the specifications in Chapter 1 and in the discussions in Section 3.2.

Selective Amplifier

The Selective Amplifier functions as a variable Q filter, which may be operated in the high-pass, low-pass, notch, bandpass, or flat mode. Because rms noise amplitude is a direct function of bandwidth, much of the noise can be rejected in this stage by filtering out all but the band containing the wanted signal. In addition, odd harmonics, to which the Synchronous Detector is sensitive, can be eliminated.

Intermediate Amplifier

The Intermediate Amplifier provides additional gain so that the signal-plus-noise applied to the Synchronous Detector is as large as possible without overload. Presenting a large signal to the Synchronous Detector minimizes, for a given overall sensitivity, the noise and dc drift contributed by the Output Channel. The Intermediate Amplifier is dc coupled, thereby eliminating dc drift problems in the Signal Channel.

3.1C REFERENCE CHANNEL

Voltage-Controlled Oscillator

The VCO either locks onto a synchronizing signal from the experiment, or provides a synchronizing signal to the experiment. The VCO drives the Synchronous Detector so that the experiment and the Model 124A are properly synchronized.

The VCO automatically phase-locks to any kind of reference waveform having a frequency within approximately two decades of the Reference Channel band setting, the only requirements being that the waveform cross the mean twice (only) each cycle, that it have a pk-pk amplitude of at least 100 mV, and that it be synchronized with the signal of interest. The VCO can also lock to the second harmonic of the reference signal, if desired.

It is important to realize that, even though the VCO will phase lock over a two decade frequency range, the boundaries of the two decades are determined by the setting of the Oscillator Range switch. The tracking range corresponding to each position of the switch is as follows.

X1	0.2 Hz to 21 Hz
X10	2 Hz to 210 Hz
X100	20 Hz to 2.1 kHz
X1K	200 Hz to 21 kHz
X10K	2 kHz to 210 kHz

In the Internal mode, a sine-wave output from the Oscillator is provided for synchronizing the experiment. The Oscillator can free run accurately at any selected frequency from 200 mHz to 210 kHz. Also, the Oscillator's frequency may be controlled by a voltage applied to a rear-panel jack.

Phase Controls

The Phase Controls combine quadrature outputs from the VCO such that the resultant sinewave presented to the Synchronous Detector has the desired phase relation to the reference (sync input and/or output).

3.1D SYNCHRONOUS DETECTOR

The Synchronous Detector inverts the polarity of the part of the input signal corresponding to the negative excursion of the phase-shifted sinewave from the VCO, and passes the remaining waveform uninverted. Therefore, the dc component of the resultant waveform is proportional to the value of signal at the same frequency and phase as the phase-shifted VCO sinewave. Because the detected signal still has noise on it, RC low-pass filters that follow the synchronous detector are used to eliminate all but the dc component representing the wanted signal. A dc amplifier following the detector provides the final gain. This amplifier drives the output connector and panel meter.

To determine the amplitude of a signal, the operator

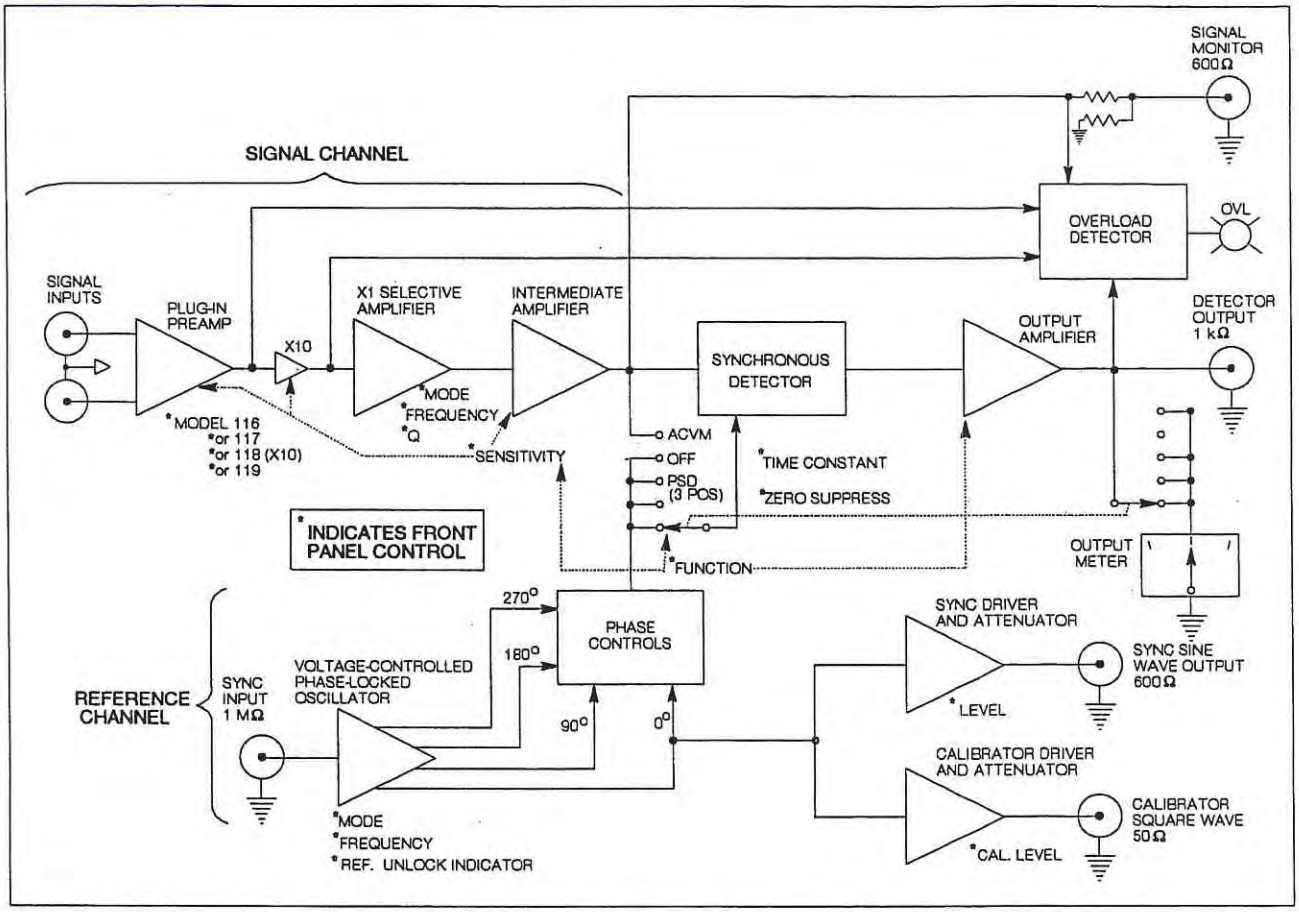


Figure 3-1. MODEL 124A FUNCTIONAL BLOCK DIAGRAM

simply adjusts the phase controls for maximum meter indication. The meter directly indicates the signal amplitude. In addition, after making this adjustment, the phase of the input signal relative to the reference may be accurately read from the Phase dial.

3.2 SIGNAL CHANNEL OPERATION

3.2A INTRODUCTION

The function of each control is indicated in Figure 1-? (Chapter 1). Instead of repeating the information given there, this section provides additional background information for setting the controls to their optimum positions.

To set up the Signal Channel controls, the operator must know the frequency or frequency range of the signal. It also helps if the expected amplitude, the amount and type of noise obscuring the signal, and the signal-source impedance are known.

The stimulus to the experiment is often chopped. Detecting at this chopping frequency eliminates all but the signal related to the stimulus. EG&G PARC manufactures several models of light chopper which are ideally suited to photo-detection applications. Chopping the source light finds its analog for other kinds of experiments in chopping the stimulus dc, rf, ac, sound, heat, etc. The chopping frequency range must be fairly well known, and sync signals must be available. Of course the frequency of interest may not be a result of chopping at all. The chopping technique discussed here merely serves as an example.

3.2B PREAMPLIFIER CHOICE

Four models of plug-in preamplifiers are available, each one providing optimum low-noise performance over a given input-resistance vs frequency range, as shown graphically in Figure 3-2 Two of these preamplifiers can be operated both in direct and transformer-coupled modes, and all four of them can be operated single-ended or differentially. A Model 1900 transformer can be used with any of the plug-ins to improve low-frequency performance when working from low source impedances. Use of the Noise Figure contours is discussed in Section 3.2G.

Another consideration in selecting a preamplifier is its ability to amplify without distortion. If an experiment involves the measurement of low level harmonics in the presence of a high level fundamental, it is important that the preamplifier not add significant harmonic signals by

non-linearly amplifying the fundamental. Except in the case of the Model 118 Preamplifier, the distortion generated by preamplifiers operating in the direct mode is so small as to be unmeasurable using conventional methods. The Model 118 can, however, distort more under certain conditions, as indicated in Figure 3-3. In the transformer mode, both phase shift and distortion must be measured for each individual operating condition.

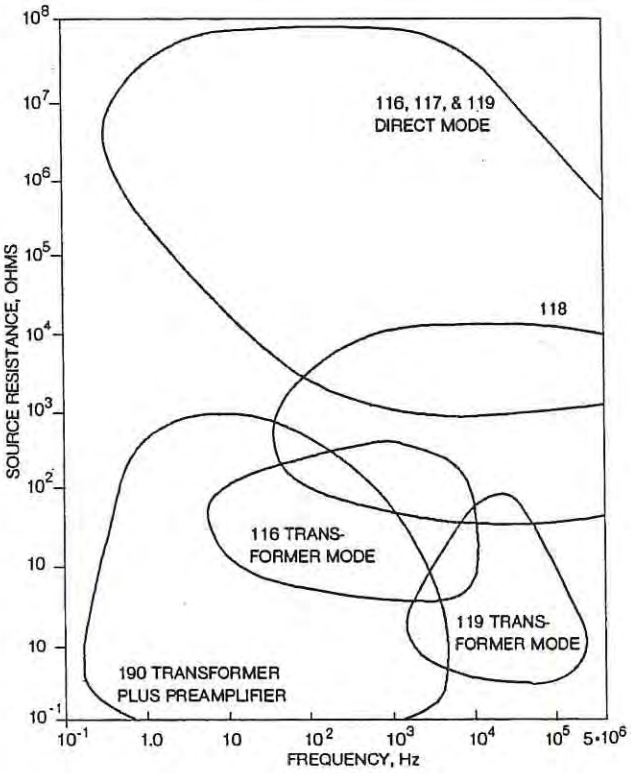


Figure 3-2. OPTIMUM PREAMP PERFORMANCE REGIONS

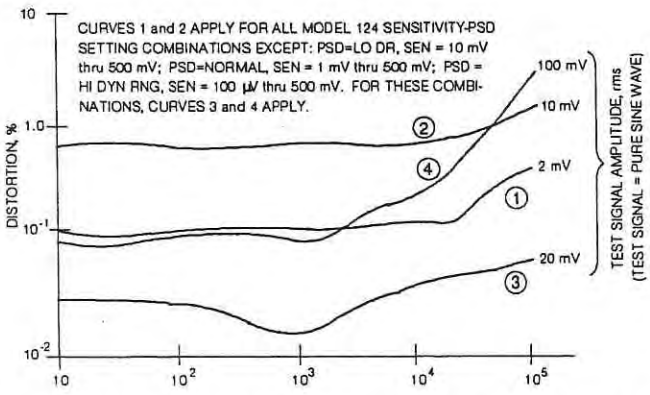


Figure 3-3. MODEL 118 FREQUENCY VS DISTORTION

3.2C GROUNDING

In any system processing low-level signals, proper grounding to minimize the effects of ground-loop currents, usually at the power frequency, is an important consideration. With the exception of the Models 184 and 185, all of the Model 124A preamplifiers allow both differential and single-ended operation. Two properties of these preamplifiers allow them to achieve a high degree of immunity to ground-loop currents. In differential operation, their extremely their extremely high common-mode rejection assures an almost total rejection of unwanted signals, which appear at both inputs at the same phase and amplitude, the usual case for ground-loop interference. In single-ended operation, their unique input grounding system, in which signal ground "floats" off chassis ground by ten ohms, assures a high degree of rejection. As a result of this ten ohm ground, ground loop signals are effectively attenuated by the ratio of ten ohms to the braid resistance (typically 20 mΩ) of the cable carrying the signal from the source to the input.

Despite the immunity granted by the ten-ohm ground, far better rejection can be achieved in processing a signal from a single-ended source if one operates differentially as shown in Figure 3-4. In single-ended operation, the preamplifier "sees" the potential difference between the center conductor of the cable and the braid, and any ground loop signal on the braid can be attenuated but not rejected altogether. In differential operation, the preamplifier "sees" the potential difference between the "A" Input and the "B" Input. Ground-loop signal current flowing in the braid is of no consequence.

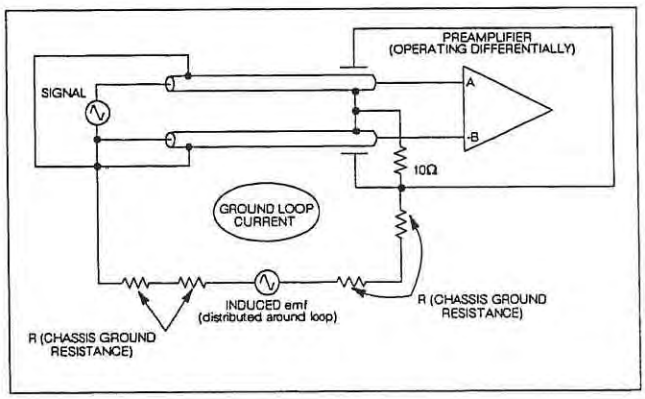


Figure 3-4. GROUND-LOOP VOLTAGE REJECTION BY USING DIFFERENTIAL INPUTS

However, when operating differentially, it is important to assure that common-mode interference arising in ground loops is just that, i.e., without a significant differential component. This should not prove a problem as long as both signal cables are the same length and follow the same path.

3.2D REMOTE PREAMPLIFIER ADAPTER

In situations where very low signal levels are encountered, it may be desirable to operate the preamplifier very close to the signal source to reduce noise and stray pickup, while leaving the main Lock-In unit at a convenient operating location. This may be accomplished with the Model 183 accessory Remote Preamp Adapter.

3.2E SINGLE-ENDED, DIFFERENTIAL, AND TRANSFORMER INPUTS

All of the preamplifiers have switch-selectable single-ended/differential inputs. The differential inputs can be used to combine signals (A - B) as well as to provide common mode rejection.

Impedance matching of the source and loading considerations often require that the input impedance of the preamplifier be known. However, do not confuse impedance matching with optimum input impedance for low-noise operation. The latter is discussed in detail in Section 3.2G.

The input impedance of each preamplifier (direct mode) is: Model 116, 100 MΩ 20 pF; Model 117, 100 MΩ 20 pF; Model 118, 10 kΩ 170 pF; Model 119, 100 MΩ 20 pF. These impedances are for each input to ground. In the differential mode, for all models except the 118, the impedance from input to input is twice that stated (i.e., R double, C half). For the Model 118, the input impedance for the differential mode is about the same as the impedance for single-ended operation. In addition, the differential input impedance of the Model 118 varies with sensitivity and the setting of the PSD switch (common-mode input impedance is 25 kΩ for all combinations). In the L. Drift mode, on the 10 mV through 500 mV sensitivity ranges, the input impedance is about three times that specified. In the Normal mode, the higher impedance applies to the 1 mV through 500 mV ranges, and in the Hi Dynamic Range mode, it applies to the 100 μV through 500 mV ranges.

For the preamplifiers having internal transformers, the Input switch operates the same for the transformer as it does for direct. The input impedance is very low in the transformer mode.

If an external transformer, such as the Model 190, is used, it is connected to the preamplifier single ended. The transformer alone provides sufficient common-mode rejection (Figure 3-5).

3.2F COMMON-MODE REJECTION

Figure 3-5 illustrates the common-mode rejection characteristics of the preamplifiers in both direct (differential) and transformer mode operation. Note that the CMR is much higher for the transformer mode than for the direct mode.

3.2G NOISE AND SOURCE RESISTANCE

Best preamplifier performance is realized under those conditions where the overall signal-to-noise ratio is least degraded. In many instances, the thermal noise generated by the signal source resistance is the dominant factor in determining the input signal-to-noise ratio. In this respect, amplifier noise performance can be specified by the amount of noise the amplifier adds to the amplified source thermal noise; expressed in decibels this is called the "Noise Figure";

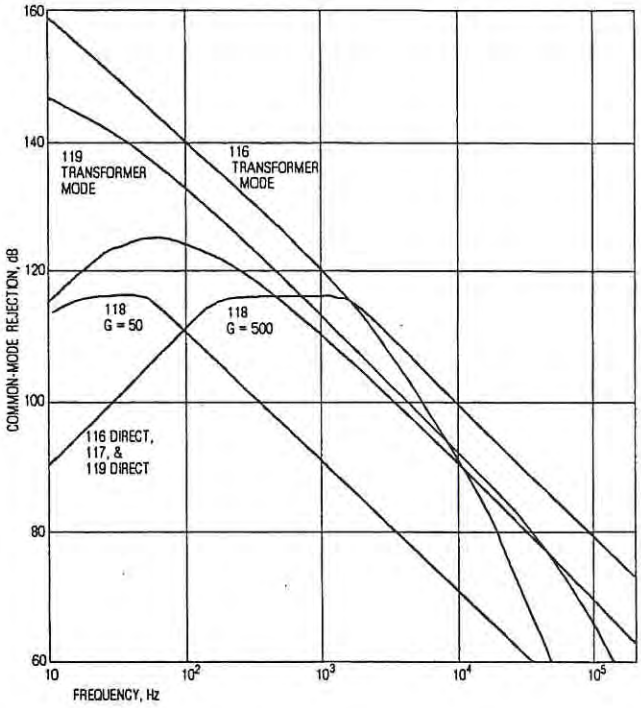


Figure 3-5. TYPICAL COMMON-MODE REJECTION

1. Noise Figure =

$$20 \log_{10} \frac{\textit{total rms noise voltage at amplifier output}}{\textit{gain x source thermal noise voltage (rms)}}$$

where the Source Thermal Noise = $(4KTR\Delta f)^{1/2}$ volts rms = E, and:

K = Boltzmann's constant, 1.38×10^{-23} joules/K
T = absolute temperature in kelvins
Δf = equivalent noise bandwidth in Hz
R = source resistance in ohms

The total output noise may be converted to an equivalent input noise by dividing by the amplifier gain. The noise figure, expressed in these terms, becomes:

2. Noise Figure =

$$20 \log_{10} \frac{\textit{total rms voltage referred to amp. input}}{\textit{source thermal noise voltage (rms)}} dB$$

Each amplifier has its own characteristic noise figure, which varies as a function of frequency and source resistance. These figures are obtained experimentally and plotted graphically. Figures 3-6 through 3-11 include typical sets of noise figure contours for the Models 116,

117, 118, and 119 operating in direct and transformer modes.

Using the applicable set of contours, the total equivalent rms input noise can be determined:

3. Total equivalent rms input noise voltage =

source thermal noise x antilog NF/20 volts rms

Notice from these equations that the bandwidth must be specified; usually determined by the external circuitry and/or the amplifier bandwidth. Figures 3-6 through 3-10 include response curves of the preamplifiers from which the bandwidth may be obtained (in the direct modes, the bandwidth is wider than the widest Tuned Amplifier Bandwidth). However, a more interesting place to determine noise level is at the output of the Tuned Amplifier. Because there is gain ahead of the Tuned Amplifier, its noise contribution referred to the input is negligible compared to that of the preamplifier. In computing the total equivalent input noise of the signal channel, the operator only need use a Δf as determined by the Selective Amplifier setting (with preamplifier limitations considered). Although the discussion of noise considerations is not complete, a simple example at this point illustrates the use of the foregoing equations and illustrates how a transformer can, on occasion, improve the signal-to-noise ratio.

Suppose that one intended to operate the Model 124A in an experiment having a source impedance of 10 Ω. Further suppose the signal frequency to be 5 kHz. A Model 116 Preamplifier is chosen. In order to see how a transformer can improve low-noise performance, the noise for the Direct mode is first calculated. Then the noise for transformer operation is calculated and the results compared. Since the source thermal noise contributing to the total noise is dependent on bandwidth, the Signal Channel bandwidth is minimized by setting the Mode switch in the Bandpass position and the Q switch to the 10% ENBW (equivalent noise bandwidth) position. The Frequency controls are set to 5 kHz. The source thermal noise in this case is:

$$E = (4KTBR)^{1/2}$$

where:

k is Boltzmann's constant = $1.38 \times 10_{-23}$ joules/K

T is the absolute temperature of the source in kelvins, presumed to be 290 K for the example

B is the noise bandwidth, = 500 Hz with the Q switch set to 10% ENBW and Frequency Controls set to 5 kHz

R is the source resistance in ohms, given as 10 Ω.

Thus:

$$E = (4 \times 1.38 \times 10^{-23} \times 2.9 \times 10^{2} \times 10 \times 5 \times 10^{2})^{1/2}$$

$$= 8.9 \times 10^{-9} \text{ V rms}$$

From Figure 3-6, the noise figure for the Model 116 at a center frequency of 5 kHz and a source impedance of 10 Ω is 20 dB. Substituting E and this NF into equation (3), we get:

total equivalent rms input noise =

$$8.9 \times 10^{-9} \times 10^{20/20} =$$

89 nV rms

With a transformer inserted between the signal source and the amplifier input we can increase the effective source impedance to a value that reduces the noise figure to less than 0.1 dB. From Figure 3-6, the source resistance should be about 200 kΩ. The transformer turns ratio required for this impedance increase is $R_2/R_i = 141$. The thermal source noise at the amplifier input is equal to the noise generated by the 10 Ω source multiplied by the turns ratio. With a noise figure near zero, the total equivalent rms input noise is also equal to the noise generated by the 10 Ω source multiplied by the turns ratio, = 1 .25 μV rms. Although the numerical value of equivalent input noise is much larger than before, the signal-to-noise ratio is substantially increased. This can be seen by considering all of the transformed source signal voltage as appearing at the amplifier input terminals, possible because the Model 116's input resistance is much larger than the 200 kΩ presented by the transformer; the signal-to-noise ratio is equal to the maximum possible Value: $e_{sig}/(E \times \text{antilog } NF/20) = e_{sig}/E$, the noise contributed by the amplifier being negligible under the "near zero" noise figure conditions. In this example the transformer increases the signal-to-noise ratio by a factor of 10.

Signal-to-Noise Improvement Ratio =

$$10^{(\text{NF unmatched} - \text{NF matched})/20} =$$

$$10^{(20 - .1)/20} = 10^{1} = 10$$

However, because of the noise contributed by the transformer, and because a transformer influences bandwidth, the results obtained using a real transformer are never as good as the ideal theoretical results predicted in the example. Also, it is seldom convenient to obtain a transformer having exactly the ideal turns ratio. It is best, therefore, to use noise figure contours and amplitude transfer curves obtained empirically for the individual transformer. Figure 3-7 shows the NF contours and amplitude transfer curves for a Model 116 operated in the transformer mode. The 10 Ω amplitude transfer curve indicates that in this example the transformer does not change the 10% equivalent noise bandwidth as set with the Q switch, so that E remains 8.9×10^{-9} V rms. The noise figure for a 10 Ω source at a center frequency of 5

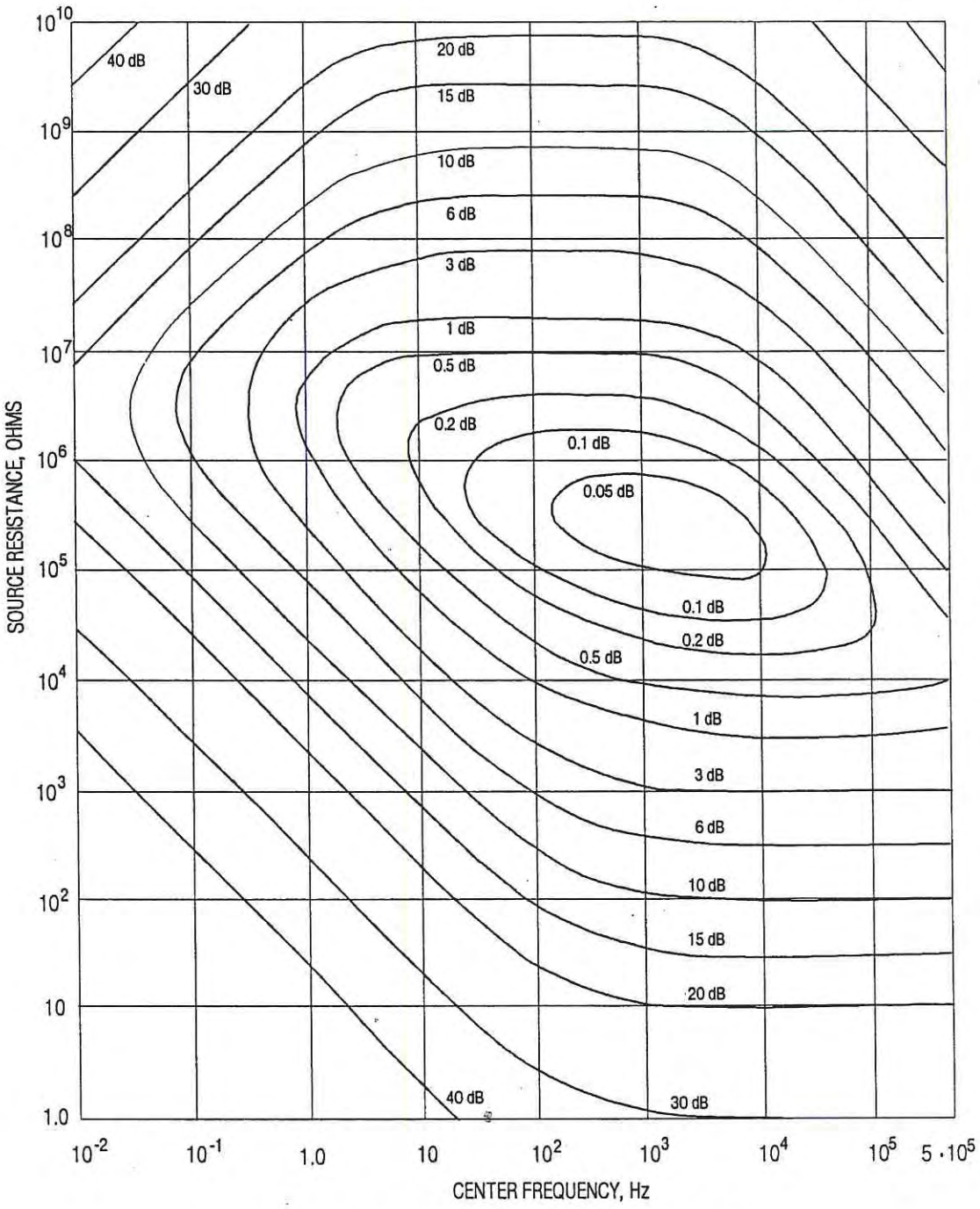


Figure 3-6. TYPICAL NOISE-FIGURE CONTOURS FOR MODEL 117, MODEL 116 (DIRECT) & MODEL 119 (DIRECT)

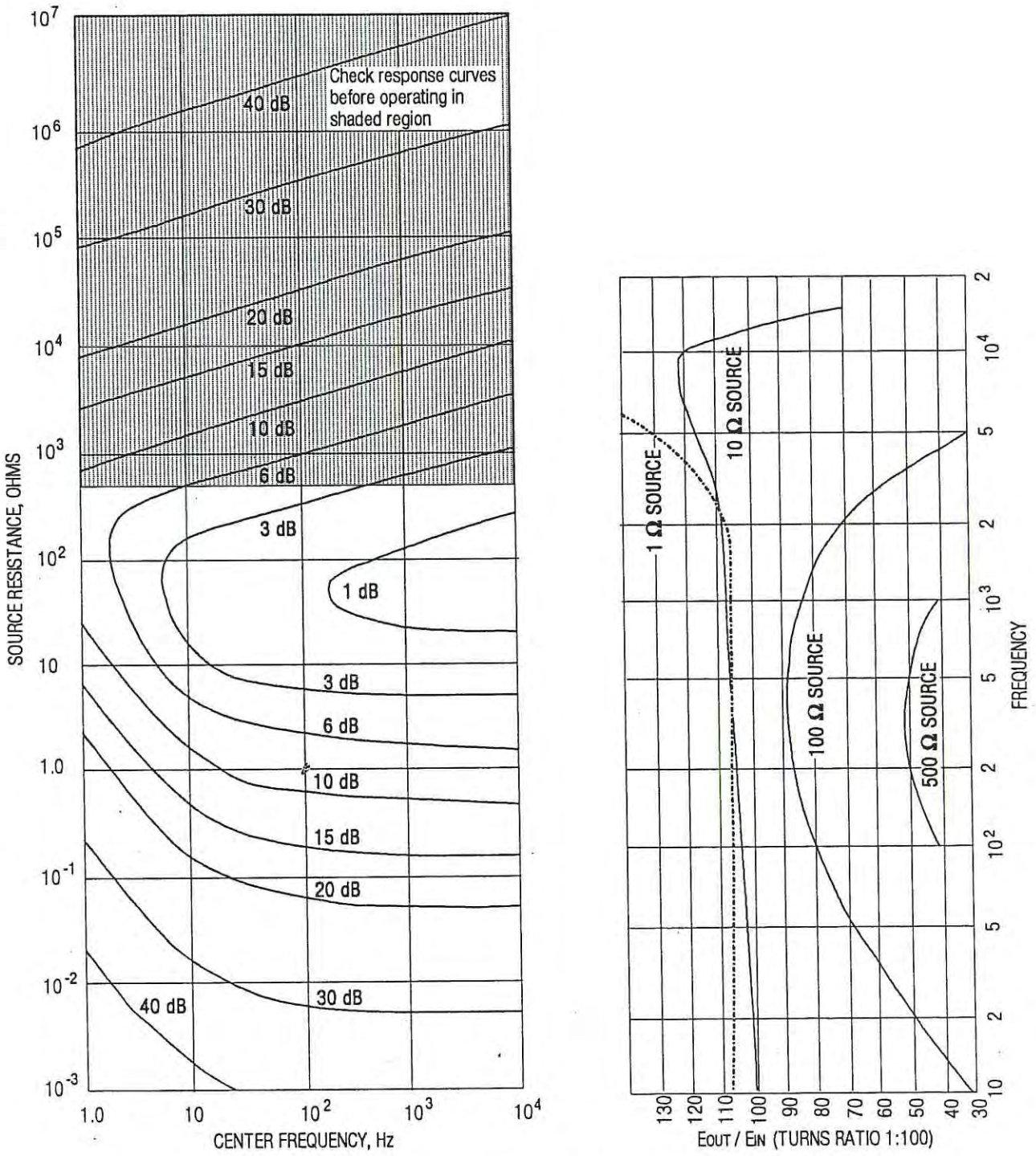
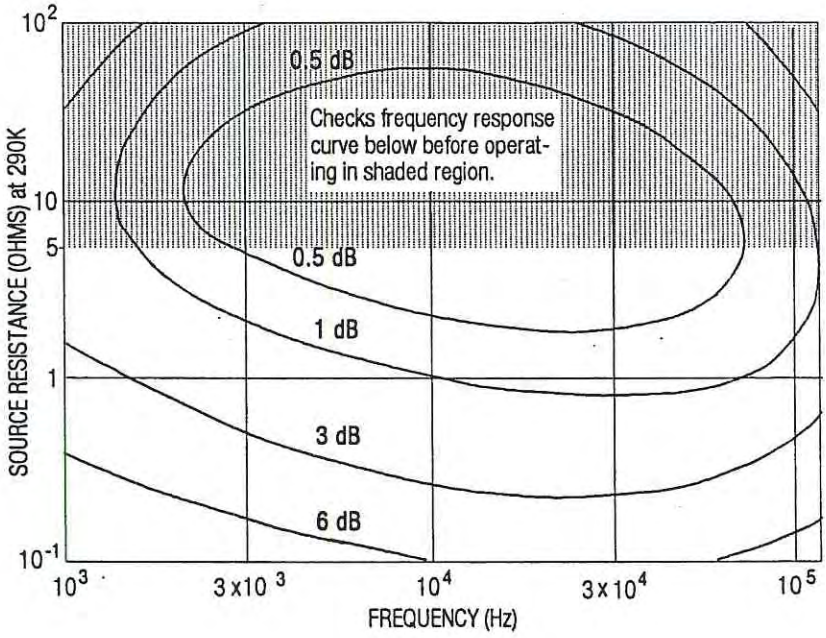


Figure 3-7. TYPICAL NOISE FIGURE AND AMPLITUDE TRANSFER CURVES FOR MODEL 116 OPERATING IN TRANSFORMER MODE



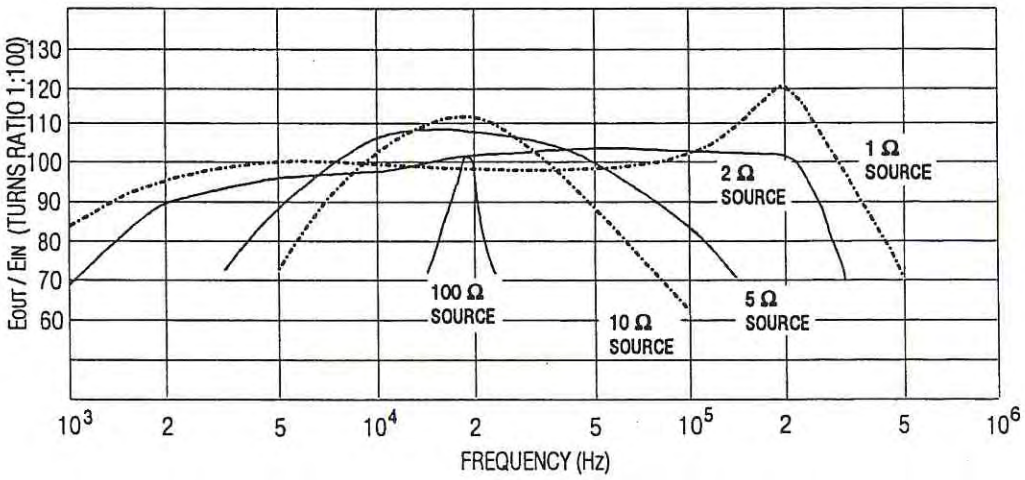


Figure 3-8. TYPICAL NOISE FIGURE CONTOURS AND AMPLITUDE TRANSFER CURVES FOR MODEL 119 OPERATING IN TRANSFORMER MODE

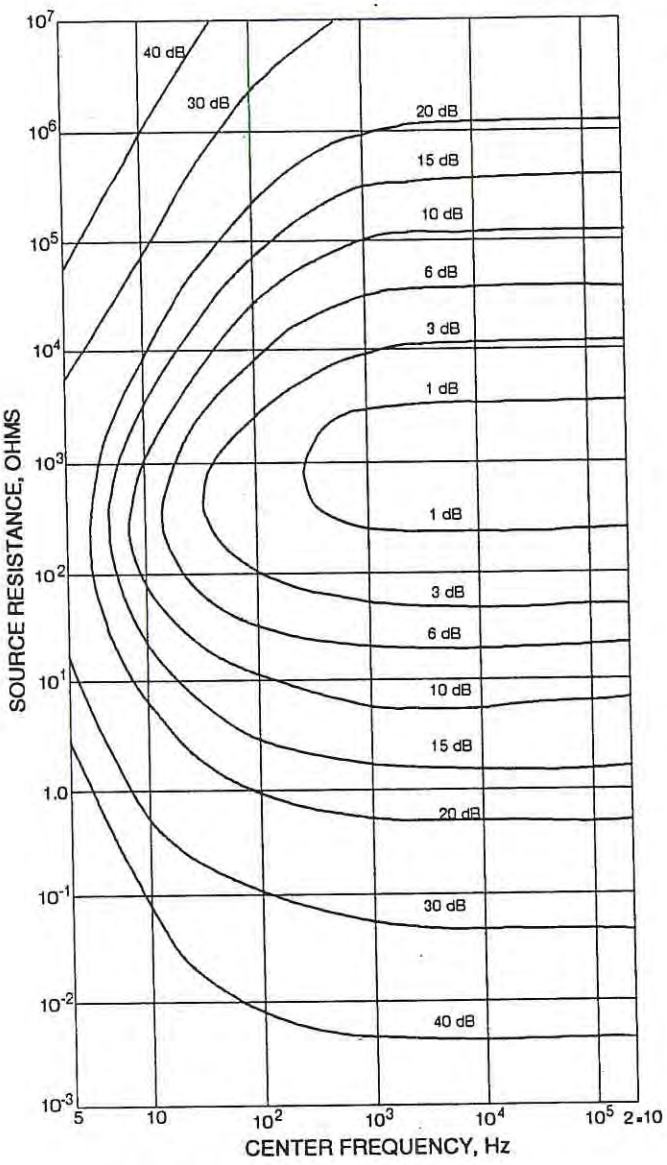


Figure 3-9. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 118

kHz is about 1.5 dB, a vast improvement over the 20 dB NF obtained without the transformer.

For optimum noise performance with a transformer, it is important that the transformer not be magnetized. A magnetized transformer is usually noisy and microphonic compared to when it is not magnetized. This noise is the most objectionable characteristic of a magnetized transformer because it affects low level signals. The distortion of high level signals described here is not usually an operating problem because the signal is seldom so large. But high level distortion is useful in determining the condition of the core and in monitoring the degaussing process.

Avoid passing excessive dc current through the primary of these transformers. The transformer used in the Model 116 and the Model 1900 transformer will permanently magnetize, and once magnetized, they will remain noisy until degaussed. More than 200 μA will magnetize the cores of these transformers. Do not measure winding resistance with an ohmmeter; ohmmeter current is sufficient to magnetize the core. The transformer used in the Model 119 has a ferrite core that will not permanently magnetize.

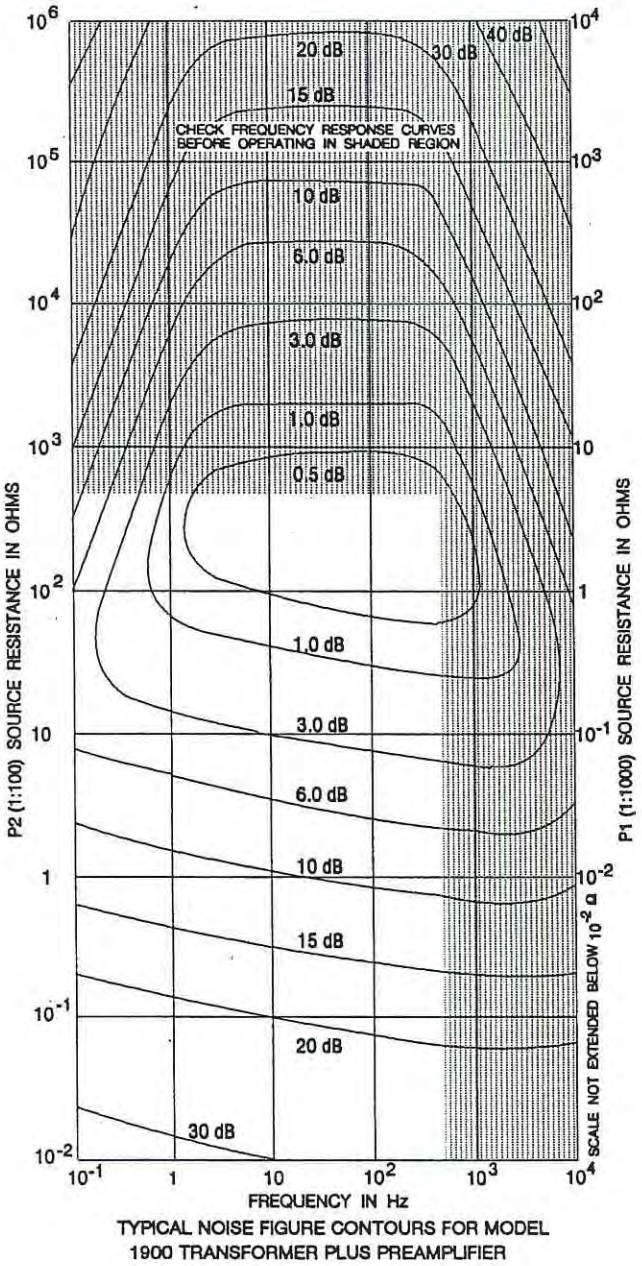
Notice from Figure 3-11 that, as long as the core is not magnetized, the transformer works on a loop around center line #1 and the signal can be of maximum amplitude. If the core becomes permanentty magnetized, the transformer works on a loop around center-line #2 (or equivalent for opposite polarity), and, if the same maximum signal current is applied, the core becomes saturated at one of the peaks of the signal. B, C, and D of Figure 3-11 show a primary signal current, corresponding core magnetization, and corresponding induced secondary voltage for a magnetized-core transformer with large signal input. Notice that the permanently magnetized core saturates sooner for one polarity of signal and later for the other polarity.

To demagnetize (degauss) the transformer, it is necessary to pass a relatively large dc current through the primary, then to very slowly decrease this current. The secondary should be open (for the Model 116, disconnect Pins 4 and 5 on the circuit board). The degaussing current is Initially large enough to magnetize the core in the direction of each corresponding polarity excursion of this current, and overrides the initial magnetization. By decreasing the current siowly, each successive magnetization will be slightly less than the preceding one of opposite polarity. As the current is decreased, the core is progressively less magnetized until it is no longer magnetized at all. Figure 3-12 illustrates the secondary waveforms as the transformer becomes demagnetized. **Important:** Use a **LOW FREQUENCY** degaussing current, 1 Hz or so, to avoid inducing excessively high voltage in the secondary, and monitor the secondary with a high impedance oscilloscope. The Model 19O0's secondary is protected with a neon lamp, but the Model 116's transformer could suffer insulation breakdown if the operator is not careful.

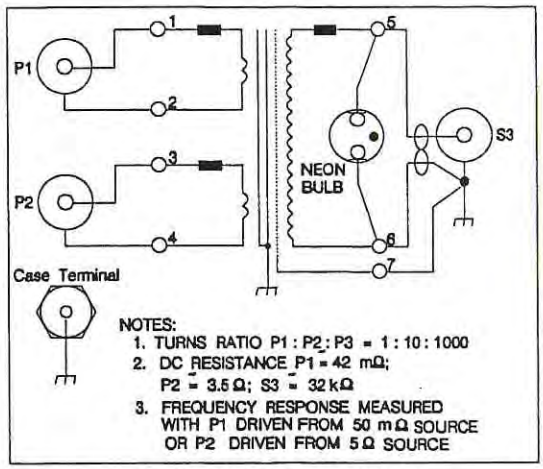
3.2H SELECTIVE AMPLIFIER

Noise other than source thermal noise is usually not wideband, and is often difficult to compute. Some kinds of noise can be dealt with very effectively using the Selective Amplifier. Examples include flicker (or 1/f) noise, nonsynchronous signals arising from the experiment, nonsynchronous signals from external pickup such as from the de power line, fast transients, and harmonics of the reference frequency.

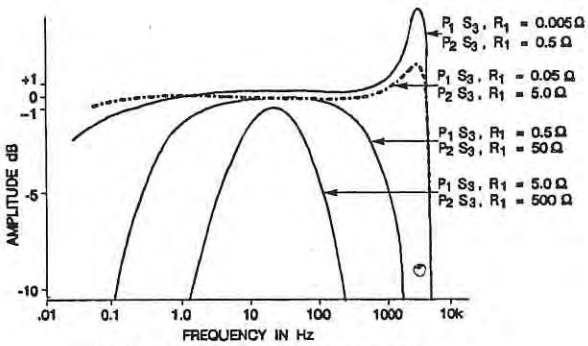
Reducing the noise level ahead of the mixer reduces the dynamic range demands on the mixer, thereby allowing signals to be measured which could not be measured otherwise.



TYPICAL NOISE FIGURE CONTOURS FOR MODEL 1900 TRANSFORMER PLUS PREAMPLIFIER



MODEL 1900 WIRING DIAGRAM



TYPICAL AMPLITUDE TRANSFORMER CURVES FOR MODEL 1900

Figure 3-10. MODEL 1900 CHARACTERISTICS & WIRING DIAGRAM

The Selective Amplifier can be operated in five different modes: Flat, Bandpass, Notch, Low Pass, and High Pass. Figures 3-13 through 3-16 illustrate typical transfer characteristics of the Selective Amplifier for the last four of these modes. Ultimate attenuation of the four frequency-dependent curves exceed 80 dB.

In selecting filtering parameters, the operator must be careful to keep the signal frequency well within the passband selected, or to make the passband such as to accommodate the signal over the range that it will occupy. If phase is important, actual measurements of phase error over the frequency range of questionable phase accuracy would be best. These regions of questionable accuracy can be determined from the individual transfer characteristics of the preamplifier, transformer, and Selective Amplifier settings. The best thing to do is to keep the bandwidth wide enough so that phase and amplitude errors are not a problem. Phase control errors are discussed in Section 3.3B. Special procedures for making accurate phase measurements are given in Section 3.9. In particular, before operating in LOW PASS or HIGH PASS, the operator is advised to check Figures 3-15 and 3-16 to determine the amplitude responses in these modes as a function of Q. "Equivalent noise bandwidth" is a concept applied to wideband noise. Although most bothersomenoise is not wideband, but rather, coherent non-synchronous signal, equivalent noise bandwidth

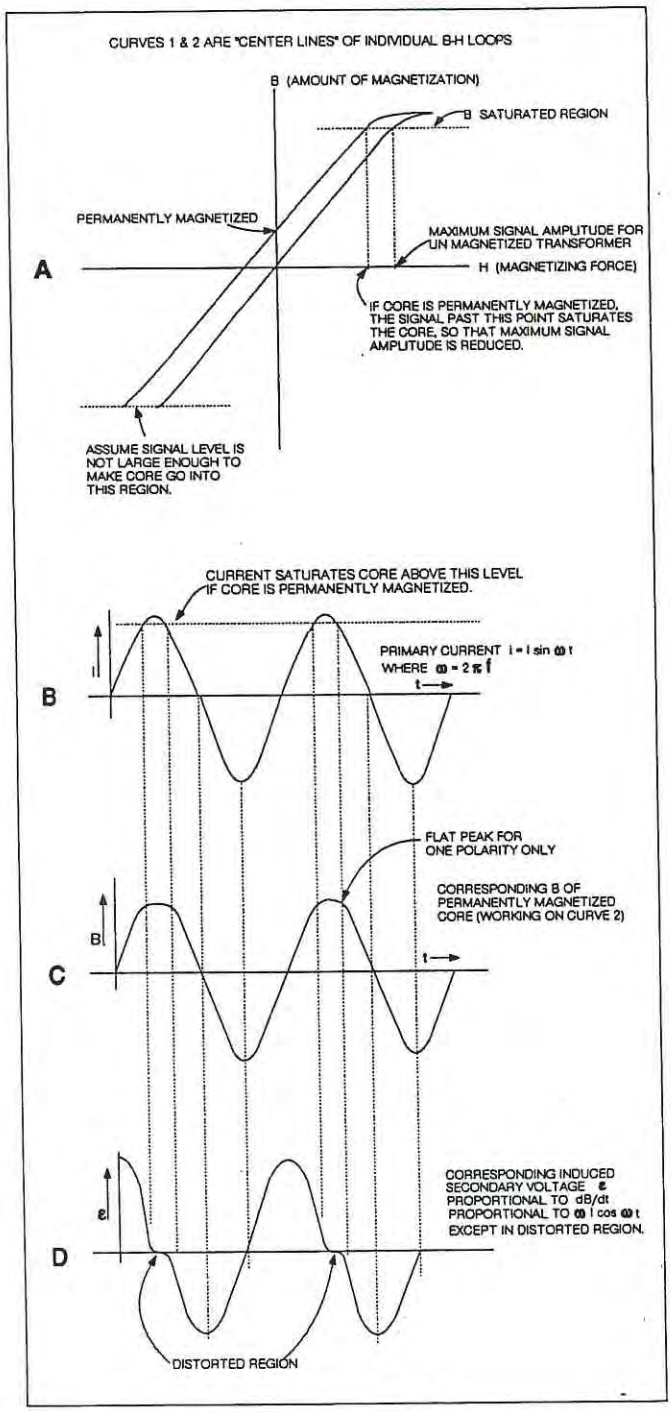


Figure 3-11. B-H CURVES AND WAVEFORMS

considerations are useful in helping to choose operating parameters. The concept of equivalent noise bandwidth arises from the fact that Noise signal bandwidths are specified as the number of Hz between two points of given attenuation on the response characteristic. Suppose one had a filter with a given signal bandwidth, and some amount of wideband noise, measured in volts/$Hz^{1/2}$, were applied to it. At the output of the filter one would measure some amount of rms noise voltage. The equivalent noise bandwidth of the filter is defined as the unattenuated bandwidth of an equivalent theoretical (but physically impossible) perfectly sharp filter that, with the same wideband input noise, yields the same rms output noise amplitude as the filter of interest.

On the Model 124A, notice from Figures 3-15 and 3-16 that the frequency dial setting corresponds to the last point for which the response is unity. However, signal bandwidth is ordinarily taken between 3 dB (half-power) points on the rolloff characteristic. For the Bandpass mode, 3 dB bandwidth is obtained from the standard formula for Q ($Q = fo/\Delta f_{3dB}$).

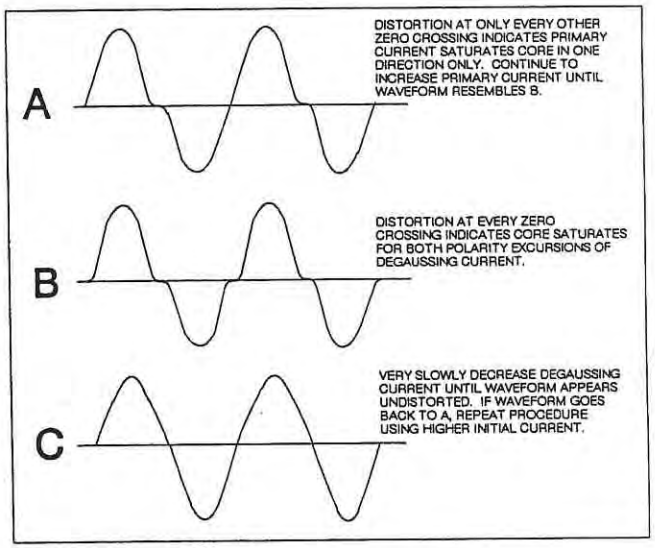


Figure 3-12. DEGAUSSING WAVEFORMS

Calculating ENBW (equivalent noise bandwidth) from the 3 dB bandwidth is frequently complicated. However, an exact conversion is seldom required. The 3 dB bandwidth and ENBW are of the same order of magnitude with the generally applicable (and sufficiently accurate) conversion factor being $\pi/2$. The FLAT mode ENBW is simply the 3 dB upper limit multiplied by $\pi/2$. The same applies to a close approximation for operation in the NOTCH mode. In LOW PASS operation, the ENBW is the product of the 3 dB down frequency as determined from Figure 3-15 times $\pi/2$. In HI PASS operation, the ENBW is $\pi/2$ times the square of the upper limit divided by the sum of the upper limit frequency and the 3 dB down frequency as determined from Figure 3-16. In BANDPASS operation, the ENBW is $\pi/2$ times f/Q, where f is the selected tuned frequency and Q is that selected by the Q switch. For all modes, bear in mind that if the signal bandwidth is limited ahead of the lock-in amplifier, the limited bandwidth applies.

In considering equivalent noise bandwidth, remember that the output meter is an average responding meter calibrated to indicate the rms amplitude of a sinewave. Gaussian noise, which has or has not been band-limited

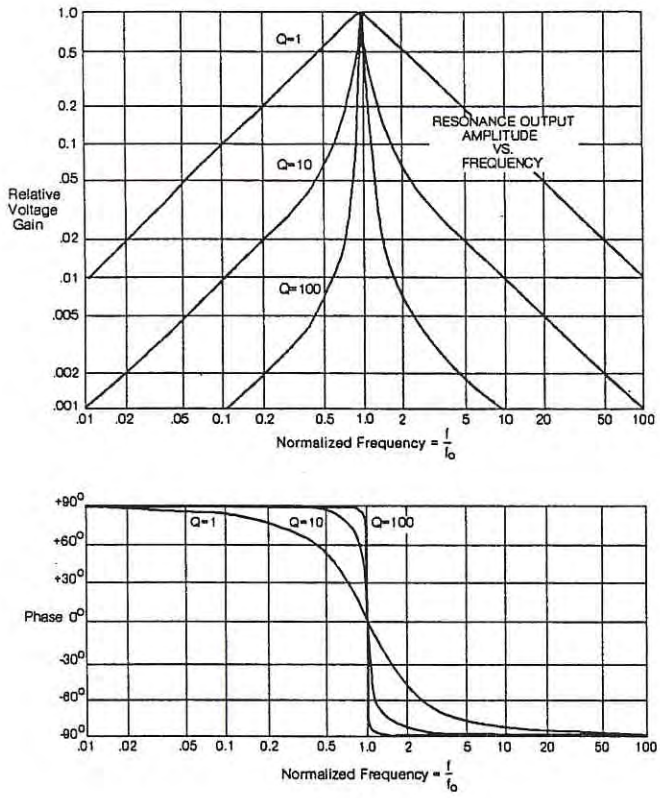


Figure 3-13. 124A BANDPASS CHARACTERISTICS

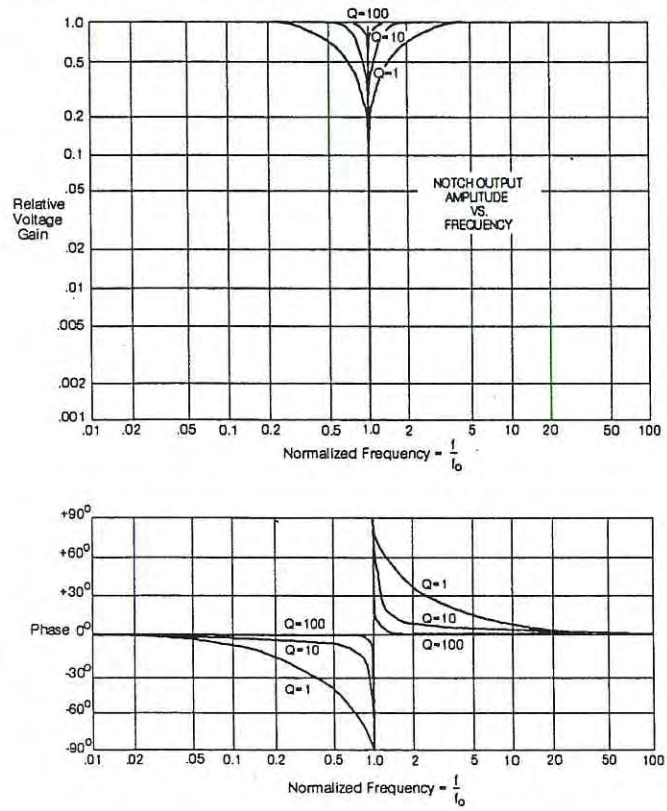


Figure 3-14. 124A NOTCH CHARACTERISTICS

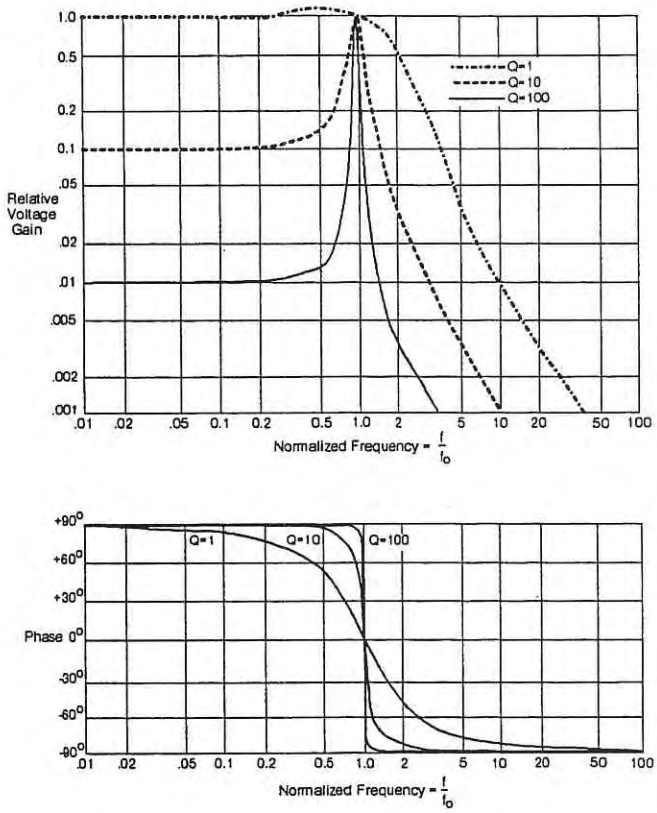


Figure 3-15. 124A LOW-PASS CHARACTERISTICS

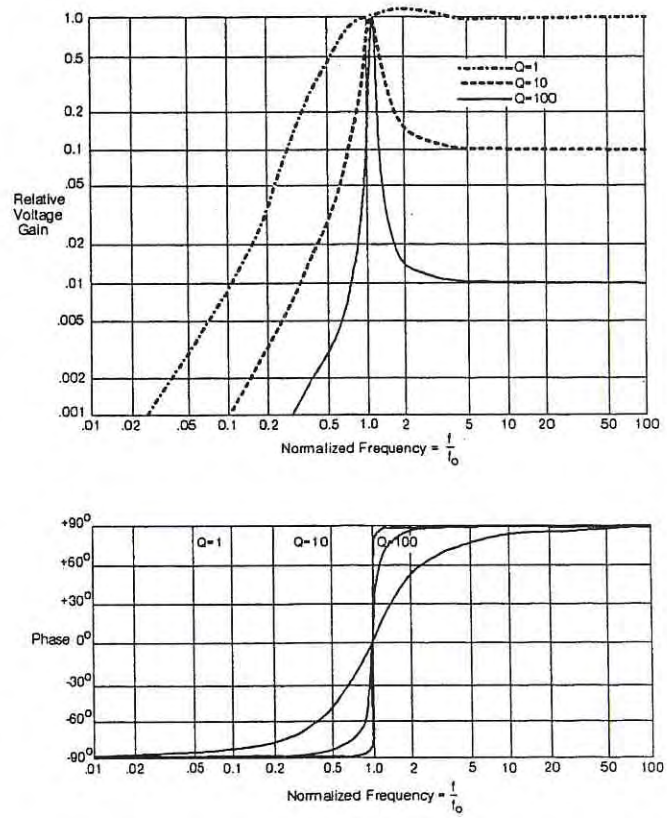


Figure 3-16. 124A HIGH-PASS CHARACTERISTICS

by filtering in the Signal and Output Channels, makes the meter indicate $(\pi/2)^{1/2}$ times the actual rms value.

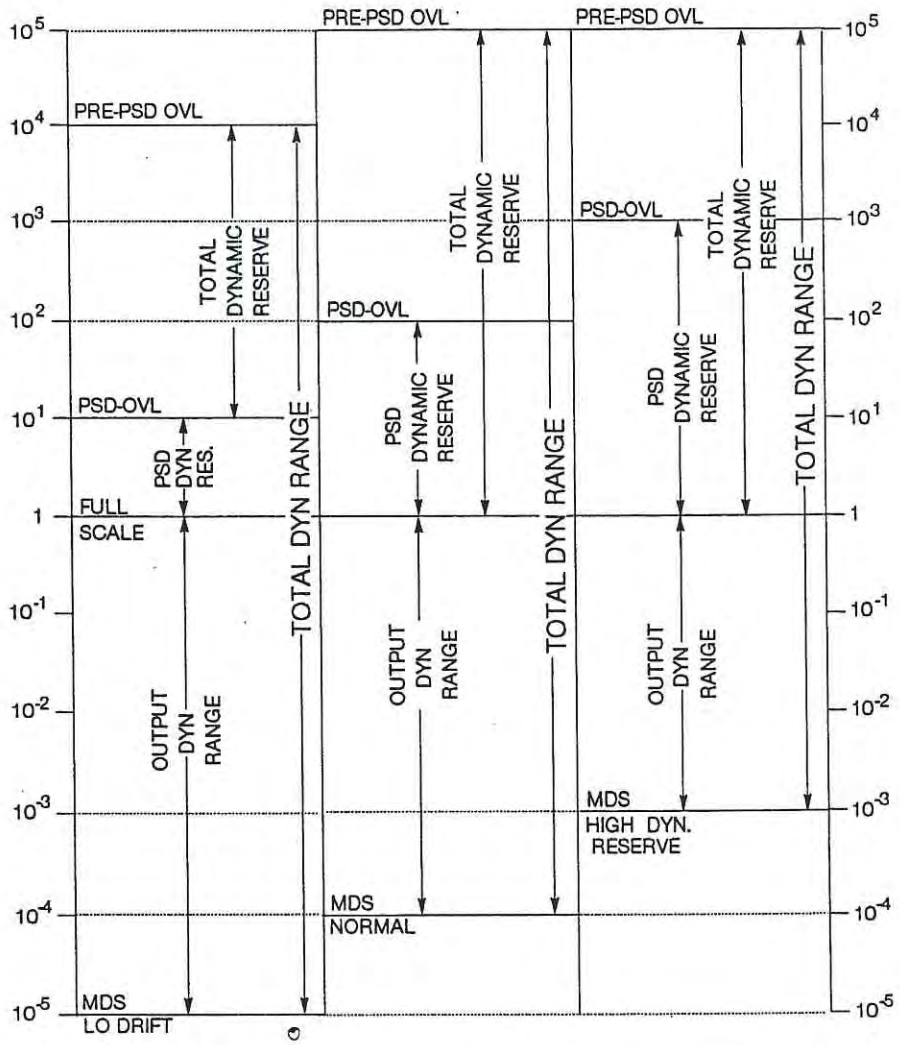
When the Q switch is set to 10% ENBW (bandpass mode), the Q of the tuned amplifier is not 15.7, as indicated above, but is instead 12.34. This lower Q is necessary to compensate the noise response of the dc voltmeter circuitry. If the voltmeter were a true rms responding voltmeter, then a Q of 15.7 would indeed be proper. With an average responding voltmeter circuit such as is employed in the Model 124A, exactly the same overall response is obtained with a Q of 12.34. In any case, 10% ENBW operation should prove suitable in most applications.

3.21 DYNAMIC RANGE

The TOTAL DYNAMIC RANGE of a lock-in amplifier is defined as the quotient of the maximum input that can be applied to the input without overload divided by the minimum discernible signal (MDS). Total Dynamic Range in turn is divided into two parts, each referenced to the input signal required to give full-scale output. The quotient of the amount of signal required for full-scale output divided by the minimum discernible signal is called the OUTPUT DYNAMIC RANGE. The quotient of the maximum input without overload (OVL) divided by the amount of signal required for full-scale output is called the DYNAMIC RESERVE of the lock-in amplifier. Thus, TOTAL DYNAMIC RANGE is simply the sum (logarithmic) of the OUTPUT DYNAMIC RANGE and the DYNAMIC RESERVE. All three are important in specifying the dynamic range characteristics of a lock-in amplifier, because, depending on where the division is made, the suitability of the lock-in amplifier to making a particular type of measurement can vary greatly. A lock-in amplifier with a Total Dynamic Range of 10^4 could have that Total Dynamic Range divided in several different ways. For example, it could have a Dynamic Reserve of 10^3 and an Output Dynamic Range of 10^1, in which case it would be well suited to processing very noisy signals but ill suited to processing small-amplitude noise-free signals. It could have a Dynamic Reserve of 10^2 and an Output Dynamic Range of 10^2, in which case it could stilt process moderately noisy signals and also be suitable for processing reasonably small noise-free signals. Finally, it could have a Dynamic Reserve of 10^1 and an Output Dynamic Range of 10^3, in which case its capability of processing a noisy signal would be severely restricted while its ability to process a small noise-free signal would be very good. Thus, the manner in which Dynamic Reserve is traded for Output Dynamic Range in a lock-in amplifier is one of the major factors involved in determining the suitability of the instrument for making a given measurement. In the case of the Model 124A, the operator has control of the dynamic tradeoff so that the dynamic range characteristics of the instrument can be optimized for the type of measurement at hand. The front-panel Function switch gives the operator the choice of LOW DRIFT, NORMAL, and HIGH DYNAMIC RANGE (Reserve) operation. Each position of the switch corresponds to a different division of the Total Dynamic Range into its Dynamic Reserve and Output Dynamic Range components.

The Dynamic Range characteristics of the Model 124A are illustrated in Figure 3-17. Referring to the figure, note that two different OVL levels are indicated. The first of these, the PSD OVL level, defines where the Phase Sensitive Detector overloads relative to a full-scale input signal. It is this overload level that determines the maximum tolerable input signal when the instrument is operated in the FLAT code. When the instrument is not being operated in the Flat mode, then the maximum tolerable input is extended to the PRE-PSD OVL for signals not in the passband of the characteristic selected (BANDPASS, NOTCH, HI PASS, LO PASS). Note that the PSD DYNAMIC RANGE of the instrument is 10^6 regardless of the selected dynamic tradeoff. Depending on the tradeoff selected, the PSD DYNAMIC RESERVE varies from 10^1 to 10^3 and the OUTPUT DYNAMIC RANGE varies from 10^3 to 10^5. The TOTAL DYNAMIC RANGE is 10^9 for LO DRIFT and NORMAL operation and 10^8 for HIGH DYNAMIC RANGE (Reserve) operation. In applications where the PSD OVL level is exceeded, the appropriate pre-PSD passband limiting is used to reduce the noise below the PSD OVL level so that the measurement can be made. Use of the Band pass, Notch, Lo-Pass and Hi-Pass characteristics in this manner does not improve the overall achievable improvement in signal-to-noise ratio, but it does achieve a real improvement in Dynamic Reserve, and hence in Total Dynamic Range. In FLAT mode operation, the PSD DYNAMIC RANGE and the TOTAL DYNAMIC RANGE are the same.

It should be noted that the Dynamic Range characteristics shown in Figure 3-17 are maximums, not applicable for all positions of the Sensitivity switch. In LO DRIFT operation, maximum Total Dynamic Range is attained with the Sensitivity switch set to 1 μV. Below 1 μV the Model 124A automatically transfers to NORMAL operation. In NORMAL and HIGH DYNAMIC RANGE (Reserve) operation, maximum Total Dynamic Range is attained with the Sensitivity switch set to 100 nV. For all three Dynamic Tradeoff possibilities, as the Sensitivity switch is set to successively lower sensitivities, the Total Dynamic Range available is proportionally reduced. Situations could arise where the signal to be measured was of relatively high amplitude, and accompanied by enough noise and interference to require that the lock-in amplifier have a very wide Total Dynamic Range. Where this is the case, attenuators can be used ahead of the lock-in amplifier to reduce the signal plus interference sufficiently to take advantage of the inherently wide Total Dynamic Range of the Model 124A. It is almost inconceivable that a real measurement problem could exist that would require all of the Total Dynamic Range available with this instrument.



NOTE: The indicated values of extended TOTAL DYNAMIC RESERVE are maximums, not achievable for all positions of the Sensitivity switch.

Figure 3-17. MODEL 124A DYNAMIC RANGE CHARACTERISTICS

3.2J DYNAMIC OVER-RIDE

Although the front-panel FUNCTION switch allows the operator to select LO DRIFT, NORMAL, or HI DYNAMIC RANGE (Reserve) operation, it is important to understand that the instrument does not necessarily operate with the dynamic tradeoff selected. For certain positions of the Sensitivity switch, there is an "over ride" action that determines the dynamic tradeoff independent of the setting of the Function switch, and it is the true or operating dynamic tradeoff that determines the overload and stability characteristics of the instrument. Thus, in using the tables that define the Overload and Output Stability of the Model 124A, the operator must always take care to read the data from the column corresponding to the true dynamic tradeoff, which may differ from that selected with the Function switch. The dynamic tradeoff obtained as a function of the setting of the Function and Sensitivity switches is as follows.

If the FUNCTION switch is set to:

LO DRIFT AND ACVM:

The unit operates in LO DRIFT except when the Sensitivity switch is set to 100 nV, 200 nV, or 500 nV. For those positions, the unit operates in the NORMAL mode and the NORMAL mode drift and noise tolerance specifications apply.

NORMAL:

The unit operates in NORMAL with Sensitivity switch settings of 100 nV through 50 mV. With settings of 100 mV through 500 mV it transfers to LO DRIFT.

HI:

The unit operates in HI with Sensitivity switch settings of 100 nV through 5 mV. With settings of 10 mV through 50 mV, it transfers to NORMAL, and with settings of 100 mV through 500 mV, it transfers

to LO DRIFT.

Generally speaking, one should operate with the switch set to LO DRIFT to take advantage of the excellent output stability obtained with this setting (see Table 3-1). However, if the noise level of the signal is high enough to overload the demodulator as explained in the following paragraphs, one can operate in either NORMAL or HI, in which the noise tolerance is increased by a factor of 10 or 100 respectively at the expense of degraded output stability.

DYNAMIC TRADEOFF	OUTPUT STABILITY	RMS OUTPUT NOISE VOLTAGE
LOW DRIFT	15 ppm/°C	10 ppm/$Hz^{1/2}$
NORMAL	100 ppm/°C	100 ppm/$Hz^{1/2}$
HI	1000 ppm/°C	1000 ppm/$Hz^{1/2}$

Table 3-1. STABILITY AND OUTPUT NOISE AS A FUNCTION OF OPERATING DYNAMIC TRADEOFF

3.2K OVERLOAD

Depending on the nature of the input signal plus noise, and on the control settings, overload can occur at several different points in the instrument. All of the critical points are monitored so that an overload anywhere in the instrument will operate the OVERLOAD light. From an operator's point of view, the problem with regard to overload is not one of determining whether overload is taking place (the Overload indicator light performs this function automatically), but rather of determining the proper action to take to eliminate the overload. The appropriate remedial action in turn depends on where the instrument is overloading. Each overload "tape" is considered in the following paragraphs.

1. DC Amplifier Overload

   Overload of the de amplifiers is the easiest type of overload to identify and detect. Such overload is usually the result of the signal amplitude (independent of noise) being too large for the selected sensitivity. When this is the case, the panel meter indication exceeds full scale and the Overload light turns on. The solution is simply to select a sensitivity setting which yields an on-scale indication.

   DC Amplifier overload can also be produced by a high-amplitude quadrature signal component, or by high amplitude spikes and other noise which may be reaching the Output Amplifier (the latter is particularly true when operating in the Flat mode). The test and solution is simply to increase the Time Constant setting. Except when operating with extremely noisy signals, a time constant of one second should suffice to eliminate quadrature and transient overload of the de amplifiers.

2. Demodulator Overload

Overload at the demodulator is also easily detected; one has only to monitor the signal at the Signal Monitor connector with an oscilloscope. If the signal exceeds 1.5 V pk, the demodulator is overloading. If the signal is less than 1.5 V pk, it is not.

There are several possible courses of action when faced with Mixer (demodulator) overload. First, one always has the option of operating the instrument with less sensitivity, Second, operating with a narrower bandwidth ahead of the Mixer may prove helpful. If the instrument is being operated in the Flat mode, and operation in the LOW PASS, HIGH-PASS, or, better yet, the BANDPASS mode is Possible, a considerable reduction in noise at the input to the Mixer may be achieved by making the transfer. If the instrument is operating in bandpass to begin with, increasing the Q will further decrease the bandwidth. If the interference is at a single frequency removed from the signal frequency, operating in the Notch mode with the signal channel tuned to the interference frequency may prove to be the best solution.

This third choice is to make a different tradeoff of dynamic reserve for output dynamic range. If the instrument is already operating with the Function switch set to HI, no improvement by this method is possible. If, however, it is operating with the switch set to NORMAL, a factor of ten reduction in the Mixer input signal amplitude can be obtained simply by setting the Function switch to HI. If the Function switch is set to LO DRIFT, a factor of 100 reduction in Mixer input signal amplitude is possible, the first factor of ten by setting the switch to NORMAL, the second by setting it to HI. In other words, in choosing the position for this switch, be sure to take the Mixer overload considerations into account as well as output drift requirements. Also, one should be aware of the dynamic override transfers that take place for certain positions of the Sensitivity switch as explained earlier.

Note that the Function switch gives a simple "test" for Mixer overload as well, which, though not as definitive as monitoring the signal at the Signal Monitor jack, may still prove useful. If the Function switch is set to LO DRIFT, and the Overload light is on, and setting the Function switch to NORMAL or HI causes the Overload light to go out, the problem is obviously one of Mixer overload. Similarly, if the switch is set to NORMAL (Overload Indicator on], and setting it to HI causes it to go out, the same is true. It does not necessarily follow that failure of the light to extinguish when making this test means the Mixer is not overloading.

MAXIMUM RMS SIGNAL INPUT						
	MIXER LIMITS			TUNED AMP LIMITS		
SENS	HI D.R.	NORMAL	LO DRIFT	HI D.R.	NORMAL	LO DRIFT
100 nV	110 μV	11 μV	←	19.6 mV	19.6 mV	←
200 nV	254 μV	25 μV	←	19.6 mV	19.6 mV	←
500 nV	635 μV	63 μV	←	19.6 mV	19.6 mV	←
1 μV	1.10 mV	110 μV	11 μV	19.6 mV	19.6 mV	19.6 mV
2 μV	2.54 mV	254 μV	25 μV	19.6 mV	19.6 mV	19.6 mV
5 μV	6.35 mV	635 μV	63 μV	19.6 mV	19.6 mV	19.6 mV
10 μV	11.0 mV	1.10 mV	110 μV	19.6 mV	19.6 mV	19.6 mV
20 μV	19.3 mV	2.54 mV	254 μV	19.6 mV	19.6 mV	19.6 mV
50 μV	19.3 mV	6.35 mV	635 μV	19.6 mV	19.6 mV	19.6 mV
100 μV	110 mV	11.0 mV	1.10 mV	196 mV	19.6 mV	19.6 mV
200 μV	193 mV	19.3 mV	2.54 mV	196 mV	19.6 mV	19.6 mV
500 μV	193 mV	19.3 mV	6.35 mV	196 mV	19.6 mV	19.6 mV
1 mV	720 mV	110 mV	11.0 mV	720 mV	196 mV	19.6 mV
2 mV	720 mV	193 mV	19.3 mV	720 mV	196 mV	19.6 mV
5 mV	720 mV	193 mV	19.3 mV	720 mV	196 mV	19.6 mV
10 mV	→	720 mV	110 mV	→	720 mV	196 mV
20 mV	→	720 mV	193 mV	→	720 mV	196 mV
50 mV	→	720 mV	193 mV	→	720 mV	196 mV
100 mV	→	→	720 mV	→	→	720 mV
200 mV	→	→	720 mV	→	→	720 mV
500 mV	→	→	720 mV	→	→	720 mV

Table 3-2. MAXIMUM RMS INPUT LEVELS FOR MIXER AND TUNED AMPLIFIER OVERLOAD AS A FUNCTION OF SENSITIVITY AND OPERATING DYNAMIC RANGE

It may prove useful to know the maximum rms input sinewave signal that can be applied to the input of the instrument without overloading the Mixer as a function of the Sensitivity and Operating Dynamic Trade-off. The input overload limits for both the mixer and the tuned amplifier are shown in Table 3-2. By referring to this table, the operator can quickly determine the best way to process a given signal with the Model 124A. For example, suppose one had a signal of nominally 1 μV amplitude. Consider the possibilities for measuring this signal given different noise levels. From Table 3-2, the mixer limit with a Sensitivity setting of one microvolt is 1.10 mV, 110 μV, or 11 μV, according to the dynamic tradeoff. What this means practically is that for noise levels below 11 μV, the signal could be measured in the FLAT mode with the Function switch set to LO DRIFT (Normal and Hi operation is, of course, also possible). If the noise level is greater than 11 μV, but less than 110 μV, LO DRIFT operation in the FLAT

mode is not possible and the operator will have to either operate in NORMAL (or Hi) or narrow the noise bandwidth ahead of the Mixer by means of the tuned amplifier. This is usually best accomplished by operating in BANDPASS. By sufficient narrowing of the pre-demodulator bandwidth, LO DRIFT operation may still be possible even with the higher input noise level. If the noise exceeds 110 μV, but is less than 1.10 mV, FLAT mode operation is only possible with the Function switch set to HI, although NORMAL, or, conceivably, even LO DRIFT operation may still be possible by sufficiently narrowing the bandwidth ahead of the Mixer. If the Noise level exceeds 1.10 mV, then FLAT mode operation becomes impossible and the operator must narrow the bandwidth ahead of the Mixer. Finally, if the input noise exceeds 19.6 mV rms, the Selective Amplifier overloads and the signal cannot be measured with the Model 124A. The only possibilities in that case are to narrow the bandwidth ahead of the lock-in amplifier, or to attenuate ahead of the lock-in amplifier, whichever technique most conveniently reduces the input noise below the 19.6 mV limit.

As a general rule, it is most desirable to operate in LO DRIFT and with the bandwidth ahead of the Mixer at maximum (FLAT). If the noise levels are such as to force tradeoffs, the operator must decide which is better to give up first, output drift or a flat pre-mixer response. Where the noise level is extremely high, there is no choice but to give up both. One way to approach the problem is to:

a. Set the Function switch to ACVM to get an idea of the signal plus noise rms amplitude.

b. Based on an estimate of the signal amplitude, determine the best combination of operating dynamic range and pre-detector bandwidth control from Table 3-2. Be sure the Sensitivity setting considered is that appropriate to the expected signal level. For a noisy signal, the Sensitivity setting will be very much different from that used in the preceding step, where one was measuring the signal plus noise.

c. Set the controls as determined in "b" and attempt the measurement. Some experimentation may be required to achieve the optimum control settings.

3. Pre-Mixer Overload
Circuits ahead of the Mixer only overload when the input level exceeds the Tuned Amplifier Limits indicated in Table 3-2. In any case, there is relatively little one can do at the Model 124A in the case of pre-mixer overload. The only action that might help is to reduce the sensitivity. For example, suppose one wished to measure a 500 μV signal accompanied by 400 mV of noise. From Table 3-2, it is clear that the Tuned Amplifier would overload if the measurement were attempted on the 500 μV sensitivity range. However, by setting the Sensitivity switch to 1 mV, the overload tolerance is increased to 720 mV, and the measurement can be made. This technique is most useful when one is near an overload tolerance crossover point, as in the example just given. Should one be far from such a point, the likelihood of improving the situation in this matter becomes remote. For example, suppose one had a 1 μV signal accompanied by 40 mV of noise. The nearest sensitivity position that could be used without overloading the Tuned Amplifier is 100 μV, where the signal would be only 1% of full scale. Given the high noise level, it would be very difficult to detect a 1% of full-scale signal, even if a very long time constant were used.

At no time can the input exceed 720 mV rms without overloading the instrument. With large input signals, this limit prevents one from processing very noisy signals. However, by inserting an attenuator ahead of the lock-in amplifier, large amplitude signals having poor signal-to-noise ratios can be measured.

3.2L OFFSET DUE TO NOISE

Because of imperfections in the Phase Sensitive Detector, large input noise levels can cause offsets to appear at the output. As shown in Figure 3-18, these offsets are generally so small as to be negligible. Even with the extremely high 1000 times full scale noise levels which can be processed in high dynamic reserve operation, the offset is typically only 1%.

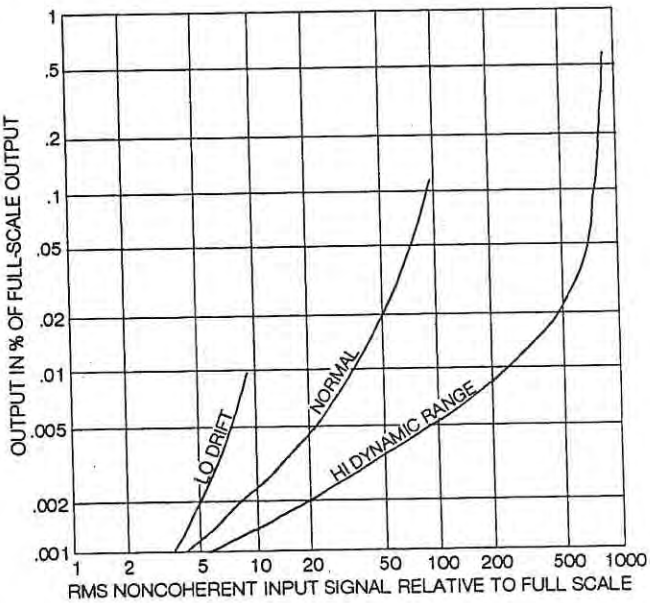


Figure 3-18. TYPICAL OUTPUT OFFSET AS A FUNCTION OF INPUT NOISE

3.2M OVERLOAD RECOVERY

The frequency range of the Signal Channel, excluding the

Preamplifier range, is 2 Hz to 210 kHz on the standard models, or 200 mHz to 210 kHz if requested upon ordering. Unless very low frequency response is really needed, we advise that units not be ordered with 200 mHz response because larger coupling capacitors make recovery time from overload much longer than for units with 2 Hz response. Typical maximum overload recovery time for units having 2 Hz LF response is 30 seconds, for 200 mHz units, 80 seconds.

3.2N SIGNAL MONITOR

The output of the Signal Channel goes to the Synchronous Detector and to the Signal Monitor jack. The Signal Monitor output is useful for monitoring the signal after Signal Channel filtering. This output makes the Model 124A usable as a straightforward Low Noise Tuned Amplifier, which can find many applications.

Notice from the Functional Block Diagram (Figure 3-1) that the signal from the Signal Channel is attenuated before being applied to the Signal Monitor jack. This is because the amplification in the Signal Channel is such as to make the average-responding meter at the Detector output indicate the rms value of the detected signal. The attenuator at the Signal Monitor jack sets the signal to a more convenient level.

The Signal Monitor output impedance is 600 Ω. The output signal amplitude corresponding to a full-scale input depends on the dynamic range. In LO DRIFT, a full-scale input yields 100 mV rms out (sinewave in; sinewave out). In NORMAL, a full-scale input yields 10 mV out, and in HI DYNAMIC RANGE a full-scale input yields 1 mV rms out. These figures depend on the "true" operating dynamic range, which, as explained earlier, according to the selected sensitivity, can differ from the dynamic range selected with the Function switch.

3.3 REFERENCE CHANNEL OPERATION

3.3A SYNC INPUT/OUTPUT

In the External Sync mode, the Reference Channel VCO automatically phase-locks to any kind of reference waveform at a frequency within the two decades listed in Table 3-3, the only requirements being that the waveform cross its mean exactly twice each cycle, that it have a peak-to-peak amplitude of at least 100 mV, and that it be synchronized with the signal of interest. The positive-going zero crossing of the zero reference phase of the VCO sinewave is coincident with the positive-going zero crossing of the sync input waveform. The VCO can be made to lock to the second harmonic of the reference signal by placing the Mode switch in the Ext. f/2 position. Maximum sync input frequency in f/2 is 105 kHz. Sync input R = 1 MΩ.

A Reference Unlock panel indicator lights when the VCO is out of Sync with the reference signal.

Often, the frequency of the signal being detected is changing. As long as the reference maintains a fixed frequency and phase relationship to the signal, detection is no different than for fixed-frequency signals. However, it is necessary that the frequency does not change so fast that the oscillator cannot stay locked in. Figure 3-19 provides stewing rate information for the oscillator.

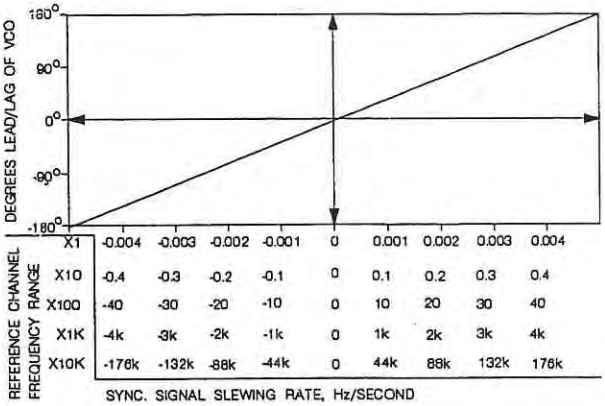


Figure 3-19. TYPICAL REFERENCE OSCILLATOR SLEWING RATE

BAND	FREQUENCY RANGE	MAX TIME
X1	200 mHz to 21 Hz	15 min
X10	2Hz to 210 Hz	2 min
X100	20Hz to 2.1 kHz	10 sec.
X1K	200Hz to 21 kHz	2 sec.
X10K	2.1 kHz to 210 kHz	2 sec.

Table 3-3. MAXIMUM FREQUENCY ACQUISITION TIMES OF OSCILLATOR

Because of the rapidity of the External Reference circuitry response time, some care must be taken to assure that there are no "extra" mean crossings in the applied reference signal. If extra crossings should occur, the Model 124A will see them as bursts of some higher reference frequency, which the Reference Channel will attempt to follow, causing phase clock loss and improper drive to the demodulator. There are three common ways in which problems of this nature occur. First, any noise accompanying the signal can cause multiple mean-crossings to occur in the region of the rise and fall of the reference signal. Thus the reference signal applied must be relatively clean. Frequently, moderately noisy signals can be cleaned up sufficiently for satisfactory operation by using a simple single-section low-pass filter. Second, if the applied reference signal has very fast rise and fall times, it will be necessary to terminate the reference signal cable in its characteristic impedance to prevent ringing. Ringing of sufficient amplitude will upset the reference circuitry in the same manner as noise. The third way of introducing additional crossings is to allow interference from motors, light switches, or any spark generating equipment to contaminate the external reference signal. Use of a shielded cable to carry the reference signal will generally prove helpful. Also, whenever possible, the amplitude of

the reference signal should be large relative to the amplitude of any possible interference, External reference signal levels on the order of several volts are advisable where interference could be a problem.

In either of the external modes, offset at the output of the Model 124A is less than 1 ppm for a shift in symmetry of the sync input signal from 0.1% to 99.9%. The response to even harmonics (Tables 3-4 & 3-5) is unchanged for this range of dissymmetry

In the Ext. and Ext. f/2 modes, one can greatly reduce the time that it takes the Oscillator to lock to the reference waveform if one knows in advance the frequency of the externally applied reference. To achieve phase lock in the minimum possible time, proceed as follows:

1. Set the frequency controls to the desired frequency (for example, if the externally applied reference is 400 Hz and the desired mode is Ext., dial in 400 Hz: if the desired mode is Ext. f/2, dial in 800 Hz).

2. Set the Mode switch to INT. for a few seconds. This presets the reference frequency so that the Oscillator does not have far to search. Then switch back to Ext. or Ext. f/2, whichever is to be used.

In the Internal mode, a sinewave output from the Oscillator is provided for synchronizing the experiment. The Oscillator can free run at any desired frequency from 200 mHz to 210 kHz, and the frequency can be accurately set with the digital controls. It is possible to move the frequency above or below the dialed frequency by applying voltage to the rear-panel VCO Input connector. By setting the dials to zero, the frequency is determined entirely by the VCO input voltage, with 0 to 10 volts corresponding to the full range of the set band. The set band can be swept in one second.

The sync sinewave output level can be adjusted to any value from 0 to 10 V rms, with eight intermediate calibrated levels. Output R = 600 Ω. This sinewave output is available even when the Oscillator is controlled by an external sync signal.

3.3B PHASE CONTROLS

The Phase controls set the phase of the synchronous detection process with respect to the phase of the sync signal. The operator adjusts the.Phase Controls for maximum meter indication. At maximum, the meter reading represents the detected signal amplitude, and the phase of the signal can be read from the phase dials.

The ease with which the fine phase control can be adjusted depends on how steadily the meter holds, and this depends in turn on the steadiness of the signal amplitude and the final noise level. The final noise level depends on the original noise level and on how well the Signal Channel and output filters are set.

When adjusting the phase controls for maximum, the amplitude peak varies as the sine of the phase adjustment; i.e., the fine peak adjustment is relatively flat, and a small amount of residual noise could make the peak hard to find. One way to get around this is to adjust the controls for as close to a peak as possible, then change the Phase Quadrature control setting by 90° and adjust for zero. This quadrature zero varies as the cosine of the phase adjustment, and is, therefore, more sensitive than the peak adjustment. The Phase Quadrature control can then be switched back to the in-phase quadrant and the reading taken. If the output signal is very clean, adjusting for the peak, rather than for quadrature null, may be more accurate because the effects of phase control error are avoided.

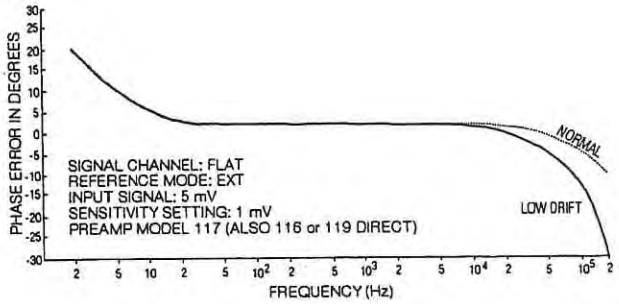


Figure 3-20. NET PHASE DIFFERENCE BETWEEN SIGNAL AND REFERENCE CHANNELS AS A FUNCTION OF FREQUENCY

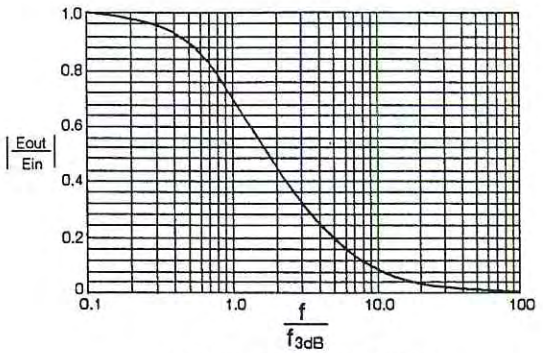
The ten-turn potentiometer, which spans 100°, together with the quadrant switch, allows the entire 360° to be covered with 0.1° resolution. The linearity is within ±2° from 2 Hz to 21 kHz and ±5° above 21 kHz. Remember that the actual difference of phase between the signal and reference channels can be in excess of the phase-shifter accuracy, depending on the filter settings and also on the frequency. Special procedures for accurately measuring the phase are given in Section 3.9.

Note: When operating the Signal Channel in the Bandpass mode, particularly with high Q, the frequency dials must also be fine-adjusted for peak meter reading. Otherwise, the filter rolloff will attenuate the signal and also cause a phase error. In all circumstances, attenuation and phase shift in the Signal Channel must be minimized or accounted for.

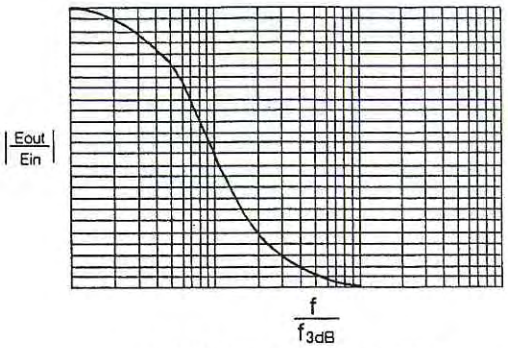
3.4 OUTPUT CHANNEL OPERATION

3.4A FILTER TIME CONSTANT

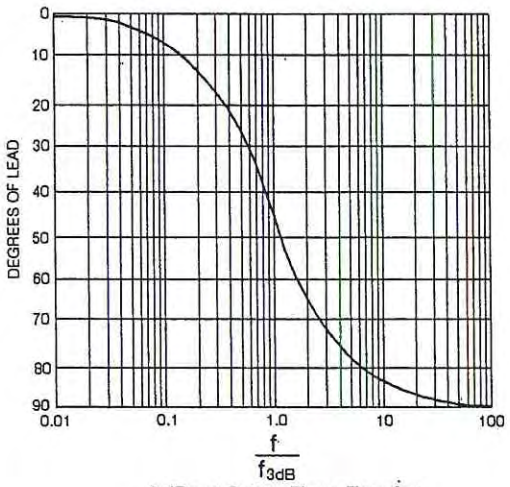
The amplified and filtered signal is synchronously detected with respect to the phase-shifted Reference Channel signal, and the detected signal is applied to the RC low-pass filter. Either a one section or a two section filter may be selected with the center knob of the Time Constant switch.



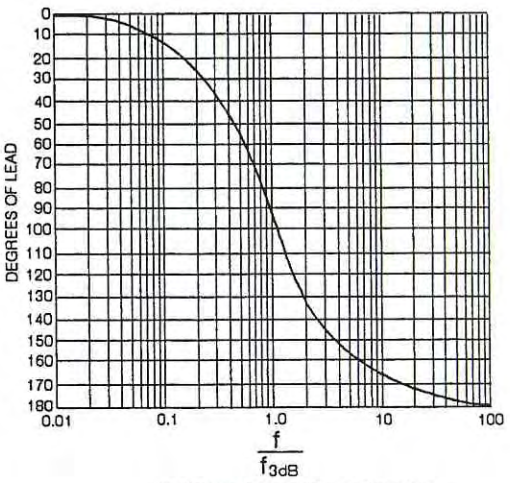
6 dB/Octave Amplitude Transfer



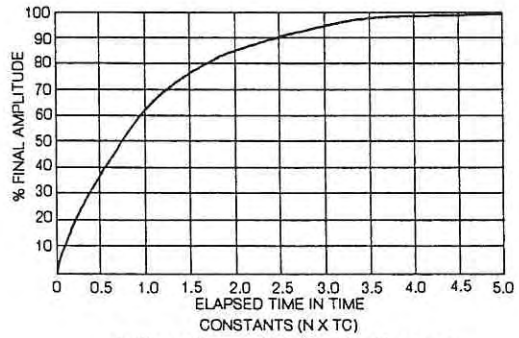
12 dB/Octave Amplitude Transfer



6 dB per Octave Phase Transfer



12 dB per Octave Phase Transfer



6 dB per Octave Step-Function Response

12 dB per Octave Step-Function Response

Figure 3-21. OUTPUT FILTER TRANSFER FUNCTIONS

The one section filter has a 6 dB/octave rolloff characteristic and an equivalent noise bandwidth of 1/4TC. The 3 dB down point on the frequency axis is $1/2\pi TC$. In the time domain, it has a step-function response of $1 - e^{-t/TC}$. The rise time from 10% of full amplitude to 90% of full amplitude is 2.2TC seconds, and from 0 to 95% is 3TC seconds. With the TC switch set to 300 s, the equivalent noise bandwidth is ≈800 μHz.

The two section filter has a 12 dB/octave rolloff characteristic and an equivalent noise bandwidth of 1/8TC. The 6 dB down point on the frequency axis is $1/2\pi TC$. In the time domain, it has a step-function response of: $1 - (1 + t/TC)e^{-t/TC}$

The rise time from 10% of full amplitude to 90% of full amplitude is 3.3TC seconds, and from 0 to 95% is 4.8TC seconds.

To obtain a time constant greater than 300 seconds, set the Time Constant switch to the Ext. position and connect a pair of capacitors of equal value between pins 8-9 and 10-11 of the rear-panel octal socket. To determine the time constant for this external mode, multiply the single capacitor value (in Farads) by 30 MΩ. The external capacitors should be low-leakage film tapes (mylar, polycarbonate, polystyrene, teflon) rated at 25 V or higher.

The Time Constant should be set so that the output noise, either as read on the panel meter or on the external monitor, is reduced to an acceptable level. If the signal amplitude is steady (independent of noise), a fairly long time constant can be used because the lag time in setting the phase controls can usually be tolerated. However, if the signal varies over a period of time, and the operator wants to observe the variations, a shorter time constant must be used at the expense of greater noise. Sometimes, for the latter case, the Signal Channel filter can be readjusted for less noise after operating parameters are better established.

When operating the instrument as a wideband dc voltmeter (by placing the function switch in the ACVM position], the Time Constant switch should be set to dampen the meter.

3.4B OFFSET CONTROLS

The ten-turn dial and its associated polarity switch allow calibrated offsets of up to ten times full scale to be applied. Two applications for this feature are that it allows small amplitude variations in a signal to be expanded and examined in detail, and that it allows a signal amplitude to be read with greater resolution than is possible with the panel meter alone. For example, suppose one had a meter indication to the right. To read the amplitude with the greatest possible resolution, the polarity switch would be set to "t" and the dial adjusted for "null" at which time the signal amplitude could be read directly from the dial.

The following example illustrates use of the Zero Suppress feature to "expand" signal amplitude variations. Suppose one had a 70 μV signal. Assuming this signal were measured on the 100 μV sensitivity range, the resulting meter indication would be 70% of full scale. To examine small variations in this signal, one would first set the Polarity switch to "+" (assume initial meter indication was to the right), followed by adjusting the dial for null. The dial setting required would be 0.70 and the meter sensitivity would be ±100 μV with respect to the 70 μV ambient level. A recorder connected to the output would allow the amplitude variations as a function of some experimental parameter to be recorded.

Because the range of the Offset dial extends to ten times full scale, the measurement can be modified slightly so that the amplitude variations are greatly expanded. In the example at hand, the Sensitivity switch could be set to 10 μV. Because the signal amplitude, 70 μV, is less than ten times the selected sensitivity (10 x 10 μV = 100 μV), it is within range of the offset dial. If the dial were adjusted for null (setting of 7.00), the meter range would then be ±10 μV full scale with respect to the 70 μV ambient signal level.

3.5 HARMONIC RESPONSE

The Synchronous Detector responds to signals which are harmonically related to, and synchronized with, the fundamental. The harmonic response is less than the fundamental response, but still may be large enough to cause significant errors in the fundamental measurement.

Remembering that Synchronous detection has features similar to full-wave rectification, one would see immediately from symmetry considerations that the response to even harmonics is different from the response to odd harmonics. For odd harmonics, the detector response relative to the fundamental response is simply 1/n, where n is the number of the harmonic. For example, the third harmonic response is 1/3 the fundamental response, the fifth harmonic response is 1/5 the fundamental response, etc.

Theoretically, the Synchronous Detector should have no response at all to even harmonics. However, the reference waveform is not perfectly symmetrical, causing a small response. The even harmonic response due to dissymmetry can be expressed as:

$$\text{Response Rel. to Fundamental} = (\sin n\pi(1 + e)/2)/n$$

where n is the number of the fundamental and e is the fractional departure of the half period from the actual half period of the reference waveform. If n is even and ne is very much smaller than unity, the expression simplifies to, approximately, $\pi e/2$. In other words, the response to all even harmonics is about the same and is determined by the symmetry of the reference signal at the Phase Sensitive Detector.

In general, a given half cycle of the reference signal will be within 0.3% of half the period, giving 0.003 as the value of e. Inserting this into the formula, one obtains 0.5%, a good working value for the response to even harmonics. Actual symmetry error varies with the phase setting, so that the response to even harmonics can be less than 0.5%.

The harmonic sensitivity of the Synchronous Detector is one reason for minimizing the passband of the Signal Channel. The portion of overall output due to harmonics will be reduced by the attenuation factor the Signal Channel provides at those frequencies. Transfer curves in Figures 3-13 through 3-16 should be referred to. Table 3-4 lists typical measured Synchronous detector responses to harmonics. Table 3-5 lists overall responses to these same harmonics if operating in the Bandpass mode with a Q of 10.

Harmonic	0°	90°	180°	270°
2nd	0.15%	0.5%	0.2%	0.5%
3rd	35%	35%	35%	35%
4th	0.13%	0.55%	0.25%	0.7%
5th	15%	15%	15%	15%

Table 3-4. TYPICAL HARMONIC RESPONSE OPERATING IN THE FLAT MODE

Harmonic	0°	90°	180°	270°
2nd	0.017%	0.017%	0.008%	0.04%
3rd	1.2%	1.2%	1.2%	1.2%
4th	0.0035%	0.014%	0.006%	0.017%
5th	0.35%	0.35%	0.35%	0.35%

Table 3-5. TYPICAL HARMONIC RESPONSE OPERATING IN BANDPASS MODE WITH Q = 10

These considerations and examples assume the worst possible phase relationship between the harmonic and the reference signal. Practically encountered phase relationships are not usually the worst case, and the true error will be smaller than the computed error.

A related problem is that of errors resulting from subharmonic components of the input signal. Subharmonic signals do not directly contribute to the output indication; that is, the Detector does not respond to them. However, if a subharmonic is distorted in the Signal Channel, output errors can be introduced. This is because distortion results in higher harmonics being generated, to which the Detector is sensitive, especially the harmonic at the primary detection frequency.

Subharmonics are not generally a significant component of the input signal, except, perhaps, when the Reference Channel is operated in the Ext. f/2 mode. In this situation, and ones similar to it, the second harmonic is regarded as the fundamental for the Signal Channel, and the original sync input fundamental is regarded as a large-amplitude subharmonic. Care must be exercised to not distort the fundamental, although it can be attenuated by filtering in the Signal Channel. Distortion in the Signal Channel, other than due to OVLD clipping, occurs mostly in the Preamplifier.

3.6 SENSITIVITY AND NOTCH CALIBRATION

The accuracy of the sensitivity calibration in the Bandpass mode requires that the notch be properly adjusted. Therefore, each time the sensitivity is calibrated, it is wise to first make the fine notch adjustment. In HIGH PASS and LOW PASS, the notch adjustment has very little effect because a Q of one is normally used in these modes. In FLAT, the adjustment has no effect at all. The procedures given here are combined procedures, first for adjusting the notch and then for calibrating the sensitivity.

The fine Notch adjustment should be made for exactly zero center-frequency signal transfer through the Signal Channel when in the Notch mode. However, because the Calibrator output is a square wave, containing harmonics, it would be difficult to use this signal for making the fine notch adjustment in the Notch mode; the harmonics would disallow an output zero, and adjusting for a definite value would be difficult. The Reference Channel's sinewave output would be better, but it is not pure enough to allow for an accurate setting. One good way to adjust the notch in the Notch mode is by using a separate high-purity sinewave source.

An alternative way to make the fine notch adjustment is to adjust the Notch Adj. control for proper center-frequency signal transfer through the Signal Channel when in the Bandpass mode. If the adjustment is off, changing the Q will change the gain at the center frequency. Making the fine notch adjustment is easy if this last fact is made use of, i.e., the fine notch adjustment should be made such that a change of Q does not change the gain at the center frequency

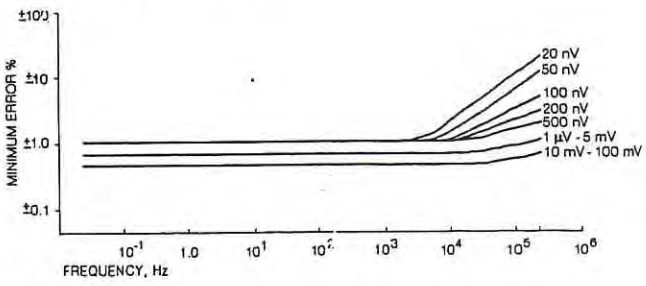


Figure 3-22. TYPICAL CALIBRATION ACCURACY

The latter method has the merit of allowing a less-pure waveform to be used because the harmonics are eliminated in the Bandpass mode. If Q's of 100 and 50 are used, the Calibrator waveform can be used for an adjustment accuracy within a few tenths of a percent. If the Reference Channel's sinewave is used, an accuracy of better than a tenth of a percent can be achieved. The

following procedure uses the Calibrator output because it is more convenient to continue on into the sensitivity adjustment. The operator ought to be able to adapt this procedure to using the reference sinewave if more accuracy is required.

Make the following preliminary control settings.

1. Reference Channel

   The Frequency switches should be set to or near the frequency which is to be used or expected when operating with the experiment, and the mode switch should be set to Internal.

   The Phase quadrant selector should be set to 270°, and the fine phase control set to 90°. Note that this adds up to 0°; setting this way allows the fine control's overlap to adjust the phase through 0°, when adjusting for maximum meter indication in the steps that follow.

2. Preamplifier

   Operate single-ended direct. Connect the Calibrator output to the Preamp input. (Use a short cable, RG-58/U or RG-59/U having BNC connectors at both ends.)

3. Output Channel

   The Time Constant switch should be set such that the signal driving the meter is well filtered. However, too long a time constant will make the adjustment time too long. Typically, if the operating frequency were 400 Hz, a good time constant setting would be 100 ms.

   The Zero Offset toggle should be set to the neutral off position, and the Function switch set to the PSD position to be used in the experiment. (The gain error introduced when switching from one PSD position to another is very small, about 0.5% maximum.)

4. Signal Channel

   The Sensitivity switch should be set to the intended operating position. However, if one of the nV ranges is used, internal noise can cause the meter reading to waver too much for making an accurate adjustment. It is better, therefore, to use one of the μV or mV positions. The gain error when switching back down to the nV range for operation will be less than the adjustment error if adjusted in a nV range. The Calibrator switch should be set to the same level as the Sensitivity switch.

   The Frequency switches should be set to exactly the same settings as the Reference Channel frequency switches.

   The Mode switch should be set to the Bandpass position.

   The Q switch should be set to 50.

Proceed to make the Notch adjustment as follows.

1. Adjust the Signal Channel frequency control and fine Phase control for maximum meter indication.

2. Change the Q switch setting to 100; if the meter indication changes, adjust the Notch Adj. screwdriver control to minimize the change. Continue switching the Q back and forth between 50 and 100 and adjusting the Notch Adj. potentiometer for no change in the meter reading.

Now that the Notch is adjusted, before adjusting the fine sensitivity control, make the following changes in the control settings:

The Calibrator output is a square wave having its fundamental rms component as indicated for each switch position. Therefore, when calibrating the sensitivity, the Mode switch should be set to the Bandpass position and the Q switch set at 10 or higher (If the Q to be used when operating is higher than 10, calibrate with that Q setting). All other controls should be left as set for the notch adjustment.

An attenuator, packaged in a small box having male and female BNC connectors, is provided with each Model 116 and 119. This attenuator attenuates 100:1 so that the Model 124A can be calibrated in the transformer mode. The attenuator output impedance is 1 Ω. If the transformer mode is to be used, connect the male BNC connector of the attenuator directly to the input BNC, and connect the calibrator output to the attenuator's female jack with a short cable. It is important that, if another source is used for calibration, the source presents an impedance of exactly 50 Ω to the attenuator.

After these settings are made, the actual procedure is simple: Adjust the fine Phase control for maximum meter indication. Then adjust the Sensitivity screwdriver control for an accurate full-scale meter indication.

3.7 AC VOLTMETER OPERATION

With the Function switch in the ACVM position, the Signal Channel output is used to operate the Synchronous Detector. This makes the Model 124A operate as a dc rms voltmeter.

If the signal driving the Synchronous detector is a clean sinewave, the rms voltage indication will be very accurate. The filter in the Signal Channel can be used to clean up a waveform if necessary. If the waveform is not clean, however, the meter reading will still be within 10 or 12

percent of the wideband rms amplitude of the input signal plus noise. This wideband capability is very useful for wideband noise and complex waveform measurements.

As in lock-in operation, the Time Constant is used to smooth the meter indication. However, bear in mind that both the signal and the noise contribute to the dc output of the detector in ACVM operation. The signal-to-noise ratio is not improved. Instead, the signal plus noise is measured, with the time constant serving solely to smooth the output indication.

It should be noted that, in ACVM operation, the Model 124A is effectively in the LO DRIFT mode, except for the 100 nV, 200 nV, or 500 nV sensitivity settings, where the unit operates in the NORMAL mode. Consequently, for all but the three "NORMAL mode" ranges, the drift and overload characteristics of the LO DRIFT mode apply.

3.8 DIGITAL PANEL METER MODIFICATION (1241/98)

If requested upon purchasing, a 3½ digital display may be installed instead of the panel meter. This display provides direct numerical readout of the output, and the corresponding digital logic is available at a rear-panel connector.

In reading the display, the numerals correspond directly to the signal voltage. However, some care must be exercised in interpreting the decimal indication. On any "1" range, 1 μV, 10 μV, 100 μV, 1 mV, 10 mV, 100 mV, etc., at full-scale output the meter will read 1.000. Above full scale the meter will follow until overload occurs. On "2" ranges, however, at full scale the meter will "try" to read 2.000, but will instead read 1 BLANK, i.e., the decimal point and the three rightmost numerals will not illuminate at full scale. On "5" ranges, at full scale the meter will read .500, and above full scale, the meter will follow until overload occurs. The voltage output at full scale is ±10 V on all ranges. No polarity symbol is displayed for positive readings. A "-" sign is displayed for a negative reading.

The information displayed on the digital meter is provided in binary coded decimal form at connector J7 at the rear. Table 3-6 identifies the pins at which this information is provided and gives the output levels. Positive logic is employed; a "1" is +3.5 V ±1 V and a "0" is 0.2 V ±0.2 V. All digital output signals are capable of sinking 5 mA at the lower logic level and sourcing 0.1 mA at the upper logic level.

During normal operation, the digital meter is triggered internally at a rate of approximately 10 times per second. Other internal trigger rates can be obtained by changing the value of the resistor (nominally 300 kΩ) connected between pins 1 and 15 of DJ-2 (upper connector on Digital Panel meter). With this resistor removed, the rate is reduced to twice a second. There may be occasions where it is advantageous to trigger externally, such as to facilitate operation of the Model 124A in conjunction with other signal processing equipment which may be monitoring the digital output. Considerations that govern external triggering are that the internal trigger must be inhibited and that the proper external trigger must be applied. Internal triggering is inhibited by grounding pin 23 (BUSY) of the digital output connector. The external trigger is applied to pin 20; it must be a logic one that goes to logic zero for at least 1.5 μs (but for less than 2 ms). This unit resets on the negative-going transition; conversion commences on the positive-going transition. The maximum allowable external trigger rate is 60 Hz.

When the Model 124A is being operated internally triggered, it is important that signals be provided to indicate when a conversion is in progress (or not in progress as the case may be) if the Model 124A is to be successfUlly incorporated into a larger digital system. Three different signals are provided for this purpose. The first is the $\overline{\text{END OF CONVERSION}}$ level at pin 14 of the Digital Output connector. This output is up (nominally +3.5 V) while a conversion is in progress, and down for the full duration of the display plus reset time. The second signal, provided at pin 19 of the Digital Output connector, is a 75 μs logic one pulse, CONVERSION COMPLETE, generated at the end of the conversion period. The third signal, provided at pin 18, is the inverse, $\overline{\text{CONVERSION COMPLETE}}$, also 75 μs but at logic 0.

In the case of an instrument equipped with both the Remote Programming Option and the Digital Panel Meter option, there are some special considerations that must be observed for proper operation. In units equipped with the Digital Panel Meter option alone, switching controlled by the front-panel Sensitivity switch sets the digital display sensitivity. In the case of units equipped with the Remote Programming option, the Sensitivity switch is rendered ineffective when the sensitivity is being controlled remotely, and control over the digital display sensitivity is lost.

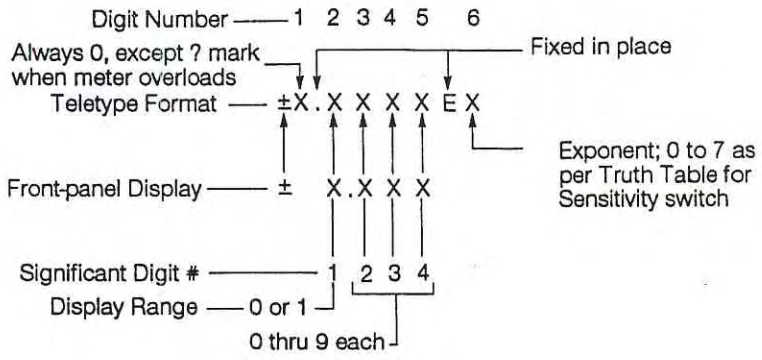
To solve this problem, an additional toggle switch has been added to the rear panel of instruments equipped with both options. This switch has two positions, **NORM**, and **D.P.M. 1.000**. For operation with the remote programming option inactive (this option is controlled by a rear-panel push button), the switch should be set to **NORM**, in which position the display functions exactly as described in Section 3.8. In remote-programmed operation, the switch should be set to **D.P.M. 1.000**, in which position the digital panel meter indicates the input signal level as a fraction of full scale, independent of the selected sensitivity. A full-scale input gives a display indication of 1.000, independent of whether the programmed sensitivity is 1 mV, 2 mV, 5 mV or some other value. Similarly, with a full-scale input applied, the BCD output will be 1.000 and the recorder output will be 10 V. The display indication and output levels are proportionally less with less than full-scale inputs. For example, if the programmed sensitivity is 200 mV, and a 100 mV signal is applied, the digital display will indicate

Model 124A J7 Pin #	Function	Function When Applied to Model 131 System Model 262
1	Polarity (Logic 1 = +)	1 = Polarity +
2	+4 V dc	Not Used
3	Overload Output (Logic 1 = Overload)	Digit 1, A
4	Overload Output (Logic 1 = Overload)	Digit 1, C
5	DVM Most Significant Digit, A	Digit 2, A
6	Digital Ground	Ground
7	DVM 2nd Most Significant Digit, A	Digit 3, A
8	DVM 2nd Most Significant Digit, C	Digit 3, C
9	DVM 3rd Most Significant Digit, A	Digit 4, A
10	DVM 3rd Most Significant Digit, C	Digit 4, C
11	DVM Least Significant Digit, A	Digit 5, A
12	DVM Least Significant Digit, C	Digit 5, C
13	Spare	
14	$\overline{\text{END OF CONVERSION}}$	
15	Spare	
16	Spare	
17	DVM Least Significant Digit, D	Digit 5, D
18	$\overline{\text{CONVERSION COMPLETE}}$	$\overline{\text{EXECUTE}}$
19	CONVERSION COMPLETE	Not Used
20	External Trigger Input	Not Used
21	Spare	
22	Spare	
23	NOT BUSY input (Output data will remain fixed when this line is at logic 0. Must be 1 or open for conversions to continue)	$\overline{\text{BUSY}}$ (from Model 262)
24	Sensitivity Switch Position A	Digit 6, A
25	Sensitivity Switch Position C	Digit 6, C
26	Sensitivity Switch Position B	Digit 6, B
27	Digital Ground	Digit 6, D
28	DVM Overload Output (Logic 1 = Overload)	Digit 1, B
29	DVM Overload Output (Logic 1 = Overload)	Digit 1, D
30	Digital Ground	Digit 2, B
31	Digital Ground	Digit 2, D
32	DVM 2nd Most Significant Digit, B	Digit 3, B
33	DVM 2nd Most Significant Digit, D	Digit 3, D
34	DVM 3rd Most Significant Digit, B	Digit 4, B
35	DVM 3rd Most Significant Digit, D	Digit 4, D
36	DVM Least Significant Digit, B	Digit 5, B

Notes:

1. Logic 1 = +3.5 V ±1 V; Logic 0 = 0.2 V ±0.2 V.
2. The notations A, B, C, and D represent 2^0, 2^1, 2^2, and 2^3.

Table 3-6A. DIGITAL OUTPUT PIN ASSIGNMENTS



Printout is in microvolts

Exp.	Switch Setting	BCD Digital Output		
		4(C)	2(B)	1(A)
7	500 mV	1	1	1
6	200 mV	1	1	0
	100 mV	1	1	0
	50 mV	1	1	0
5	20 mV	1	0	1
	10 mV	1	0	1
	5 mV	1	0	1
4	2 mV	1	0	0
	1 mV	1	0	0
	500 μV	1	0	0
3	200 μV	0	1	1
	100 μV	0	1	1
	50 μV	0	1	1
2	20 μV	0	1	0
	10 μV	0	1	0
	5 μV	0	1	0
1	2 μV	0	0	1
	1 μV	0	0	1
	500 nV	0	0	1
0	200 nV	0	0	0
	100 nV	0	0	0

Table 3-6B. DIGITAL OUTPUT FORMAT AND EXPONENT TABLE

0.500 (half scale), the BCD output will be 0.500, and the recorder output will be 5 V.

3.9 PHASE MEASUREMENTS

To measure phase with a Model 124A, the Phase controls are adjusted to obtain a positive peak indication, the same as for an amplitude measurement. When positive peak is achieved, the Phase controls will indicate the number of degrees by which the input signal leads the applied reference. If the angle is greater than 180°, it may be more convenient to subtract the indicated angle from 360° and state the difference as the angle by which the input signal lags the reference. **Note:** Any internal phase shifts, such as might be introduced by the signal amplifiers, must be taken into account for accurate measurements.

Sometimes, after the lock-in amplifier has been peaked up, a change in an experimental parameter will cause a phase shift and a resultant loss in peak indication. If this happens, it may be of interest to know whether the shift was a lead or a lag. To determine the direction of a phase shift, simply readjust the 124A Phase controls as required to restore the peak indication, and while so doing, note whether the new phase setting is higher or lower than the old one. If the new phase setting is higher, the phase shift of the signal relative to the reference was in the leading direction. If the new phase setting is lower, then the shift was in the lagging direction.

As mentioned previously, when the phase controls are adjusted for peak meter reading, they indicate the phase of the signal with respect to the reference signal. However, a more accurate determination can be made by taking advantage of the greater quadrature adjustment sensitivity. Also, the phase shift differences between the Reference Channel and the Signal Channel must be accounted for if an accurate phase determination is required. When adjusting for the peak, the meter reading varies around the peak as the sine of the phase angle for small errors. If the phase is adjusted for quadrature null instead, the meter reading varies around null as the cosine of the phase angle for small errors. Therefore, for any small number of degrees change of the Phase vernier while adjusting for a quadrature null, the meter reading changes much more than for the same vernier change while adjusting for an in-phase peak. Two high-sensitivity procedures follow.

Procedure #1

This procedure is relatively simple, and can be used with signals that vary in amplitude (independent of noise).

1. Measure the amplitude of the signal in the normal manner, so that the controls are initially optimized for time constant, dynamic range, Signal Channel filter settings, etc. Use the Bandpass mode and high Q, if possible (frequency constant), to eliminate the effects of harmonics on making the null settings below. If the frequency is changing, it would be best to use a wide bandwidth and avoid using a transformer input, because internal phase variations as a function of frequency could not be accounted for.

2. Disconnect the signal from the Preamplifier, and connect the sinewave from the Reference Channel Out jack to the Preamplifier's A input. If this output is already being used for synchronizing the experiment, use a "T" connector. The amplitude must be low enough so that the Signal Channel is not overloaded. The phase of this sinewave is going to be used for zero reference. If a clean sinewave having a phase more suitable for zero reference is available, use it.

   If a transformer input is used, it is important that the Reference output impedance be made to look the same as that of the signal source. An appropriately designed attenuator can generally be used to achieve this goal. Otherwise, phase measurement errors will be introduced.

3. Set the Preamplifier Mode switch to "A". (The Transformer/Direct switch should be set as appropriate for the intended input coupling.)

4. Set the Zero Offset switch to OFF (center position).

5. Adjust the Phase controls for an exact meter null. Increase the Signal channel sensitivity as much as possible without overload while making this adjustment.

6. Record the Phase dial setting (phase zero).

7. Disconnect the Reference Channel sinewave from the Preamplifier and reconnect the signal to be measured.

8. Adjust the Phase controls for exact meter null. Increase the Signal Channel sensitivity as much as possible without overload while making this adjustment.

9. The difference between the zero reference phase recorded in step (6) and the phase set in step (8) is the accurate phase of the signal with respect to the reference signal.

Procedure #2

This procedure is more complicated, but it has the advantage of providing a voltage output (& digital output if the optional digital meter is installed) proportional to the sine of the phase angle, which can be sent to a computer or used for other purposes. It is important that the amplitude (independent of noise) of the zero reference signal and the signal whose phase is to be measured be constant. This procedure is often used to monitor the relative phase change, as an ongoing function of time, of a signal that does not vary in amplitude.

1. Measure the amplitude of the zero-phase reference signal and the signal whose phase is to be measured in the normal manner, and record the amplitudes measured. If the relative phase variations of a signal are to be measured, however, the amplitude need not be known but it must be constant.

2. Apply the zero-phase reference signal to the input.

3. Set up the Signal Channel filter parameters. If the frequency is constant, use a Q of 100 and the Bandpass mode. If the frequency is changing, it would be best to use a wide bandwidth and to avoid using a transformer input, because internal phase and amplitude variations as a function of frequency could not be accounted for.

4. Set the Zero Offset toggle to neutral. Then adjust the Phase controls for a positive peak. Also, if the Bandpass mode is used, fine adjust the frequency controls for a positive peak.

5. Adjust the fine sensitivity (screwdriver) control for an exact + full-scale meter indication. (This throws the gain calibration off, so after the phase measurement is complete, the instrument should be recalibrated.) The Sensitivity switch setting at which this full-scale adjustment is made is referred to below as the "reference full-scale range".

   Because of the limited range of the fine sensitivity control, for a fixed reference amplitude it is not always possible to adjust for exact full-scale meter indication. In such a situation a different level of reference signal should be used. If this is not possible, an intermediate level on the scale can be referred to as "full scale". However, the following procedure and readings must be modified accordingly.

6. Set the Zero Offset control to "+", and turn the Offset vernier exactly ten turns clockwise from zero. The overload lamp will light, and the meter will peg downscale.

7. Increase the sensitivity by a factor of 10 (sensitivity control 3 positions ccw), so that the meter again reads on scale.

8. Adjust the Phase dial for an up-scale peak. If operating in the Bandpass mode, alternately adjust the Vernier and Signal Channel Frequency fine controls for an up-scale peak. Alternate between the two adjustments until no further increase in the meter indication can be obtained.

9. Adjust the fine sensitivity screwdriver control for an exact meter null (which, incidentally, corresponds to a more exact full-scale setting for the 10 x less sensitive range).

10. Change the Phase quadrant 90°, and return the Zero Offset toggle to neutral (center position. The meter should read near zero, but the small phase error will probably cause a reading slightly off null. Adjust the Phase dial control for exact meter null. Turn the Sensitivity switch counterclockwise as far as possible without overload while making this adjustment.

11. Return the Sensitivity switch to the reference full-scale range setting.

12. Apply the signal whose phase is to be measured to the Preamplifier input. The meter indication with respect to the unity meter scale is accurately equal to the cosine of the phase angle if the reference signal and measured signal are exactly equal in amplitude. Because the full-scale output is 10 V, the output voltage is 10 x the cosine of the phase angle. If the reference signal and the signal whose phase is being measured are unequal in amplitude, the cosine function must also be multiplied by the ratio of the amplitudes of the two signals, V_{ref}/V_x. The amplitudes were measured in step (l).

    For small angles, much higher resolution can be obtained by increasing the sensitivity. Remember, however, to always refer voltages and meter readings obtained with increased sensitivity back to the full-scale reference range by a multiplier equal to the ratio of the ranges.

13. Use a cosine table or a computer to convert the readings and voltages obtained to the phase angle.

3.10 REAR PANEL CONNECTORS

3.10A INTERFACE CONNECTOR (J9)

J9 is a 14-pin connector having outputs as given in Table 3-7. This connector mates with Amphenol #57-30140, and is wired for compatibility with the Model 127, which is a two-phase accessory. If it is desired to operate a Model

Pin	Signal
1	Ground
2	+24 V
3	-24 V
4	No connection
5	0° Reference
6	90° Reference
7	180° Reference
8	Signal Out
9	Signal Ground
10	No Connection
11	VCO Input
12	Reference Input
13	No Connection
14	270° Reference

Table 3-7. INTERFACE CONNECTOR SIGNALS & PINS

123 AC Zero Offset Accessory with the Model 124A, a special cable is available which interconnects between the Model 123 and J9 of the Model 124A. Note that the VCO Input (pin 11) is also accessible by means of a rear-panel BNC jack.

3.10B EXT. TIME CONSTANT

J8 is the External Time Constant socket. By connecting external capacitors to the proper pins of this socket, time constants in excess of 300 s can be obtained. Two capacitors are required, one to be connected between pins 8 and 9, and the other between pins 10 and 11. The resulting time constant is $3C \times 10^7$ seconds, where C is the capacitance (single capacitor) in farads. A table of the signals provided at this connector follows.

Pin	Function
1	Ground
2	+24 V (max 100 mA)
3	-24 V (max 100 mA)
4	No connection
5	-31 V in (for battery operation)
6	No connection
7	+31 V in (for battery operation)
8	One lead of first time constant capacitor
9	Second lead of first time constant capacitor
10	One lead of second time constant capacitor
11	Second lead of second time constant capacitor

Table 3-8. EXTERNAL TIME CONSTANT CONNECTOR SIGNALS AND PINS

3.11 BATTERY OPERATION

Battery operation of the Model 124A Lock-In Amplifier may be necessary where no dc power is available, or as a last resort where power line interference is a problem. Battery operation is particularly straightforward because the necessary internal points are available at the rear panel 11-pin socket. Two batteries are required, one to supply +31 V (400 mA) and the other to supply -31 V (360 mA). The t31 V source should be connected to pin 7. The -31 V source should be connected to pin 5. Ground for both is at pin 1. It is generally a good idea to fuse the battery lines external to the instrument, and to provide an ON/OFF switch as well. The front-panel ON/OFF switch is not functional when the instrument is operated from batteries. The line cord should be disconnected. Other than the already mentioned ON/OFF switch not functioning, there is only one other point of difference between a battery operated instrument and one operated from the line, and that is that the pilot lamps which illuminate the panel meter will not light. Because of the dc power requirements of the digital panel meter, **units incorporating the digital panel meter option cannot be operated from batteries.**

3.12 PHASE METER MODIFICATION (1241/85)

A Model 124A equipped with this option can be operated either as a normal lock-in amplifier or as a Phase Meter, depending on the position of the rear-panel NORMAL/PHASE switch.

When the instrument is operated as a phase meter, the input signal, after some initial dc gain, is routed through an amplifier limiter that has a constant amplitude (clipped) rectangular output. This signal, when synchronously demodulated, yields a dc output that is a linear function of the phase difference between the reference and input signals. The phase sensitivity is 100 mV out per degree with the Function switch set to LOW DRIFT. Only LOW DRIFT operation can be used and the Sensitivity switch is constrained to settings in the range of 1 μV to 500 mV. In the case of units equipped with the Digital Panel Meter option, Phase measurements can only be made with the Sensitivity switch set to 1 μV, 10 μV, 100 μV, 1 mV, 10 mV, or 100 mV. In other words the "Z" and "5" positions should not be used for making phase measurements if the unit is equipped with a digital panel meter.

In phase-meter operation the input signal should be limited to less than ten times full scale (but not more than 200 mV) for Sensitivity switch settings from 1 μV to 100 mV. For the 200 mV and 500 mV sensitivity positions, the maximum input signal is 500 mV. The phase indication will not be in error by more than 5° maximum providing the signal amplitude is at least 100 μV or 20% of full scale as indicated by the setting of the Sensitivity switch, whichever is greater.

3.13 MIXER MONITOR MODIFICATION (1241/92)

Units equipped with the Mixer Monitor Option have an additional rear-panel BNC connector. The signal available at this output is taken directly from the output of the Mixer and before any filtering. Figure 3-23 illustrates the Mixer output corresponding to in-phase and quadrature signals respectively. If the signal and reference inputs to the Mixer are either in phase or 90° out-of-phase, the signal at the output of the Mixer will be as shown. For signals 180° out-of-phase, the Mixer output will be the inverse of the 90° output. Taking the maximum possible area that can be enclosed by one cycle (one Polarity) as a unit output, the output averaged over a cycle for any Mixer input phase relationship is simply the unit output times the cosine of the angle between the input and reference signals.

The cosine response depends on the sinusoidal nature of the input signal. If the signal were a square wave and the tuned amplifier were not used, the Mixer output would vary linearly with the angle between the signal and reference inputs. Nevertheless, maximum output would still be at 0° and 180°, and zero output would be obtained at 90° and 270°. Note that when the Model 124A is being operated in the Phase Meter mode (assuming the instrument in question is equipped with that option), internal limiting circuitry "converts" any input to a rectangular wave of the same period, and it is this rectangular wave that would be observed at the Mixer Monitor connector.

The amplitude of the Mixer Monitor output is 555 mV peak with a full-scale input signal at 0° and operating in the LO DRIFT mode. Operated in NORMAL, the Mixer Monitor signal decreases to 55.5 mV for a full-scale input and in HI, it decreases to 5.55 mV. The output resistance is 1000 Ω.

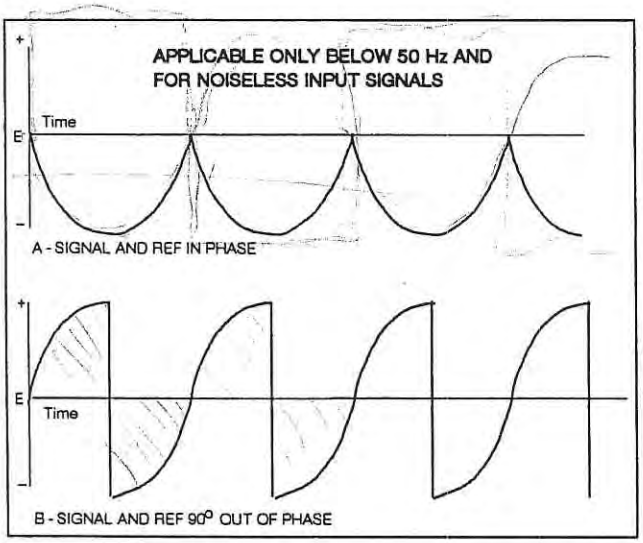


Figure 3-23. MIXER OUTPUT FOR IN-PHASE AND QUADRATURE SIGNALS

It might be mentioned that the waveforms illustrated in Figure 3-23 apply only at frequencies below 50 kHz and with a noise-free input signal. At higher frequencies, switching spikes become visible and some Mixer filtering effects become evident. Even relatively small amounts of input noise can completely obscure the signal at the Mixer Monitor output, especially in FLAT mode operation.

3.14 REMOTE PROGRAMMING OPTION MODIFICATION (1241/83)

In units equipped with this option, the Sensitivity and Dynamic Range Tradeoff can be remotely controlled by applying logic 0 (ground) to the appropriate pins of the rear-panel Remote Interface connector, J8001. Associated with the connector is a pushbutton switch that transfers the instrument from local to remote operation and vice versa. In Local operation, the Sensitivity and Dynamic Range Tradeoff are controlled by the front-panel controls in the usual manner. In Remote operation, these parameters are independent of the front-panel control settings and are determined instead by the inputs to the Remote Interface connector. Table 3-9 indicates the pin assignments of this connector. Note that there are three "groups" of control input lines. To obtain any given combination of Sensitivity and Dynamic Tradeoff, one input in each group is grounded. Usually, all of the other pins can be left "floating". However, in a noisy environment, particularly where the cable leading to J8001 is relatively long, it may be advisable to apply logic 1 (+3.5 V ±1 V) to the other active input pins to assure stable operation. Otherwise, transient pickup could cause undesired "switching" of the Sensitivity and Dynamic Range Tradeoff. A connector (AMPHENOL 57-30360) that mates with J8001 is supplied with the modification.

In addition to the three groups of input lines, two outputs, OVERLOAD and REF. UNLOCK, are provided. Each of these outputs is "up" when the corresponding lamp is illuminated, and "down" when the corresponding lamp is dark. There are two operating "restrictions" that the operator should bear in mind when operating a unit equipped with this modification. First of all, the Dynamic Tradeoff Over-rides that occur as a function of selected (programmed) Sensitivity apply in Remote Programmed operation exactly the same as in Local operation. (For details. Second, there is a reduction in the amount of ±24 V power available for external use. From Table 3-8 ±100 mA are available. In the case of units equipped with the Remote Programming Option, these levels are reduced to ±80 mA.

In the case of an instrument equipped with both the Remote Programming Option and the Digital Panel Meter option, there are some special considerations that must be observed for proper operation. In units equipped with the Digital Panel Meter option alone, switching controlled by the front-panel Sensitivity switch sets the digital display sensitivity. In the case of units equipped with the Remote Programming option, the Sensitivity switch is rendered ineffective when the sensitivity is being controlled remotely, and control over the digital display sensitivity is lost.

Pin	Use
1	OVERLOAD - logic 0 = lamp off
2	REF UNLOCK - logic 1 = lamp on
3-18	No connection
19	100 nV Sensitivity
20	1 μV Sensitivity
21	10 μV Sensitivity
22	100 μV Sensitivity
23	1 mV Sensitivity
24	10 mV Sensitivity
25	100 mV Sensitivity
26	LO DRIFT Tradeoff
27	NORMAL Tradeoff
28	HI DYNAMIC RANGE (Reserve) Tradeoff
29-32	No Connection
33	X1.0 Sensitivity Multiplier
34	X5.0 Sensitivity Multiplier
35	X2.0 Sensitivity Multiplier
36	Ground

Table 3-9. REMOTE PROGRAMMING CONNECTOR PIN ASSIGNMENTS

To solve this problem, an additional toggle switch has been added to the rear panel of instruments equipped with both options. This switch has two positions, **NORM**, and **D.P.M. 1.000**. For operation with the remote

programming option inactive (this option is controlled by a rear-panel pushbutton), the switch should be set to **NORM**, in which position the display functions exactly as described in Section 3.8. In remote-programming operation, the switch should be set to **D.P.M. 1.000**, in which position the digital panel meter indicates the input signal level as a fraction of full scale, independent of the selected sensitivity. A full-scale input gives a display indication of 1.000, independent of whether the programmed sensitivity is 1 nV, 2 mV, 5 mV, or some other value. Similarly, with a full-scale Input applied, the BCD output will be 1.000 and the recorder output will be 10 V. The display indication and output levels are proportionally less with less than full-scale inputs. For example, if the programmed sensitivity is 200 mV, and a 100 mV signal is applied, the digital display will indicate 0.500 (half scale), the BCD output will be 0.500, and the recorder output will be 5 V.

3.15 SELECTIVE EXTERNAL REFERENCE MODIFICATION (1241/77)

In some applications, it may happen that the reference signal produced by the experimental apparatus is of very poor quality, that is, it is accompanied by much noise and interference. As explained previously, use of a simple low-pass filter in series with the reference signal will usually clean up such a signal sufficiently to make it acceptable to the Model 124A reference circuits. Nevertheless, there could arise situations where this relatively simple technique would prove inadequate. If this is the case, the best one can do is to pass the reference signal through a tuned bandpass filter of moderate Q, perhaps 10. Even the poorest reference waveform, once it has been passed through such a filter, will be of sufficiently good quality to allow normal reference channel operation. The sacrifice one makes in using such a filter is that, for all practical purposes, the tracking capability of the Reference Channel is given up. Any change in the frequency of the reference signal results in amplitude loss and phase shift as the frequency moves out of the center of the passband.

Such a filter can, of course, be connected externally. However, in the case of a Model 124A equipped with the Selective External Reference Modification, a Q-of-10 filter is provided internally. These units are equipped with a rear-panel switch that allows the Selective External (tuned) Reference mode to be selected. With the switch in the NORMAL position, the instrument works exactly as described previously. With the switch in the SEL. EXT. position, the instrument operates in the Selective External Reference mode providing the front-panel Reference Mode switch is set to INT/VCO. If the front-panel Reference Mode switch is in any other position when the rear-panel switch is set to SEL. EXT, improper Reference Channel operation results. The only other consideration in using the Selective External Reference mode is to tune the Reference Channel to the frequency of the input reference signal. This is easily done by applying the reference signal, and then monitoring the amplitude of the signal at the Reference OUT connector with the Signal Channel. A suitable procedure follows.

1. Set the controls as follows.

   Power: ON
   Sel Ext Sel switch (rear panel): SEL. EXT
   Ref Mode switch: INT/VCO
   Ref Level switch: 10 (if using Model 118, set to 1)
   Ref Level Vernier: CAL.
   Function switch: ACVM
   Sensitivity: 500 mV
   Signal Mode: FLAT
   Signal Input switch: A

2. Set the Reference Frequency controls to the approximate frequency of the Reference signal.

3. Connect the Reference signal to the REF IN connect for. **Note:** The amplitude of the Reference signal should be in the range of 100 mV pk-pk to 3 V pk-pk.

4. Connect a cable from the REF OUT connector to the "A" Input connector of the preamplifier. The panel meter should show some deflection. If it does not, adjust the Reference Frequency controls as required to obtain some deflection and then further adjust them for maximum meter indication. If the meter indication exceeds full scale, use the Reference Level vernier to reduce the indication to about 50% of full scale. Then readjust the Reference Frequency controls for the desired maximum indication.

This completes the tuning procedure. The internal bandpass filter is now tuned to the reference frequency. The cable interconnecting the REF OUT connector and the "A" Input of the Preamplifier can now be removed and the instrument operated in the usual manner, bearing in mind that, if the reference frequency is changed, retuning wilt be required.

Chapter 4
Alignment Procedure

4.1 INTRODUCTION

The Model 124A Lock-In Amplifier is a reliable, conservatively-designed instrument. High-quality, stable components have been used throughout in its construction and one can reasonably expect a long period of troublefree operation without any need for realignment. However, to be assured of continued high confidence in the experimental data obtained with the Model 124A, it may be advisable to run through the following alignment at one year intervals, and after doing a repair on the instrument. Due to possible interaction between some of the adjustments, it is necessary that they be carried out in the indicated sequence. Any decision to make a partial alignment should be reserved to someone having sufficient knowledge of the Model 124A to fully understand all possible interactions. Figure 4-1 identifies the adjustments and board edge testpoints. To identify the gold pin-type testpoints by their "TP" number (these testpoints are not located at the board edge), it will be necessary to refer to the appropriate individual-board layout diagram in Chapter 6. Some of these testpoints are also identified by an "E" or "B" number printed on the board. This number also appears in the text references, allowing the testpoints to be easily identified.

Note that this alignment procedure is not intended to be used in troubleshooting. If the unit is suspected to be malfunctioning, go directly to Chapter 5, which deals with troubleshooting. The instrument must be working normally before it can be aligned.

4.2 EQUIPMENT NEEDED

1. DC Voltmeter with "center zero". A dc coupled scope may be used instead.
2. Digital Voltmeter.
3. General purpose oscilloscope.
4. General purpose sinewave generator.
5. Frequency counter.
6. AC Voltmeter such as the HP Model 400EL.
7. Two BNC shorting plugs, CW-159/U (Amphenol or equivalent).
8. Extender Board, Princeton Applied Research #1710-00-1403S.
9. Nonmetallic alignment tool to be used for high frequency "screwdriver adjustments".

4.3 PROCEDURE

4.3A PRELIMINARY STEPS

1. Plug in any of the following preamplifiers, Model 116 operated direct, Model 117, Model 118, or Model 119 operated direct. **Note:** If a Model 118 or Model 185 Preamplifier is used, it will be necessary to take into account the factor of ten higher gain of these preamplifiers. This is done by always selecting a sensitivity that is a factor of ten lower than that called for in the procedure.
2. Connect the BNC shorting plugs to both inputs of the Preamplifier.
3. Remove the top and bottom covers.The top cover slides off to the rear after removing the two screws underneath the upper cover overhang at the rear of the instrument. The bottom cover slides off to the rear after removing the two screws that secure the two rear bumper feet.
4. Set the Model 124A controls as follows.

   Sensitivity: 500 μV
   Mode: FLAT
   Signal Frequency Digits: 4.00
   Signal Frequency Multiplier: X100
   Signal Q: 1
   Reference Frequency Controls: NORM, 4.00,
   X100Reference Mode: INT/VCO
   Reference Level: 10
   Reference Level Vernier: CAL (fully/clockwise)
   Phase dial: 0.00°
   Phase switch: 0°
   Time Constant: MIN
   6 dB/12 dB switch: 6 dB
   Zero Suppress Toggle switch: OFF (center position)
   Zero Suppress dial: 0.00
   Function: HI DYNAMIC RANGE
   Calibrate: 100 mV
   Power: ON

5. Allow a fifteen minute warmup.

4.3B 124 V ADJUSTMENTS (R6028 and R6010) - POWER SUPPLY BOARD

1. Monitor the voltage at TP6002 (yellow testpoint) with the digital voltmeter (referred to hereafter as DVM).
2. Adjust R6028 (-24 V ADJ) for a DVM indication of -24.0 V.

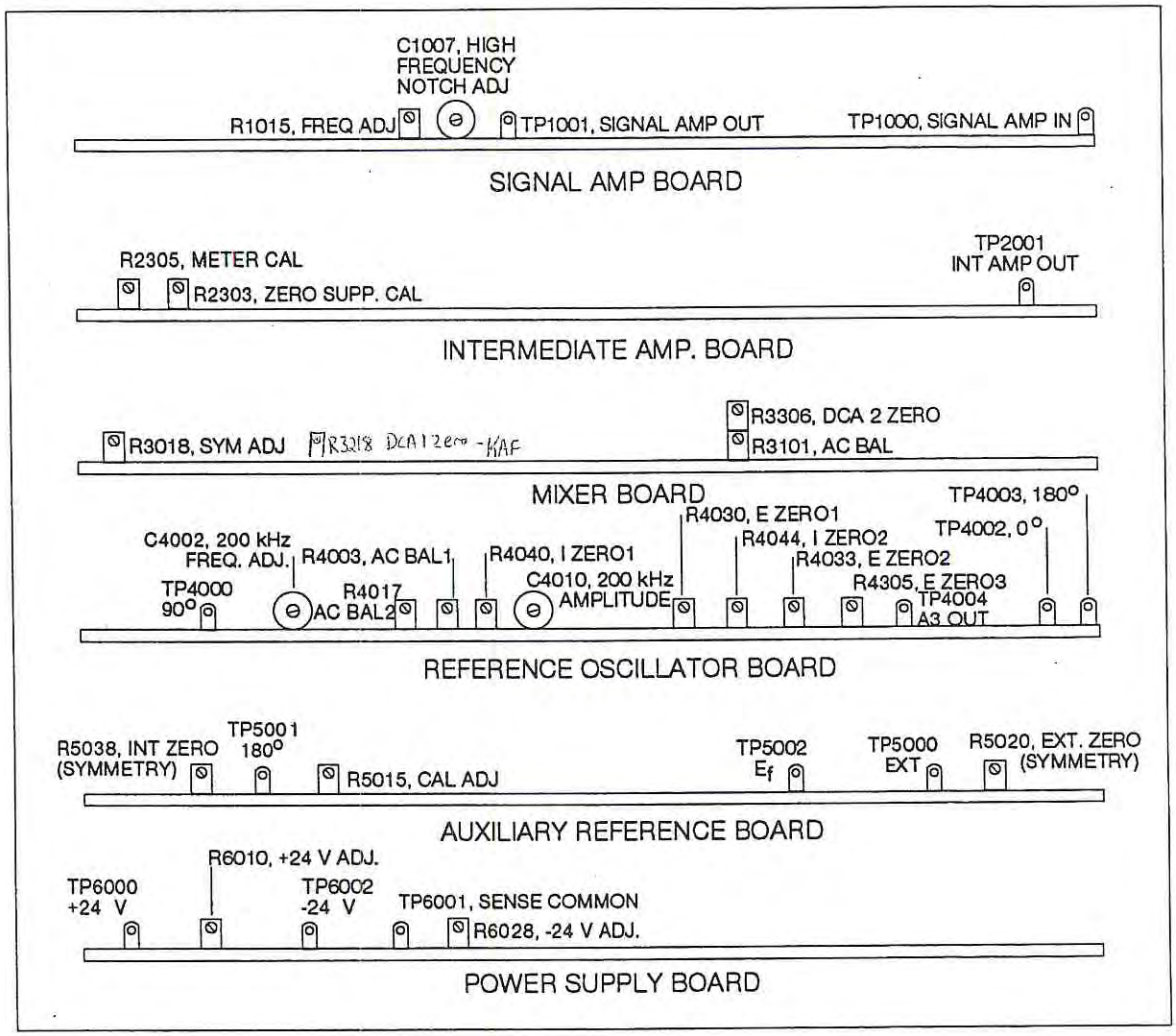


Figure 4-1. 124A ADJUSTMENTS AND TEST POINTS

3. Transfer the DVM to TP6000 (red testpoint).

4. Adjust R6010 (+24 V ADJ) for a DVM indication of +24.0 V.

4.3C INITIAL REFERENCE OSCILLATOR BOARD ADJUSTMENTS

1. Turn off the power. Then remove the Reference Oscillator board and plug the Extender board into the unit in place of the Reference Oscillator board.

2. Plug the Reference Oscillator board into the Extender board, turn on the power, and allow a five-minute warmup.

3. E ZERO 3 ADJUST (R4305)

   a. Connect the dc voltmeter (not the DVM) to TP4004 (gray testpoint).

   b. Connect a jumper between CR4007 and R4050. Under no circumstances use chassis ground as the circuit may oscillate.

   c. Adjust R4305 (E ZERO 3 ADJ) for 0 V ±1 V at the testpoint. Note that this is an "open loop" high gain adjustment, and so will be difficult to set, and, once set, will drift quickly from the ideal "O" reading.

   d. Remove the jumper. The dc voltage at the gray testpoint should stabilize at -3.8 V ±0.5 V.

4. I ZERO 1 ADJUST (R4040)

   a. Connect two jumpers, one from TP4005 (B1) to ground and the other from TP4006 (E1) to ground. TP4005 and TP4006 are both gold pin testpoints down on the board.

   b. Connect the voltmeter to TP4001 (green testpoint).

c. Adjust R4040 (I ZERO 1 ADJ) so that the monitored voltage is drifting equally about zero.

d. Remove the jumper which extends from TP4006 (E1) and ground, but leave the jumper which extends from TP4005 (B1) and ground.

5. E ZERO 1 ADJUST (R4030)

a. Adjust R4030 (E ZERO 1 ADJ) for equal drift about zero in the monitored voltage (voltmeter still connected to TP4001).

b. Remove the jumper which extends from TP4005 (B1) and ground.

6. I ZERO 2 ADJUST (R4044)

a. Connect two jumpers, one from TP4007 (B2] and ground, and the other from TP4008 (E2) and ground. These are both gold-pin testpoints down on the board.

b. Connect the voltmeter to TP4003 (violet testpoint).

c. Adjust R4044 (I ZERO 2) such that the monitored voltage drifts equally plus and minus about zero.

d. Remove the jumper which extends from TP4008 (E2) and ground, but leave the jumper which extends from TP4007 (B2) and ground.

7. E ZERO 2 ADJUST

a. Adjust R4033 (E ZERO 2 ADJ) for equal drift about zero as measured at TP4003 (violet testpoint).

b. Remove the jumper which extends from TP4007 (B2) and ground.

8. Turn off the power. Then remove the Reference Oscillator board from the extender, remove the extender, and return the Reference Oscillator board to its proper place in the instrument. Turn the power back on.

4.3D AUXILIARY REFERENCE BOARD ADJUSTMENTS

1. INTERNAL ZERO SYMMETRY ADJUST (R5038)

a. Connect the oscilloscope to the front-panel CALIBRATE OUT connector. The sweep time should be 0.2 ms/cm and the oscilloscope should be adjusted to trigger on the positive slope of a 222 mV pk-pk square wave.

b. Carefully note the duration of the positive half cycle of the square wave, Then trigger on the negative slope of the square wave and Carefully note the duration of the negative half cycle. The two "half cycles" should have exactly the same duration. If they do not, adjust R5038 (INT ZERO ADJ) as required to obtain the desired symmetry.

3. DC CALIBRATE ADJUST (R5015)

a. Set the fronts panel Calibrate switch to 222 mV dc.

b. Remove the oscilloscope from the Calibrate jack and connect the DVM there instead.

c. Adjust R5015 [DC CAL ADJ for a DVM indication of -0.2220 V. Remove the DVM.

4. EXT. ZERO SYMMETRY ADJUST (R5020)

a. Set the front panel Reference Level switch to "2".

b. Connect the oscilloscope to TP5000 (green testpoint).

c. Connect a cable from the REF. OUT jack to the REF. IN jack.

d. While observing the square wave at TP5000, gradually rotate the front-panel Reference Vernier counterclockwise. As the control is adjusted, a point will be reached where the symmetry of the square wave will begin to degrade, When this occurs, adjust R5020 (EXT. ZERO SYMMETRY ADJ) as required to maintain as near perfect symmetry as possible. Continue until the waveform "locks" to either "+" or ground, indicating that the vernier is too far counterclockwise.

e. Set the Reference Level switch to 10 and rotate the vernier to the fully clockwise (CAL) position.

f. Remove the cable interconnecting the REF IN and REF OUT connectors.

4.3E MIXER BOARD ADJUSTMENTS

1. Turn off the power. Then remove the Mixer board and plug in the Extender board in its place.

2. Plug the Mixer board into the Extender board, turn the power back on, and allow a five minute warmup. Set the Function switch to LO DRIFT.

3. DC AMP 2 ZERO ADJUST (R3306)

a. Connect jumpers from TP3301 to TP3302 and to

TP3303. Note that these are not board-edge testpoints but rather gold-pin testpoints down on the board.

b. Adjust R3306 (DC AMP 2 ZERO] for "O" on the front-panel meter. This is a drifty open-loop adjustment.

c. Remove the jumpers

d. Turn off the power, separate the Mixer board and the Extender, and remove the Extender. Then return the Mixer board to the instrument and turn the power back on.

4. DC AMP 1 ZERO (R3218)

a. Set the Function switch to HI DYN RANGE.

b. Connect the DVM to the FUNCTION OUT jack.

c. Adjust R3218 (DC AMP 1 ZERO) for 0.00 V at the DVM. Remove the DVM.

5. AC BAL ADJ (R3101)

a. Connect the oscilloscope to the front panel FUNCTION OUT connector.

b. Set the Time Constant switch to MIN.

c. Adjust R3101 (AC BAL ADJ) for minimum ripple as observed at the oscilloscope.

d. Increase the time constant to 300 ms and remove the oscilloscope.

6. SYMMETRY ADJUST (R3018)

a. Change the instrument control settings as follows.

Signal Frequency Digits: 8.00
Signal Mode: BANDPASS
Signal Q: 20
Function: ACVM
Sensitivity: 10 mV
Reference Frequency controls: NORM, 3.(10) 1, X100 (net freq.= 401 Hz)

b. Remove the shorting plug from the A Input of the Preamplifier. Then connect the External Signal Generator to the "A" Input. Be sure the Input Selector of the Preamplifier is set to "A". The frequency of the signal generator output should be 800 Hz.

c. Adjust the amplitude of the signal generator output for an "on scale" indication on the Model 124A panel meter. Then carefully vary the frequency of the signal generator output for maximum deflection of the panel meter.

d. Readjust the amplitude of the signal generator output for exactly full scale deflection of the Model 124A panel meter.

e. Set the function switch to HI DYNAMIC RANGE and the Time Constant switch to 1 SEC.

f. Set the Sensitivity switch to 100 μV.

g. Adjust the Reference Frequency controls for a panel meter "beat" of about 1 Hz.

h. Adjust R3018 (SYMMETRY ADJ) for minimum pk-pk amplitude in the observed beat.

i. Set the Phase switch to 90°. Then note and record the pk-pk amplitude of the beat.

j. Adjust R3018 (SYMMETRY ADJ) as required to reduce the amplitude of the "beat" by exactly one half.

k. Reset the Phase switch to 0° and check to see that the "beat" is the same amplitude on 0° as it is on 90°.

l Reset the Time Constant to 300 ms. Remove the signal from the input and reconnect the shorting plug removed in step b.

4.3F INTERMEDIATE AMPLIFIER BOARD ADJUSTMENTS

1. ZERO SUPPRESS CAL (R2303]

a. Set the Function switch to LO DRIFT.

b. Set the Zero Suppress Polarity switch to "-"

c. Set the Zero Suppress dial to 1.00 (one turn from the fully counterclockwise position).

d. Connect the DVM to the front-panel FUNCTION OUT connector. Then adjust R2303 (ZERO SUPPRESS CAL) for a DVM indication of +10.00 V.

2. METER CAL R2305)

a. Note the panel meter indication. It should be near full scale to the right.

b. Adjust R2305 (METER CAL] for exactly full-scale panel meter deflection.

c. Set the Zero Suppress Polarity switch to the center (OFF) position.

4.3G FINAL REFERENCE OSCILLATOR BOARD ADJUSTMENTS

1. AC BAL 1 and AC BAL 2 ADJUSTMENTS (R4003 and R4017)

   a. Connect the de voltmeter to TP4000 (white testpoint).

   b. Set the Model 124A Reference Frequency controls to NORM, 4.00, Xl00 (400 Hz).

   c. Set the Reference Level switch to "l" and the Reference Vernier fully clockwise.

   d. Connect the Frequency Counter to the REF. OUT connector.

   e. Carefully note the signal level at TP4000. Then transfer the dc voltmeter to TP4002 (blue testpoint) and note the signal level there.

   f. Adjust R4003 (AC BAL 1] so that the amplitude at TP4002 is the same as it is at TP4000.

   g. Note the difference between the frequency indicated by the counter (about 400 Hz) and the frequency set by the Reference Frequency controls (exactly 400 Hz). Then readjust R4003 (AC BAL 1) as required to reduce the difference frequency by exactly a factor of two.

   h. Adjust R4017 (AC BAL 2) for a counter indication of exactly 400 Hz.

2. HIGH-FREQUENCY AMPLITUDE ADJUST (C4010) and 200 kHz FREQ. ADJ (C4002)

   a. Set the Reference Frequency controls to NORM, 2.00, and Xl0K.

   b. Note and record the frequency indicated on the counter.

   c. Set the Reference Frequency controls to ADD 10, 10.00, and Xl0K.

   d. Connect the dc voltmeter to TP4002 (blue testpoint).

   e. Adjust C4010 HIGH FREQ. AMP. ADJ) for an dc voltmeter indication of exactly 1 V rms. Be sure to use the non-metallic alignment tool for this adjustment.

   f. Adjust C4002 (200 kHz FREQ. ADJ) for a counter indication exactly ten times that noted in step "b".

   g. Reset the Reference Frequency controls to NORM, 2.00, and Xl0K. The frequency should be the same as noted in "b". If it has changed, record the new frequency, and then set the Frequency controls back to ADD lO, 10.00, and Xl0K. Readjust C4002 (200 kHz FREQ. ADJ) to obtain a counter reading exactly ten times the new frequency.

4.3H SIGNAL BOARD ADJUSTMENTS

1. SIGNAL FREQUENCY ADJUST (R1015)

   a. Set the controls as follows.

   Signal Frequency controls: 4.05 Xl00 (405 Hz)
   Reference Frequency controls: NORM, 4.05 Xl00 (405 Hz) **Note:** Do not change Reference Controls during this check.
   Signal Mode: BANDPASS
   Function: ACVM
   Signal Q: 100
   Calibrate: 2 mV
   Sensitivity: 2mV
   Preamp Input Selector: A

   b. Remove the shorting plug from the "A" Input of the preamplifier and connect a cable from the "A" Input to the Calibrate Output.

   c. Adjust the third dial of Signal Frequency control for peak panel meter indication.

   d. Change the setting of the Signal Q switch from 100 to 10% ENBW. The signal amplitude should not change. If it does, change the setting of the front-panel NOTCH ADJUST screwdriver adjustment as required so that no amplitude change takes place when the Q is switched from 100 to 10% ENBW. Leave the Q set to 100.

   e. Now set the third Signal Frequency dial to "5". **Note:** Both Signal and Reference Frequency controls should be set the same.

   f. Adjust R1015 (SIG. FREQ. ADJ) for maximum panel meter indication.

2. HIGH FREQUENCY NULL ADJUSTMENT (C1007)

   a. Set the controls as follows.

   Signal Frequency controls: 10.95, Xl0K (109.5 k Hz)
   Reference Frequency controls: NORM, 10.95, X10K (109.5 kHz)

   b. Adjust the third dial of the Reference Frequency controls for peak panel meter indication. Carefully note the panel meter indication.

c. Set the Q Selector to 10% ENBW. If the meter indication changes, adjust C1007 (HIGH FREQ. NULL) so that there is no meter indication change as the Q is switched back and forth between 100 and 10% ENBW. Leave the Q set to 10% ENBW.

d. Disconnect the cable which extends From CAL OUT to the A INPUT.

4.31 FINAL ADJUSTMENTS

The following adjustments can be made only after the instrument has been thoroughly warmed up with the cover in place. At the factory, a special top cover is used, one having holes drilled in it to give access to R3101, R3718, and C1007. The first two of these adjustments are located on the Mixer board. The third is located on the Signal board. It is not expected that the person doing the alignment will drill holes in his cover. By substituting a piece of cardboard for the cover the alignment can be successfully completed. Be sure the holes are accurately located and no larger than they have to be. With the "cover" in place, allow a one hour warmup before proceeding.

1. AC BAL. ADJ (R3101) MIXER BOARD

   a. Set the front-panel controls as follows.

      Reference Frequency controls: NORM, 4.00, X10
      Sensitivity switch: 5 mV
      Time Constant: MIN
      Function Switch: HIGH DYNAMIC RANGE

   b. Connect a shorting plug to the "A" Input.

   c. Connect the oscilloscope to the FUNCTION OUT connector.

   d. Adjust R3101 (AC BAL ADJ) so that the square wave ripple observed is minimum. It should be possible to get it below 400 mV pk-pk.

2. **HIGH-FREQUENCY NULL ADJUSTMENT (C1007) - SIGNAL BOARD**

   a. Set the controls as follows.

      Signal Frequency: 10.95, X10K (109.5 kHz)
      Reference Frequency: 10.95, Xl0K (109.5 kHz)
      Function: ACVM
      Calibrate and Sensitivity: 2 mV

   b. Remove the shorting plug from the "A" Input of the Preamplifier and connect a cable from the "A" Input to the Calibrate Output.

   c. (c) Adjust the third dial of the Reference Frequency controls for peak panel meter indication. Carefully note the meter indication.

   d. Set the Q Selector to 10% ENBW. If the meter indication changes, adjust C1007 (HIGH FREQ. NULL) so that there is no meter indication change as the Q is switched back and forth between 100 and 10% ENBW.

   e. Remove the cable interconnecting the CAL output and "A" Input. Then return the shorting plug to the "A" Input.

3. DC AMP 1 ZERO ADJ (R3218) - MIXER BOARD

   a. Set the controls as follows.

      Sensitivity: 500 μV
      Signal Frequency Digits: 4.00
      Signal Frequency Multiplier: Xl00
      Reference Frequency controls: NORM, 4.00, X 100
      Function: HIGH DYNAMIC RANGE

   b. Connect the DVM to the FUNCTION OUT connector.

   c. Adjust R3218 (DC AMP 1 ZERO ADJ) for 0.00 V at the DVM.

This completes the alignment. All test equipment can be removed and the covers secured in place.

4.3J PHASE METER OPTION ALIGNMENT

The following alignment is carried out only on units equipped with the Phase Meter Option. This procedure is to be performed **after** the regular alignment is completed.

1. Remove the top cover. Then turn on the power and allow a fifteen minute warmup.

2. Set the Model 124A controls as follows.

   Input Selector (Preamplifier): A
   Sensitivity: 5O mV
   Signal Mode: FLAT
   Reference Frequency controls: NORM, 4.00, Xl00
   Reference Mode: INT
   Reference Level switch: .1 V
   Reference Level vernier: fully clockwise
   Phase dial: 9.00 (90°)
   Phase switch: 270°
   Time Constant: 300 ms (6 dB)
   Zero Offset dial: 0.00 (fully counterclockwise)
   Zero Offset switch: OFF (center position)
   Function switch: ACVM
   NORM/PHASE switch (rear panel): PHASE

3. Connect a cable from the Reference Channel OUT connector to the Preamplifier "A" Input.

4. Connect the oscilloscope, dc coupled, to pin 9 of the Phase board. **Note:** This board is mounted against the

Signal Amplifier board shield.

5. The signal observed at the oscilloscope should be a 400 Hz square wave. After verifying that the signal is as indicated, rotate the front-panel Reference Level vernier counterclockwise as required to make the square wave noisy.

6. Adjust the A2 DC control (located on the Phase board) for best symmetry in the observed square wave. When best Symmetry is obtained, try further reducing the Reference Output amplitude and repeat the symmetry adjustment. Repeat these two steps until no further improvement in the setting of the symmetry adjustment can be made.

7. Before proceeding, check at pin 5 of the Phase board for a sinewave output with an amplitude of approximately 20-to-60 mV pk-pk. Then set the rear-panel NORM/PHASE switch to NORM, and adjust the Reference Level Vernier for 1 V pk-pk at the oscilloscope.

8. Connect the oscilloscope to J3-9 (Mixer board). Then set the Sensitivity switch to 5 mV and adjust the Reference vernier for 1 V pk-pk amplitude in the observed signal.

9. Set the Sensitivity switch to 50 mV.

10. Adjust the A1 GAIN trim potentiometer (located on the Phase board) for 0.1 V pk-pk amplitude in the observed signal.

11. Set the NORM/PHASE switch back to PHASE. Then set the Model 124A Function switch to LOW DRIFT.

12. Observing the oscilloscope, adjust the front-panel Reference Level vernier until the amplitude of the monitored sinewave is just high enough to cause both negative and Positive clipping.

13. Adjust the CLIPPING SYMMETRY trim-potentiometer, located on the Phase board, for symmetrical clipping of the observed signal. Then remove the oscilloscope.

14. Connect the DVM (digital voltmeter) to the front-panel Function OUT connector. Then adjust the A2 AMPLITUDE trim-potentiometer (located on the Phase board) for a DVM indication of 9.00 V.

15. Carefully set the front-panel Phase dial for peak DVM indication. Then readjust the A2 AMPLITUDE trim-potentiometer for the desired 9.00 V reading.

This completes the Phase board alignment.

4.4 MODEL 116, 117,OR 119 PREAMPLIFIER ALIGNMENT

To align the preamplifier, it will be necessary to use a Model 183 Remote Preamplifier Adapter with extender cable.

4.4A PRELIMINARY STEPS

1. Plug the Model 183 Remote Preamplifier Adapter into the Model 124A. Then interconnect the Model 183 and the Preamplifier with the Extender Cable.

2. Remove the two screws at the rear of the preamplifier that secure the cover. Then slide the cover back onto the cable to get it out of the way.

3. Set the Preamplifier Input Selector to "A - B". In the case of a Model 116 or a Model 119, set the Mode selector to DIRECT.

4. Set the Model 124A controls as follows.

   Sensitivity: 500 μV
   Mode: FLAT
   Signal Channel Frequency
   dials: setting immaterial
   multiplier switch: setting immaterial
   Q Selector: setting immaterial
   Reference Channel Frequency
   dials: 4.00, NORMAL
   multiplier switch: X100
   Mode: INT/VCO
   Phase switch: 0°
   Phase dial: 90.0°
   Reference Level: 1.0 V rms
   Function: NORMAL
   Calibrator Output Level: setting immaterial
   Power: ON

4.4E PROCEDURE

1. BIAS ADJUST (R101)

   a. Connect the DVM to that end of R130 which is in common with R127 and R133.

   b. Adjust R101 (BIAS ADJUST) for a voltage indication of -5.1 V.

2. DC ZERO (R119)

   a. Transfer the DVM to either end of R132.

   b. Adjust R119 (DC ZERO) for a voltage indication of 0.00 V.

3. COMMON-MODE REJECTION (R136)

   a. Connect the 124A Reference Channel output to both the A and B inputs of the preamplifier.

Note: If an overload indication occurs, ignore it.

b. Monitor the signal at R132 with an dc voltmeter or sensitive oscilloscope. Then adjust R136 (COMMON-MODE REJECTION) for a null in the dc voltmeter indication.

4. HIGH-FREQUENCY COMMON-MODE REJECTION (C109)

a. Change the setting of the Reference Frequency controls to 10.00, NORMAL, X10K. The frequency of the applied signal will now be 100 kHz. Set the 124A Reference output level to 0.5 V.

b. While continuing to monitor the signal at R132 with the dc voltmeter (or oscilloscope), adjust C109 for a null in the dc signal level.

5. DC ZERO CHECK

a. Disconnect the calibrator output from the preamplifier inputs. Also, remove the dc voltmeter from R132 and connect the DVM to this point instead.

b. The indicated voltage should be 0 V ±50 mV. If it is not, touch up the setting of R119 as required to obtain an indicated voltage of 0.00 V.

This completes the preamplifier alignment. The preamplifier cover can now be returned to its normal position.

4.5 MODEL 118 PREAMPLIFIER ALIGNMENT

To align the preamplifier, it will be necessary to use a Model 183 Remote Preamplifier Adapter with extender cable.

4.5A PRELIMINARY STEPS

Perform steps 1 through 4 inclusive of the procedure outlined in Section 4.4A.

4.5B PROCEDURE

1. DC ZERO (R105 and R133)

a. Connect the DVM to R125.

b. Adjust R105 (DC ZERO) for an indicated voltage of 0.0 V.

c. Alternate the voltmeter between resistors R125 and R144, and adjust R133 (DC ZERO) until the voltage at both points is the same.

d. Readjust R105 (DC ZERO) for 0.0 V at R125.

2. COMMON-MODE REJECTION (R130) AND RC BAL (R103)

a. Set the Sensitivity to 1 mV. Then connect the 124A Reference output to both the A and B preamplifier inputs. Reduce the frequency to 40 Hz.

b. Monitor the signal at R125 with the dc voltmeter. Then alternately adjust R130 (CMR ADJ.) and R103 (RC BAL) for a null in the measured signal level. Continue until no further improvement in the null can be obtained.

This completes the preamplifier alignment.

Chapter 5
Troubleshooting

5.1 INTRODUCTION

This section consists of a series of procedures in be followed in troubleshooting the Model 124A. The purpose of the procedure is to narrow the trouble down to a specific circuit board by making voltage and waveform checks at critical points. Once the faulty board has been identified, the operator can contact the factory or one of its authorized representatives for advice on how to get the instrument back into operation in the shortest possible time. It may prove expedient to simply exchange the board for a new one. In the case of units still in Warrants', It is particularly important that the factory or one of its authorized representatives be contacted before doing and repair work on the board itself, because any damage that occurs as a result of unauthorized work could invalidate the Warranty.

Although past experience indicates that most instrument failures turn out to be the fault of a specific component failure on one of the boards, it is of course perfectly possible that some component other than the one located on a circuit board could go bad. Where this is the case, the person troubleshooting will have to appropriately adapt the procedure to isolate the faulty component.

In general, it is suggested that the person who carries out the troubleshooting procedure be well grounded in basic transistor electronics. The procedure is more to be thought of as a general guide for an experienced repairman than as a minutely detailed treatise to educate the newcomer.

5.2 EQUIPMENT REQUIRED

1. General purpose oscilloscope.

2. DC Voltmeter.

3. Signal Generator able to supply a 1 V rms sinewave at 1 kHz.

4. Extender Board, Princeton Applied Research #1710-00-1403S. This item is not really required for any of the checks called for in the following pages. However, it will prove indispensable for the troubleshooter who wants to go a little beyond the checks provided to isolate the trouble more specifically than is possible with the procedure. In using the board, be sure to install and remove circuit boards with the power off.

5.3 INITIAL STEPS

1. Remove the top cover. It slides off to the rear after the two screws which secure it are removed. These two screws are located on the underside of the upper cover overhang at the rear of the instrument.

2. After removing the hold-down strap, lift each circuit board and give each a brief visual damage inspection. If any "charred" or otherwise damaged components are noticed, there is little point in going further.

3. Be sure to check the fuses. There are two on the Power Supply board and one at the rear panel. They are discussed in Section 5.4, which follows.

5.4 POWER SUPPLY

1. On the Power Supply board, check the voltage at TP6000 (red testpoint) for +24 V and at TP6002 (yellow testpoint) for -24 V. If the voltages are correct, go on to Section 5.5. If the voltages are incorrect or missing, proper power supply operation must be established before any further checks can be made. Note from the schematic (Chapter 6) that the -24 V regulator supplies the reference voltage for the +24 V regulator. Thus, any trouble with the -24 V supply would cause loss of regulation in the +24 V circuit as well.

2. Note that the unregulated input to both regulators is fused. If a check shows one of these fuses to be blown, try replacing it once. If it blows again, it will be necessary to locate and repair the short. One way to narrow the short down is to pull all boards but the Power Supply board (power off when boards are removed or replaced) and then to turn the power back on. If the fuse still blows, the trouble is most likely on the Power Supply board. If it does not blow, the board having the short can be easily determined by returning them one at a time until the fuse blows.

3. If the regulator input fuses are not blown, but the ±24 V levels are missing or incorrect, check the unregulated supply levels (nominally ±31 V) to isolate the problem to the Power Supply board or to the Unregulated Supply components (line fuse, transformer, rectifiers, or Filter capacitors). Note that the high-power transistors are not located on the Power Supply board, but are instead mounted on the same plate as the transformer and filter capacitors.

5.5 REFERENCE CHECKS

1. Control Settings

   Meter: Check the mechanical zero and adjust it if necessary.
   Preamplifier: Plug in a Model 117 Preamplifier, or a Model 116 or 119 operated in the DIRECT mode. A Model 118 or Model 185 can also be used, but certain Signal Channel checks will have to be modified as indicated in the text.

Sensitivity: 1 mV
Signal Channel Mode: FLAT
Reference Channel Mode: INT/VCO
Reference Frequency: 3.99, X100 (399 Hz)
Reference Level: 1 V rms (red inner knob fully clockwise)
Phase switch, 0°
Phase dial: 90°
Time Constant: 300 ms, 6 dB/octave
Zero Offset
dial: 0.00 (fully counterclockwise)
toggle switch: center (OFF) position
Function switch: NORMAL
Calibrator: 1 mV (100 μV if preamplifier is a Model 118)
Power switch: ON

2. Reference Oscillator Board

   a. Check for -3.6 V ±0.5 V at TP4004 (gray testpoint on Reference Oscillator board). As indicated in the schematic, TP4004 monitors the output of A3, the Buffer between the front-panel Reference Frequency dials and the Voltage Controlled oscillator. If the voltage reading is correct, one can reasonably assume that the dial-controlled voltage dividers and Buffer A3 are functioning normally.

   b. Monitor TP4002 (blue testpoint] with the oscilloscope and check for a 2.8 V ±0.3 V pk-pk sinewave at 399 Hz. **Note:** A faulty circuit will usually give indication of a "gross" error. For this reason it is not generally advisable to spend much time trying to determine whether the frequency or amplitude are "exactly" as specified. This applies to both this step and to the remainder of the procedure.

   c. Similarly check fora 2.8 V ±0.3 V pk-pk at 399 Hz at TP4003 (violet), at TP4000 (white), and at TP4001 (green). These testpoints, together with TP4002, give access to the four outputs of the Reference Oscillator. If these signals are normal, one can be reasonably confident that the Reference Oscillator board is functioning normally.

   d. Transfer the oscilloscope to the Reference Output connector (front panel) and check for a 2.8 V ±0.3 V pk-pk sinewave at 399 Hz. If this signal is as indicated, one can assume that the Reference Output Power Amplifier, located on the Power Supply board, is functioning normally.

3. Auxiliary Reference Board

   a. Connect a 1 V pk-pk sinewave at 1 kHz from the signal generator to the Reference Channel IN connector.

   b. Set the Reference Channel Mode switch to EXT. The REF UNLOCK light should glow for a few seconds and then extinguish.

   c. Monitor the signal at the Reference Out connector with the oscilloscope. One should observe a 1 V rms (2.8 V ±0.3 V pk-pk) sinewave at 1 kHz.

   d. Set the toggle switch to EXT f/2. Again, the REF UNLOCK light should glow, this time for about seven seconds, and then extinguish.

   e. Verify that the signal at the Reference Out connector is unchanged in amplitude but that its frequency has doubled (2 kHz).

   f. Reset the Reference Mode switch to INT/VCO but leave the signal generator connected to the Reference Input connector.

Note: If normal indications were obtained in steps "a" through "f", one can reasonably assume that the Auxiliary Reference board is functioning normally and go on to Section 5.6. If abnormal indications were noted, there is a good possibility of a malfunction on this board. The remaining steps in this sequence may prove helpful in narrowing the problem down to the specific mal-functioning circuit.

   g. +5 V Regulator: Check the voltage at the positive end of capacitor C5004. This voltage; which is indicative of the current flow through Q5001 (and hence the +5 V load), should be +11 V ±3 V. C5004 is the 35 μF capacitor located near the upper edge of the board. Next check the +5 V regulator output, which should be +5 V ±0.5 V. This is most easily checked at the positive end of capacitor C5005, the 15 μF 6 V capacitor located near the upper edge at about the center of the board.

   h. Schmitt Triggers: Check for a 399 Hz square wave at TP5001 (blue testpoint). The upper and lower levels of the square wave should be +4.5 V ±1 V and 0.3 V ±0.3 V respectively. If the signal is as described, the Schmitt Trigger driven from the 180° output of the Reference Oscillator is functioning normally,

      Next transfer the oscilloscope to TP5000 (green testpoint). A 1 kHz square wave with the same level limits as described in the preceding paragraph should be observed. If the signal is normal, one can conclude that the Schmitt Trigger driven from the External deference signal is functioning normally.

   i. Frequency Comparator: A thorough checkout procedure for this circuit is beyond the scope of

this manual. Nevertheless, failure to pass the following two tests is a clear indication of malfunction. If these tests are passed, no clear conclusions concerning the normality of these circuits can be made.

Test 1: Check for +4 V ±1 V at pin 11 of integrated circuit U5006. **Note:** IC packages U5001 through U5006 are labeled as "1" through "6" with labels consisting of small etched foil digits on the side of the board opposite the components. Pin 1 of each 14 digit package is similarly marked. The pins are counted clockwise (viewed from the label side).

Test 2: Check for a 399 Hz square wave at TP5002 (gray testpoint). The lower level of the square wave should be 0 V. There should be two upper levels, both between +3 and +4 V.

The signal generator should be disconnected from the Reference Input at this time.

Note: If steps "g" through "i" fail to identify the faulty circuit, but the board continues to malfunction, there is a strong possibility that the trouble is with the associated wiring or switches.

5.6 SIGNAL CHANNEL

All of the gain switching in the Model 124A is done by means of relays. In the following checks, the various amplifiers are isolated by appropriately selecting the Sensitivity and Function. By applying a suitable signal and checking at critical points, a malfunctioning amplifier can be quickly identified. Table 5-1, which lists the gain and energized relays for all possible combinations of Sensitivity and PSD Function, is provided as a convenient reference.

Note that overload level signals are applied at various points throughout the following procedure to assure that the signal level at the output of the early amplifiers will be above the noise floor. Anytime the applied signal is greater than the selected sensitivity, overload is a possibility, and the operator should not be concerned if the Overload light glows during such a measurement. However, if the Overload light should glow with normal signal levels applied, a malfunction is indicated, and it should be corrected before proceeding.

5.6A PREAMPLIFIER

Note: If the preamplifier to be used is a Model 118 or Model 185, set the Calibrator Output level to 100 μV and the Sensitivity to 1 mV. In the case of a type 117 Preamplifier, or a Model 116 or 119 operated direct, both the Sensitivity and the Calibrator Output level should be set to 1 mV. For all preamplifiers, the Function switch should be set to NORMAL.

1. Connect a cable from the Calibrate Output to the "A" Preamplifier Input.
2. Monitor the signal at TP1000 (green testpoint) on the Signal board. The observed signal should be an 11 mV pk-pk square wave at 399 Hz, indicating that the preamplifier gain is five (fifty for a Model 118). **Note:** A square wave with an rms value (fundamental frequency component only) of 1 mV has a pk-pk amplitude of 2.22 mV. Therefore, the total signal amplitude at the output of the Preamplifier is 2.22 x 5 = 11 mV. This "X2.22" factor must be taken into account throughout the entire procedure. The operator is again cautioned not to spend an undue amount of effort convincing himself that the observed signals comply with the text descriptions down to the last decimal place. In most instances of malfunction, the signal discrepancy will be so large as to leave no doubt.

   If the signal is as indicated, the operator can conclude that the Preamplifier is functioning properly in its gain-of-five mode (gain-of-fifty for Model 118 or Model 185). If the signal is incorrect or missing, the trouble probably is in the Preamplifier and the operator can proceed to the schematic for his particular Preamplifier if he wishes to troubleshoot further. As can be seen from the Signal board schematic, the signal is actually being monitored after relay K1008 on the Signal board. Hence, if the signal is missing, it might be worth checking for the signal on coupling capacitor C1004 to isolate the relay, Also, take a moment to be sure that the Calibrator Output signal is normal, that is, a square wave with a pk-pk amplitude of 2.22 times the selected Calibrator Output level.

3. Change the Sensitivity setting to 500 μV, thereby energizing Preamplifier relay K100 and increasing the preamplifier gain to X50 (X500 for a Model 118 or a Model 185). The amplitude of the signal at TP1000 should increase to 111 mV pk-pk, reflecting the increased gain. If this check is normal, one can reasonably assume that the preamplifier is functioning normally, at least with respect to providing the proper gain. Noise and common-mode rejection checks are beyond the scope of this procedure. If this check does not give a normal indication, but step 2 does give a normal indication, relay K100 should be suspected.

5.6E SIGNAL AMPLIFIER

The Signal Amplifier gain, measured from the output of the Preamplifier to the output of the Signal Amplifier, is either X10 (K1008 energized) or X1 (K1009 energized). Note that the gain of the amplifier circuit is always X10. The factor of ten gain reduction achieved when K1009 is energized and K1008 is de-energized is accomplished by reducing the amplitude of the signal applied to the amplifier input with a relay controlled attenuator.

1. Transfer the oscilloscope to TP1001 (violet testpoint). The observed signal should be a 1.11 V pk-pk square wave, indicating that the Signal Amplifier has a gain

AC RELAYS AND GAIN											DC GAIN						TOTAL GAIN	
SEL SENSITIVITY			PREAMP		SIG AMP		INTER AMP		MIXER AC		TOTAL AC GAIN	MIXER BOARD DC							
FUNC SWITCH SETTING			ACTIVE RELAY	P.A. GAIN[1]	ACTIVE RELAY	S.A. GAIN	ACTIVE RELAYS	I.A. GAIN	ACTIVE RELAY	AC GAIN[2]		LO DFT		NORM		HI			
LO DFT	NORM	HI										RELAYS[3]	GAIN[3]	RELAYS[3]	GAIN[3]	RELAYS[3]	GAIN[3]	GAIN[4]	SENS[5]
100 nV			K100	X50	K1008	X10	K2007, K2003, K2005	X100	K3101	X11	5.5E5	K3202	200						
200 nV			"	"	"	"	K2008 " "	X50	"	"	2.7E5	"	"						
500 nV			"	"	"	"	K2009 " "	X20	"	"	1.1E5	"	"						
1 µV	100 nV		"	"	"	"	K2007 " "	X100	"	"	5.5E5	NONE	20	K3202	200				
2 µV	200 nV		"	"	"	"	K2008 " "	X50	"	"	2.7E5	"	"	"	"				
5 µV	500 nV		"	"	"	"	K2009 " "	X20	"	"	1.1E5	"	"	"	"				
10 µV	1 µV	100 nV	"	"	"	"	K2007, K2004 "	X10	"	"	5.5E5	"	"	"	"	K3201, K3202	2000	1.1E8	100 nV
20 µV	2 µV	200 nV	"	"	"	"	K2008 " "	X5	"	"	2.7E5	"	"	"	"	"	"	5.5E7	200 nV
50 µV	5 µV	500 nV	"	"	"	"	K2009 " "	X2	"	"	1.1E5	"	"	"	"	"	"	2.2E7	500 nV
100 µV	10 µV	1 µV	"	"	"	"	K2007 " K2006	X1	"	"	5.5E5	"	"	"	"	"	"	1.1E7	1 µV
200 µV	20 µV	2 µV	"	"	"	"	K2008 " "	X.5	"	"	2.7E5	"	"	"	"	"	"	5.5E6	2 µV
500 µV	50 µV	5 µV	"	"	"	"	K2009 " "	X.2	"	"	1.1E5	"	"	"	"	"	"	2.2E6	5 µV
1 mV	100 µV	10 µV	"	"	"	"	K2007 " "	X1	K3102	X1.1	5.5E5	"	"	"	"	"	"	1.1E6	10 µV
2 mV	200 µV	20 µV	"	"	"	"	K2008 " "	X.5	"	"	2.7E5	"	"	"	"	"	"	5.5E5	20 µV
5 mV	500 µV	50 µV	"	"	"	"	K2009 " "	X.2	"	"	1.1E5	"	"	"	"	"	"	2.2E5	50 µV
10 mV	1 mV	100 µV	NONE	X5	"	"	K2007 " "	X1	"	"	55	"	"	"	"	"	"	1.1E5	100 µV
20 mV	2 mV	200 µV	"	"	"	"	K2008 " "	X.5	"	"	27	"	"	"	"	"	"	5.5E4	200 µV
50 mV	5 mV	500 µV	"	"	"	"	K2009 " "	X.2	"	"	11	"	"	"	"	"	"	2.2E4	500 µV
100 mV	10 mV	1 mV	"	"	K1009	X1	K2007 " "	X1	"	"	5.5	"	"	"	"	"	"	1.1E4	1 mV
200 mV	20 mV	2 mV	"	"	"	"	K2008 " "	X.5	"	"	2.7	"	"	"	"	"	"	5.5E3	2 mV
500 mV	50 mV	5 mV	"	"	"	"	K2009 " "	X.2	"	"	1.1	"	"	"	"	"	"	2.2E3	5 mV
	100 mV	10 mV	"	"	"	"	K2007 " "	X1	"	"	5.5			NONE	20	K3202	200	1.1E3	10 mV
	200 mV	20 mV	"	"	"	"	K2008 " "	X.5	"	"	2.7			"	"	"	"	5.5E2	20 mV
	500 mV	50 mV	"	"	"	"	K2009 " "	X.2	"	"	1.1			"	"	"	"	2.2E2	50 mV
		100 mV	"	"	"	"	K2007 " "	X1	"	"	5.5					NONE	20	1.1E2	100 mV
		200 mV	"	"	"	"	K2008 " "	X.5	"	"	2.7					"	"	5.5E1	200 mV
		500 mV	"	"	"	"	K2009 " "	X.2	"	"	1.1					"	"	2.2E1	500 mV

[1]STATED PREAMPLIFIER GAIN FIGURES APPLY FOR MODEL 117 AND FOR MODEL 116 OR 119 OPERATED DIRECT. WITH MODEL 118 OR MODEL 185, PREAMP GAIN WILL BE FACTOR OF 10 HIGHER. IF TRANSFORMER COUPLING IS USED, TRANSFORMER TURNS RATIO MUST BE TAKEN INTO ACCOUNT AS WELL.

[2]GAINS ARE TEN PERCENT HIGH TO COMPENSATE FOR THE MIXER BEING AVERAGE RESPONDING AS OPPOSED TO RMS RESPONDING.

[3]READ SELECTED SENSITIVITY FROM CORRESPONDING COLUMN AT LEFT.

[4]TOTAL GAIN DOES NOT VARY WITH SELECTED FUNCTION (LOW DRIFT, NORMAL, HI DYNAMIC RANGE).

[5]MATCH TOTAL GAIN TO SELECTED SENSITIVITY FROM THIS COLUMN.

Table 5-1. GAIN AND RELAY SWITCHING FOR THE MODEL 124A

of ten. If the signal is normal, chances are the amplifier circuit is functioning normally. If the signal is absent, the problem could lie with the amplifier circuit or with K1008, the energized input relay.

2. Set the Sensitivity switch to "10 mV". The signal amplitude should decrease to 11 mV pk-pk, indicating that the gain of both the Preamplifier and Signal Amplifier went down by a factor of ten. If the signal is as indicated, chances are that the Signal Amplifier Input Attenuator is functioning normally. If an incorrect reading is obtained, K1009, the input attenuator relay energized with this Sensitivity switch setting, should be checked.

3. Set the Signal Mode switch to BANDPASS and the Signal Channel Frequency controls to 3.99, X100 (399 Hz). Then set the Signal Q switch to "10". The observed signal at TP1001 should now be sinusoidal with an amplitude of 14 mV pk-pk. It may be necessary to slightly adjust the third Signal Frequency dial to obtain the indicated amplitude. The amplitude drops off sharply if the dial is set high or low. If the indicated effects are observed, the selective amplifier circuits of the Signal Amplifier are functioning normally.

5.6C INTERMEDIATE AMPLIFIER

There are two amplifiers on the Intermediate Amplifier board, each with a nominal gain of ten. The relay switching on the board, controlled by the Sensitivity switch, actuates various attenuators so that the overall board gain varies from X100 to X0.2, according to the Sensitivity switch position. Not all possible gains are checked. Instead, each decade is checked, and also the X1, X0.5, X0.2 sequence within one decade. This is sufficient to check all of the relays as well as the amplifiers. Note from the schematic that the front-panel Sensitivity Adjustment affects the gain of the second amplifier and hence the overall gain of the Intermediate Amplifier. Hence, it may be necessary to change the setting of this adjustment to obtain signals of the indicated level. However, once set, the control setting should not have to be changed again, at least not for the remainder of the Intermediate Amplifier checks.

1. Set the Sensitivity switch to 100 nV and the Function switch to NORMAL. Then set the Calibrator output to "2 μV" (200 nV with a Model 118 or 185).

2. Monitor the signal at TP2000 (green testpoint). The observed signal should be a 399 Hz sinewave with a pk-pk amplitude of 0.28 V. It is perfectly normal for this signal to be obscured by noise. If this signal is as indicated, one can assume that both amplifiers on the Intermediate Amplifier board are functioning normally. If the signal is not normal, the problem could be with one of the two amplifier circuits or with one of the relays. With this combination of Sensitivity and Function, the energized relays are K2003, K2005, and K2007.

3. Set the Sensitivity to "1 μV" and the Calibrate Output to 20 μV (2 μV with a Model 118 or 185). The observed signal should still have the same amplitude (the gain reduction is exactly compensated by the increased calibrator output), but the noise should have gone down by a factor of ten. The only relay change between this step and the preceding one is that K2004 is now energized and K2003 de-energized.

4. Set the Sensitivity switch to 10 μV and the Calibrate Output to 200 μV (20 μV with a Model 118 or 185). As in the preceding step, the decrease in gain is compensated by the increase in calibrator output and the amplitude of the observed signal should remain constant (0.28 V pk-pk). A further factor of ten reduction in the observed noise will take place. The relay state changes are that K2006 is now energized and K2005 is de-energized.

5. Set the Sensitivity switch to 2 mV and the Calibrate Output to 2 mV. The amplitude of the observed signal should decrease to 0.14 V pk-pk, indicating the gain reduction which occurs as K2007 is de-energized and K2008 is energized.

6. Set the Sensitivity switch to 5 mV. The amplitude of the observed signal should decrease to 57 mV pk-pk, reflecting the gain reduction which occurs as K2008 drops out and K2009 is energized.

All of the Intermediate Amplifier board relays have now been checked. If proper operation to this point was obtained, the Intermediate Amplifier board can be presumed to be functioning normally.

5.6D MIXER BOARD AC GAIN

The Mixer board dc gain is either X11 or X1.1 as determined by attenuator controlling relays K3101 and K3102. The gains are made 10% "high" to compensate for the fact that, although the instrument reads out in rms, the Mixer is average responding.

1. Set the Sensitivity switch to 50 μV and the Calibrate Output to 500 μV (50 μV with a Model 118 or 185). Then monitor the signal at the front-panel SIGNAL MONITOR connector. The observed signal should have a pk-pk amplitude of 28.3 mV. This signal will be noisy.

2. Set the Sensitivity switch to 100 μV and increase the Calibrator Output to 1 mV (100 μV with a Model 118 or 185). The observed signal should remain the same in amplitude (gain decrease compensated by increased calibrator output) but the noise should decrease.

If the indicated signal levels were observed, one can assume that the dc amplifier portion of the Mixer circuitry

is functioning normally.

5.6E MIXER SCHMITT TRIGGERS

Connect the oscilloscope to TP3002. One should observe a 400 Hz square wave with the lower level at -l2 V and the upper one at 0 V. If this waveform is as indicated, the Mixer Schmitt Triggers are probably working normally. If the waveform is absent, check for a 2.8 V pk-pk sinewave at C3005 before concluding there is a problem in the Schmitt Trigger circuit. Note from the schematic that the blue testpoint gives access to only one "half" of the complementary Schmitt Trigger output. The complement (collector of Q3003) could be checked at R3112 or at R3110.

5.6F MIXER CIRCUIT

1. Set both the Sensitivity and Calibrate switches to 5 mV (Calibrate Output to 500 μV with a Model 118), and the Function switch to LO DR1FT.

2. Monitor the signal at the junction of R3202 and R3204. Then set the Phase switch to 270°. The observed signal should be a full-wave rectified sinewave, although a slight adjustment of the Phase dial may be required to obtain this waveform. The amplitude of the half waves should be about 80 mV relative to a 0 V baseline. If the signal is as indicated, the Mixer circuit is probably functioning normally.

5.6G DC AMPLIFIERS

With Sensitivity switch settings from 1 μV through 5 mV, the dc gain is determined solely by the position of the Function switch. In LO DRIFT it is X20, in NORMAL it is X200, and in HI DYNAMIC RANGE it is X2000. For a given sensitivity, changing the function does not change the output dc level because the dc gain varies as well as to keep the overall instrument gain constant. Thus the dc amplifiers are checked simply by monitoring the dc output and observing that it does not change as the Function switch is rotated through its three PSD positions.

1. Adjust the Phase dial and the third Signal Frequency dial for maximum panel meter deflection. Then set the screwdriver adjustable Sensitivity Adj. control for exactly full-scale panel-meter deflection. If this cannot be done, there is probably a malfunction in one of the dc amplifiers or in the meter. The meter can be eliminated by checking the dc level at the front-panel Function Out connector. Ten volts corresponds to full-scale panel meter deflection.

2. At this point, the Function switch should still be set to LO DRIFT. Successively set it to NORMAL and then to HI DYNAMIC RANGE. The panel meter should continue to indicate full scale ±3%. If it does, one can reasonably assume that the dc amplifiers are functioning normally. If necessary, one could check the output of the first dc amplifier separately. This is most easily done at R3228, the emitter resistor of Q3203. The voltage there should be -1.5 V ±0.5 V. The output of the second amplifier should, of course, be +10 V.

3. Check the ACVM function by setting the Function switch to ACVM. The meter indication should remain unchanged. Note that dc voltmeter operation is achieved simply by taking the drive to the Mixer Schmitt Trigger from the Signal Channel instead of from the Reference Channel. No new circuits are activated.

If the instrument has passed all tests to this point, but the unit is still malfunctioning in some way not revealed by these tests, then the Problem is beyond the scope of the troubleshooting procedure and the operator should contact the factory or one of its authorized representatives for advice on how to proceed.

5.7 NOISE CHECKS

These checks allow the operator to determine whether the internally generated noise in his instrument is normal. Note that these checks vary according to the type of preamplifier used.

1. Set the front-panel controls as follows. **Note:** If preamplifier is a Model 184, go directly to step 10.

   Input Selector (Models 116, 117, 118, & 119): A
   Transformer/Direct switch (Models 116 & 119): DIRECT
   Ground Isolation (Model 185): IN
   Sensitivity
   Models 116, 117, & 119: 1 mV
   Models 118 & 185: 10 mV
   Signal Mode: BANDPASS
   Signal Frequency dials: 4.05
   Signal Range: Xl00
   Signal "Q": 100
   Reference Frequency dials: 4.05
   Reference Frequency Range: Xl00
   Phase switch: 270°
   Phase dial: 90°
   Zero Offset toggle switch: OFF (center position)
   Function switch: ACVM
   Calibrate switch: 1 mV

2. Connect a cable from the front-panel CALIBRATE connector to the preamplifier input.

3. Adjust the right-most Signal Frequency control for peak panel-meter indication.

4. Set the Function switch to NORMAL. Then adjust the Phase dial for peak meter indication.

5. Set the front-panel Sensitivity Calibrate adjustment for exactly full-scale meter indication.

6. Set the Signal "Q" switch to 10.

7. Remove the cable that interconnects the Calibrate Output and the Preamplifier Input. Then short the preamplifier input using a shorting plug such as the CW-159/U.

8. Set the Sensitivity switch to 100 nV. Then set the Time Constant switch to 100 ms (Preamplifier is Model 116, 117, or 119) or to 300 ms (Preamplifier is Model 118 or 185).

9. Note the pk-pk meter fluctuations about zero over a ten second period. If the preamplifier is a Model 116, 117, or 119, the fluctuations should not exceed ±25% of meter full scale. If the preamplifier is a Model 118 or a Model 185, the fluctuations should not exceed ±80% of meter full scale.

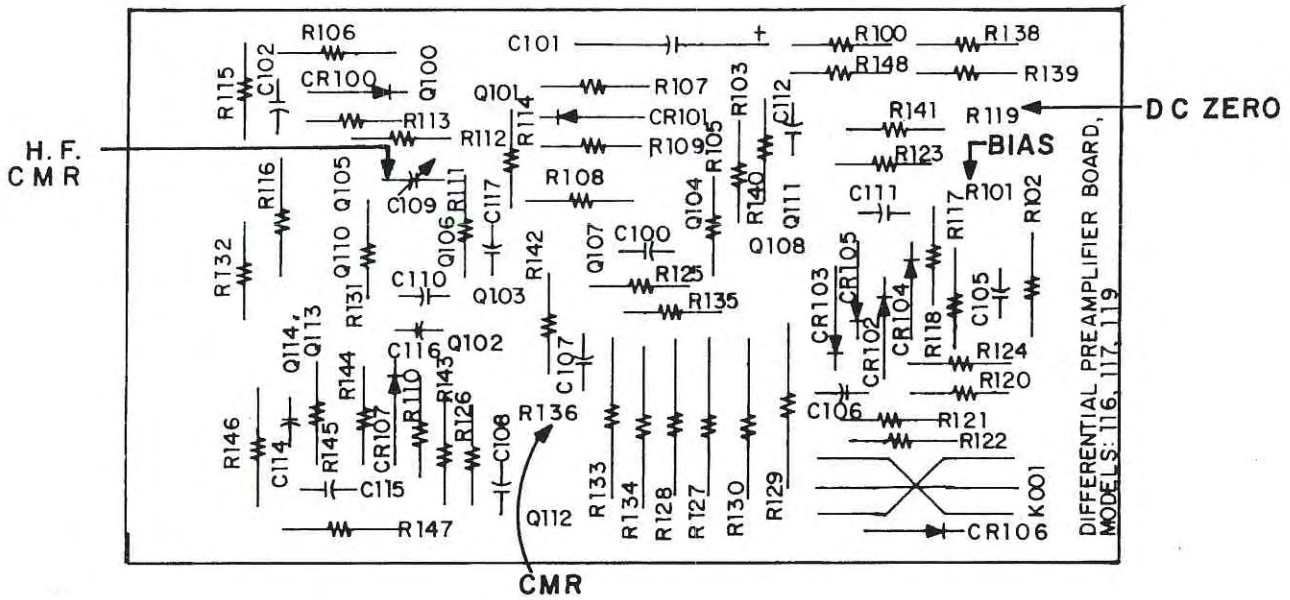
10. MODEL 184 ONLY: Set the controls as indicated in step 1 with the following exceptions. The Sensitivity of the Model 124A should be set to 1 μV, the Q to 10, the Time Constant to 1 SEC, and the Preamplifier Range control to 10^{-7} A/V. DO NOT ATTEMPT STEPS 2 THROUGH 9 WITH A MODEL 184 PREAMPLIFIER.

11. Connect a BNC cap (shielded open) to the Model 184 input.

12. Note the pk-pk fluctuations of the panel meter over a ten-second period. They should not exceed ±50% of meter full scale.

Chapter 6
Schematics

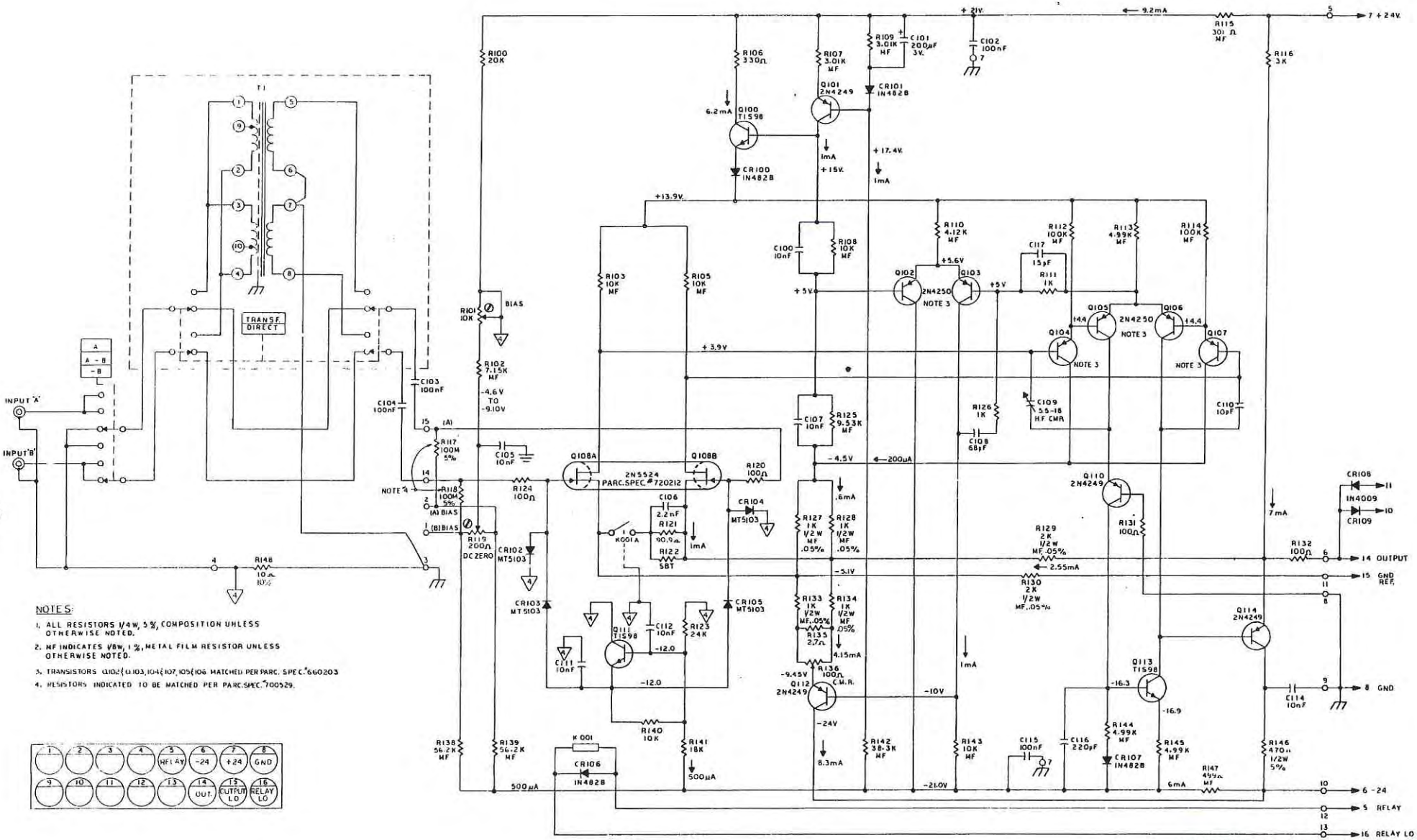
	Page
Table of	59
Layout Diagram, Models 116, 117, & 119	60
Model 116 Schematic (4852-D-SD)	61
Model 117 Schematic (6075-D-SD)	62
Model 119 Schematic (5076-D-SD)	63
Model 118 Layout Diagram	64
Model 118 Schematic (5074-D-SD)	65
Selective Amplifier Layout Diagram	66
Signal Amplifier Board Schematic (4867-D-SD; sheet 1 of 3)	67
Signal Amplifier Board Schematic (4867-D-SD; sheet 2 of 3)	68
Signal Amplifier Board Schematic (4867-D-SD; sheet 3 of 3)	69
Intermediate Amplifier Layout Diagram	70
Intermediate Amplifier Board Schematic (7577-C-SD; sheet 1 of 2)	71
Intermediate Amplifier Board Schematic (7577-D-SD; sheet 2 of 2)	72
Reference Oscillator Board Schematic (4870-D-SD; sheet 1 of 3)	73
Reference Oscillator Layout Diagram	74
Reference Oscillator Board Schematic (4870-D-SD; sheet 2 of 3)	75
Reference Oscillator Board Schematic (4870-D-SD; sheet 3 of 3)	76
Mixer Board Schematic (7165-C-SD; sheet 1 of 3)	77
Mixer Board Layout Diagram.	78
Mixer Board Schematic (7165-D-SD; sheet 2 of 3)	79
Mixer Board Schematic (7165-D-SD; sheet 3 of 3)	80
Power Supply Board Schematic (4872-D-SD; sheet 1 of 2)	81
Power Supply Board Layout Diagram	82
Power Supply Board Schematic (4872-D-SD; sheet 2 of 2)	83
Auxiliary Reference Board Layout Diagram	84
Auxiliary Reference Board Schematic (4871-D-SD)	85
Switch Schematic (7720-D-SD; sheet 1 of 3)	86
Switch Schematic (7720-D-SD; sheet 2 of 3)	87
Chassis Wiring Schematic (7720-E-SD; sheet 3 of 3)	88
Phase Meter Option Schematic (6084-C-SD; sheet 1 of 2)	89
Phase Meter Option Layout Diagram	90
Phase Meter Option Schematic (6084-C-SD; sheet 2 of 2)	91
Digital Option Layout Diagram	92
Digital Option Chassis Wiring Diagram (6725-D-SD)	93
Remote Programming Option Schematic (7877-D-SD)	94
Remote Programming Option Layout Diagram	95



SYMBOLIZATION MASTER

DIFFERENTIAL PREAMPLIFIER BOARD

MODELS: 116, 117, 119



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. TRANSISTORS Q102-Q103, 104-107, 105-106 MATCHED PER PARC. SPEC.#660203
4. RESISTORS INDICATED TO BE MATCHED PER PARC.SPEC.#700529.

1	2	3	4	5 RELAY	6 -24	7 +24	8 GND
9	10	11	12	13	14 OUT.	15 OUTPUT LO	16 RELAY LO

DIFFERENTIAL PREAMPLIFIER
SUB ASSEMBLY 1160-2000-00s

MODEL 116

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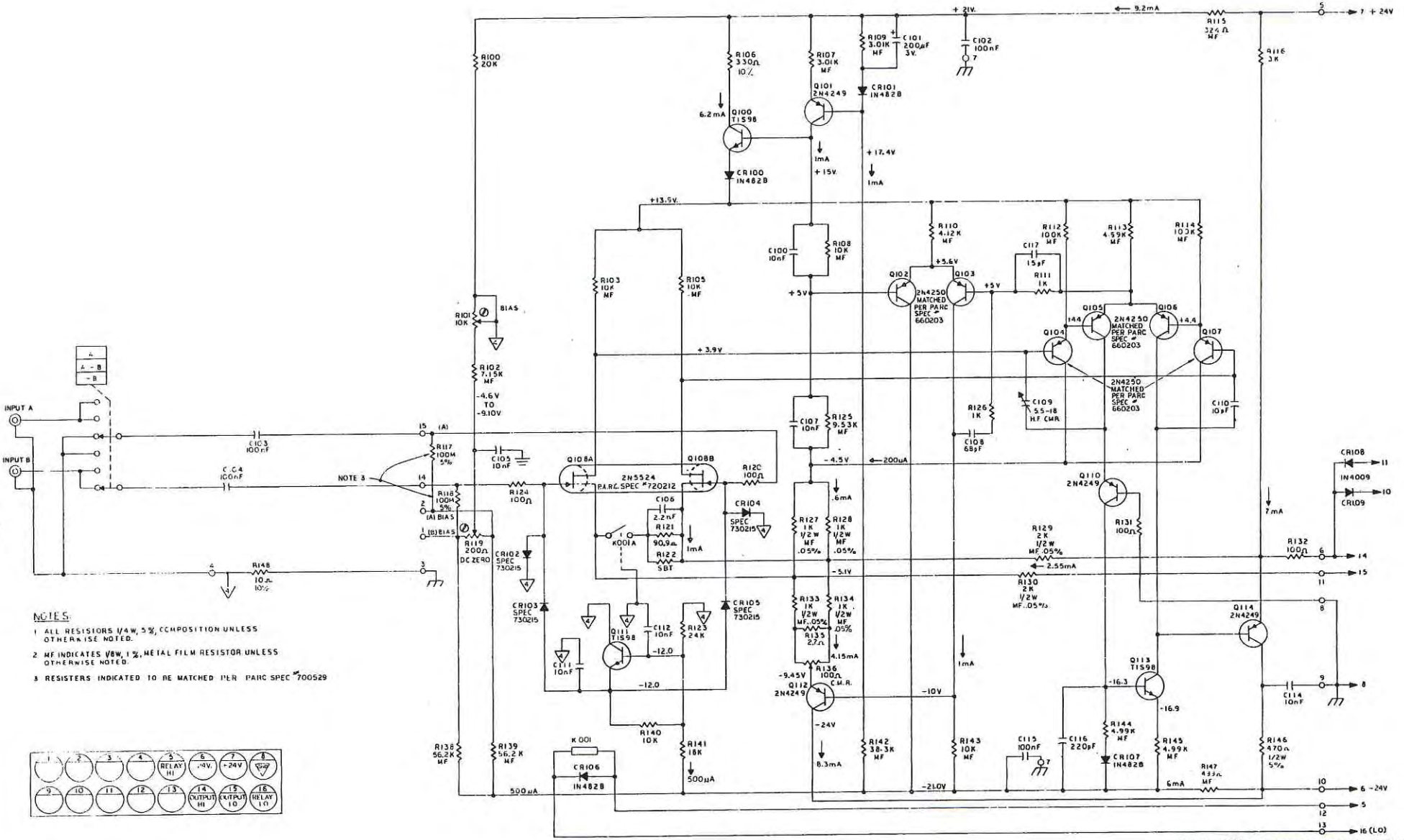
4852 D SD A



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. RESISTERS INDICATED TO BE MATCHED PER PARC SPEC # 700529

DIFFERENTIAL PREAMPLIFIER
SUB ASSEMBLY 1160-2000-00s

MODEL 117

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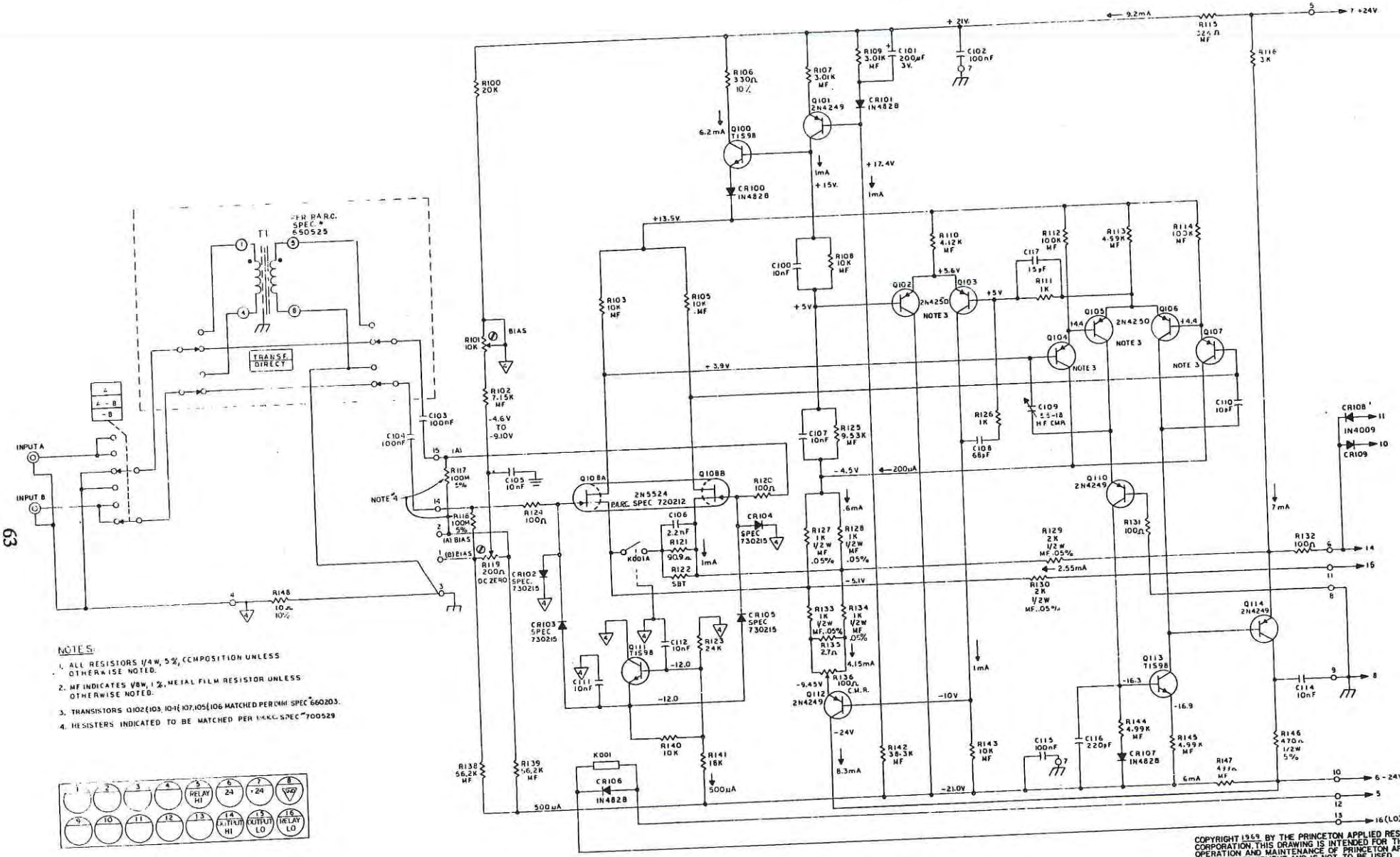
5075 | D | SD | E



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. TRANSISTORS Q102{103, 104{107, 105{106 MATCHED PER PARC SPEC 660203.
4. RESISTERS INDICATED TO BE MATCHED PER PARC SPEC 700529

1	2	3	4	5	6	7	8
				RELAY HI	24	-24	GND

9	10	11	12	13	14	15	16
					OUTPUT HI	OUTPUT LO	RELAY LO

DIFFERENTIAL PREAMPLIFIER
SUB ASSEMBLY 1160-2000-00s

MODEL 119

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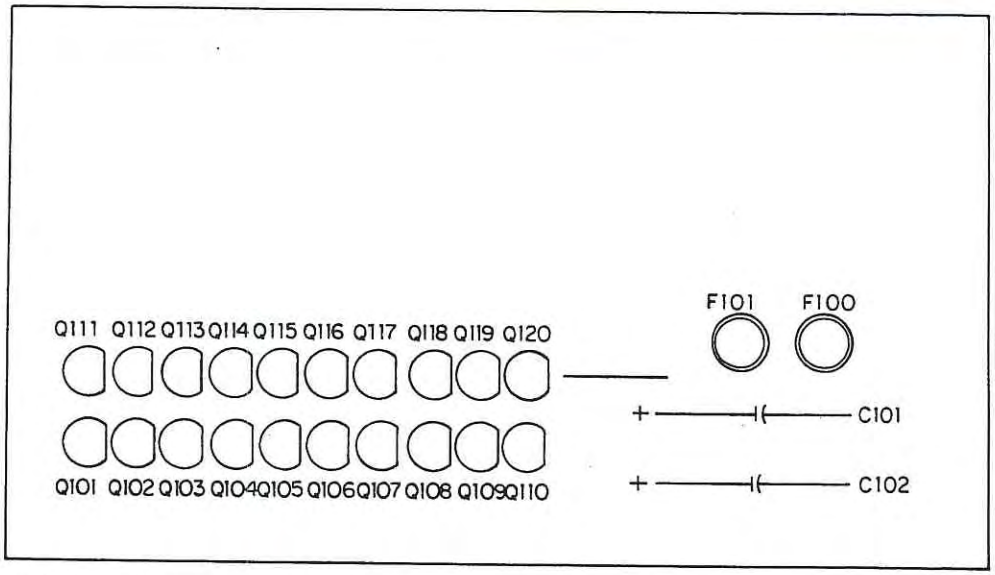
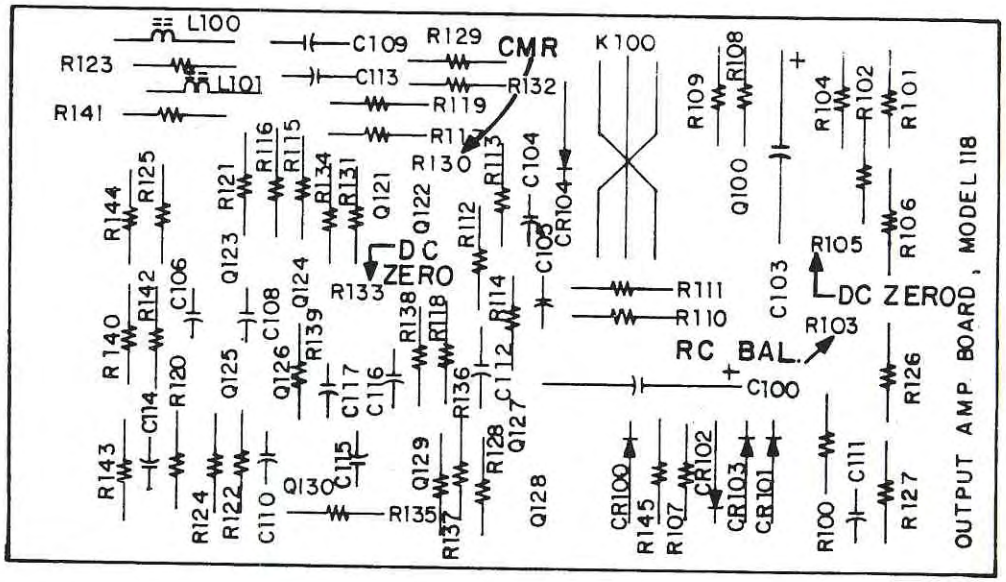
5076 D SD F



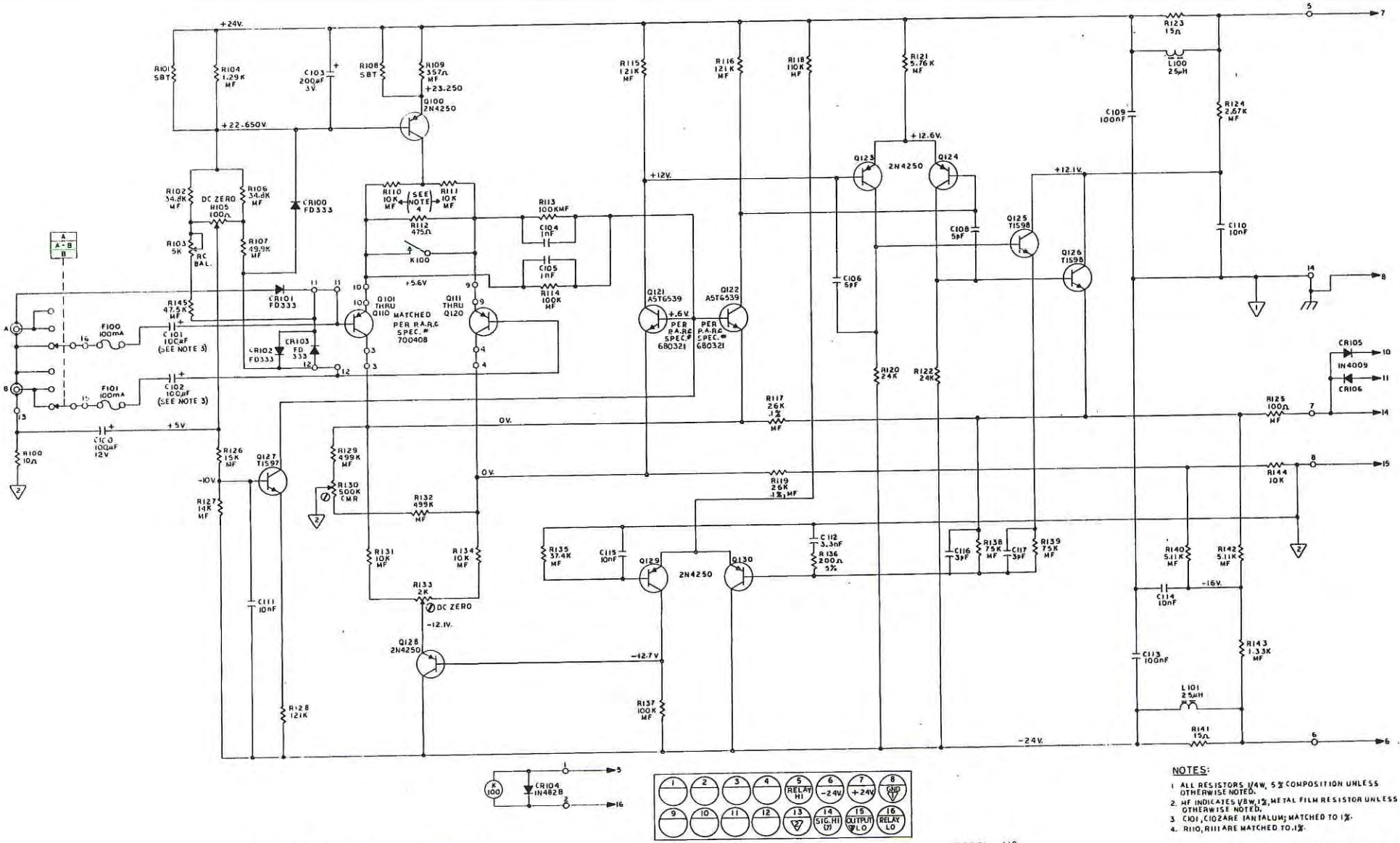
MODEL 118
INPUT AMP BOARD



SYMBOLIZATION MASTER

OUTPUT AMP. BOARD

MODEL 118



MEDIUM Z DIFFERENTIAL PREAMPLIFIER

INPUT AMP. ASSEMBLY 1180-2100-05S
(Q101 THRU Q120; C101 & C102; F100 & F101)
OUTPUT AMP. ASSEMBLY 1180-2000-06S

MODEL 118

NOTES:

1. ALL RESISTORS 1/4W, 5% COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1% METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. C101, C102 ARE TANTALUM; MATCHED TO 1%.
4. R110, R111 ARE MATCHED TO .1%.

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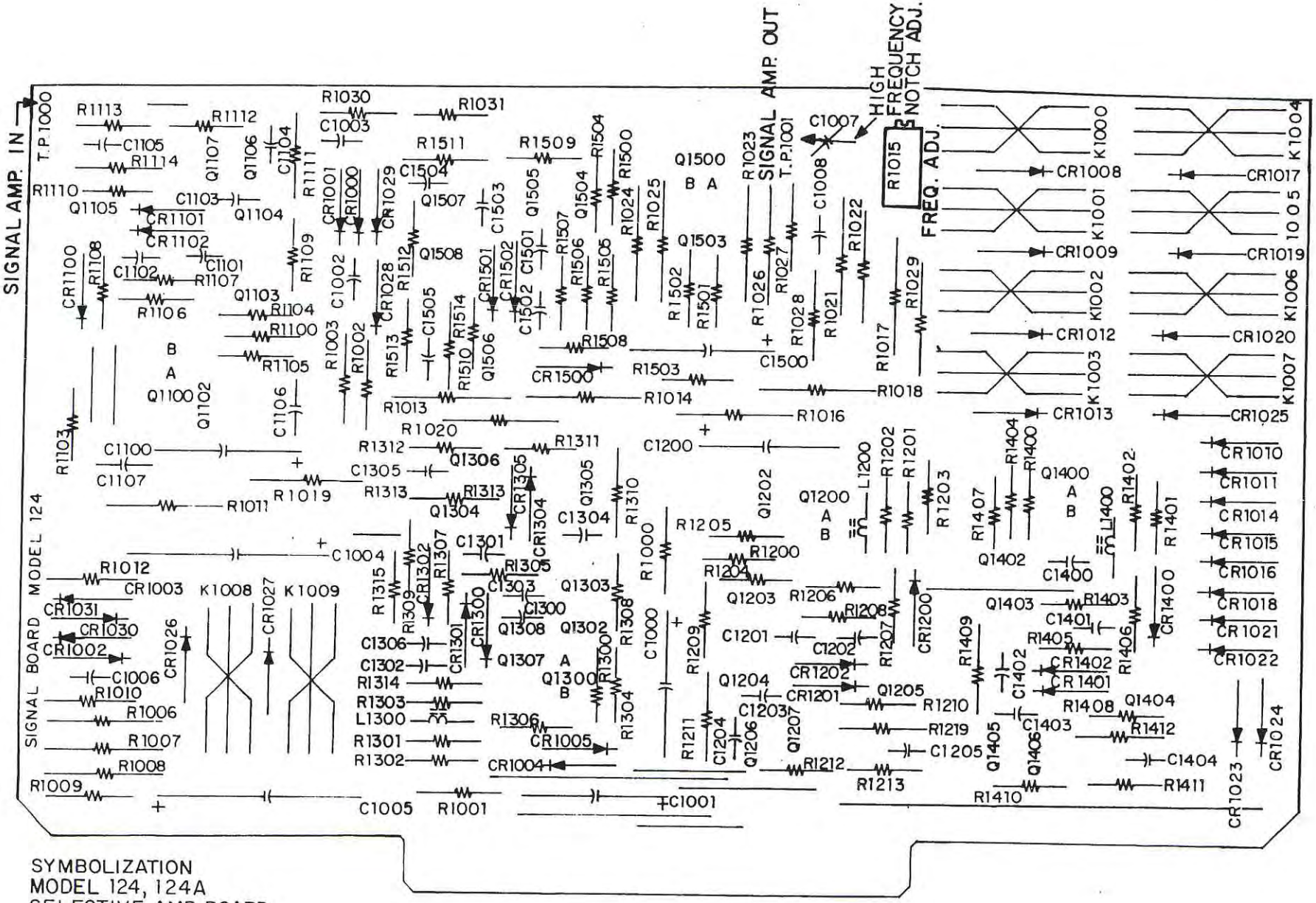
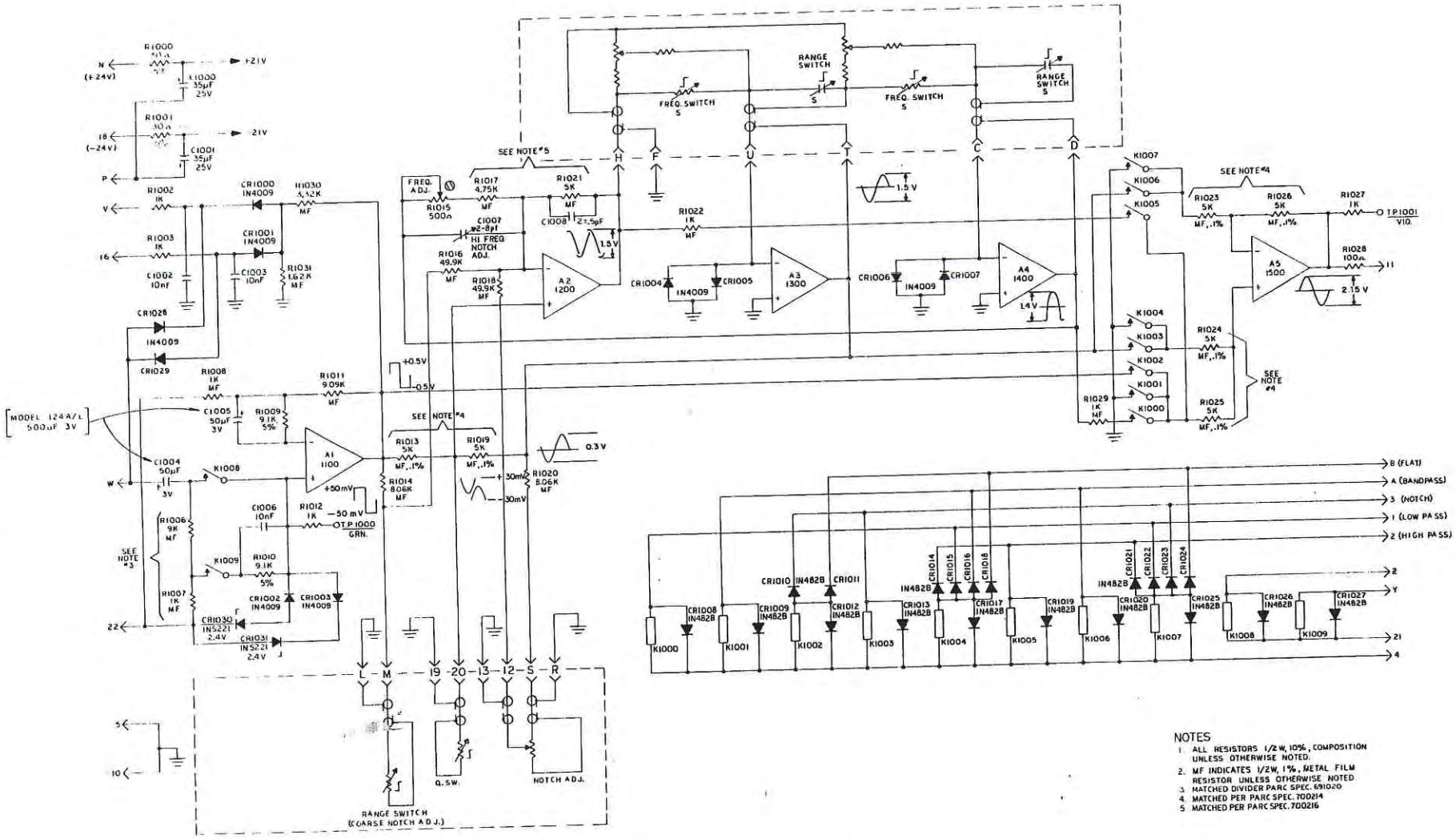
5074-D-SD-D

5074 | D | SD | D



SYMBOLIZATION
MODEL 124, 124A
SELECTIVE AMP. BOARD
FAB. # 4971-MD-C



NOTES
1. ALL RESISTORS 1/2 W, 10%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/2W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED
3. MATCHED DIVIDER PARC SPEC. 691020
4. MATCHED PER PARC SPEC. 700214
5. MATCHED PER PARC SPEC. 700216

1 LOW PASS	2 HIGH PASS	3 NOTCH	4 RELAY GND	5 GND	6 GND	7 NC	8 NC	9 NC	10 GND	11 OUTPUT	12 NOTCH ADJ.	13 GND	14 NC	15 NC	16 OVERLOAD	17 NC	18 -24V	19 GND	20 "Q" SW.	21 RELAY GND	22 INPUT GND
A BAND PASS	B FLAT	C RANGE SW.	D RANGE SW.	E NC	F GND	H FREQ. SW.	J NC	K NC	L GND	M RANGE SW.	N +24V	P P.S. GND	R GND	S NOTCH ADJ.	T RANGE SW.	U RANGE SW.	V OVERLOAD (+)	W SIG. INPUT	X NC	Y X0.1 RELAY	Z X1 RELAY

SIGNAL AMP. BD.
SUB-ASSEMBLY
*1240-2500-09 (PARTIAL)

MODEL 124 & 124A

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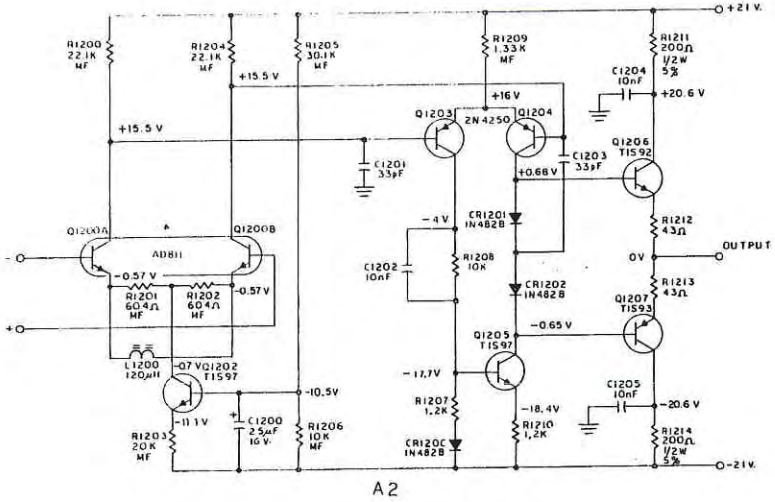

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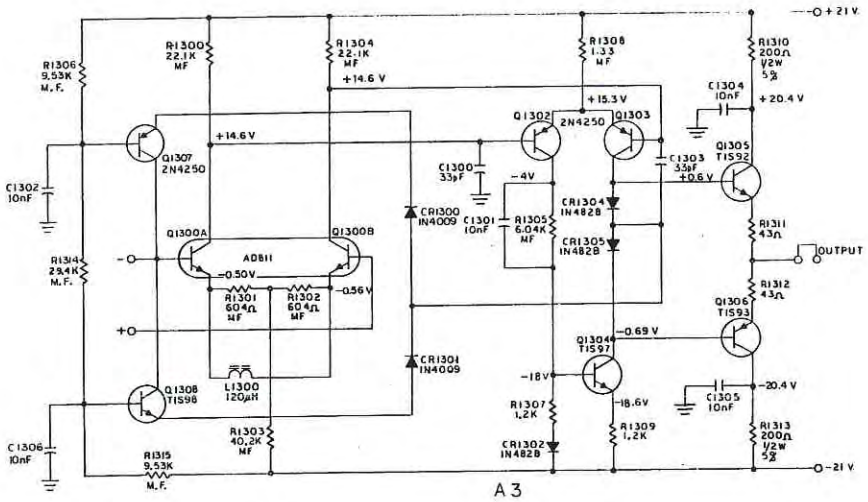
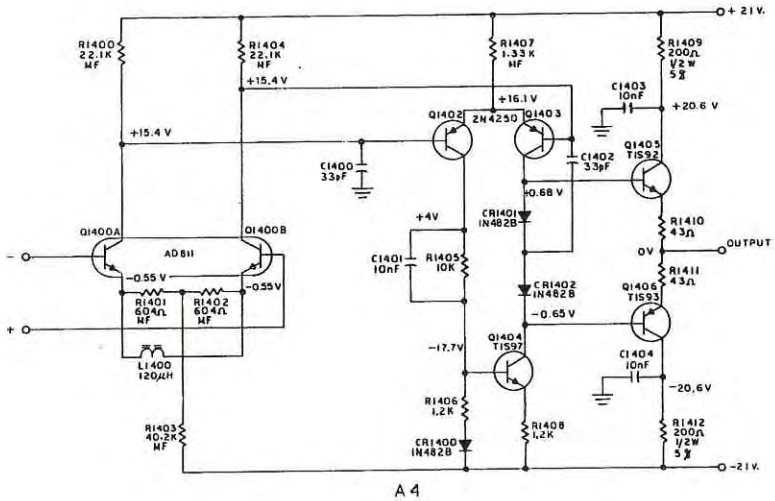


A3



A4

OPERATIONAL AMPLIFIERS A2,A3,A4

SIGNAL AMP. BD.

SUB-ASSEMBLY #1240-2500-09(PARTIAL)

MODEL 124 & 124A

NOTES:

1. ALL RESISTORS ARE 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.

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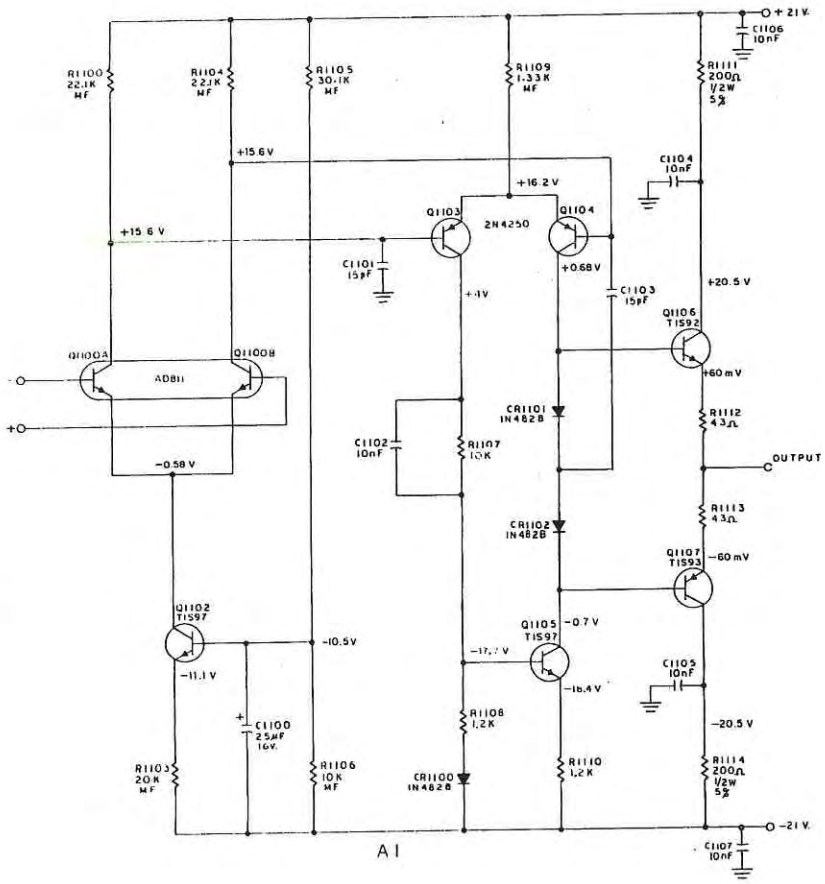
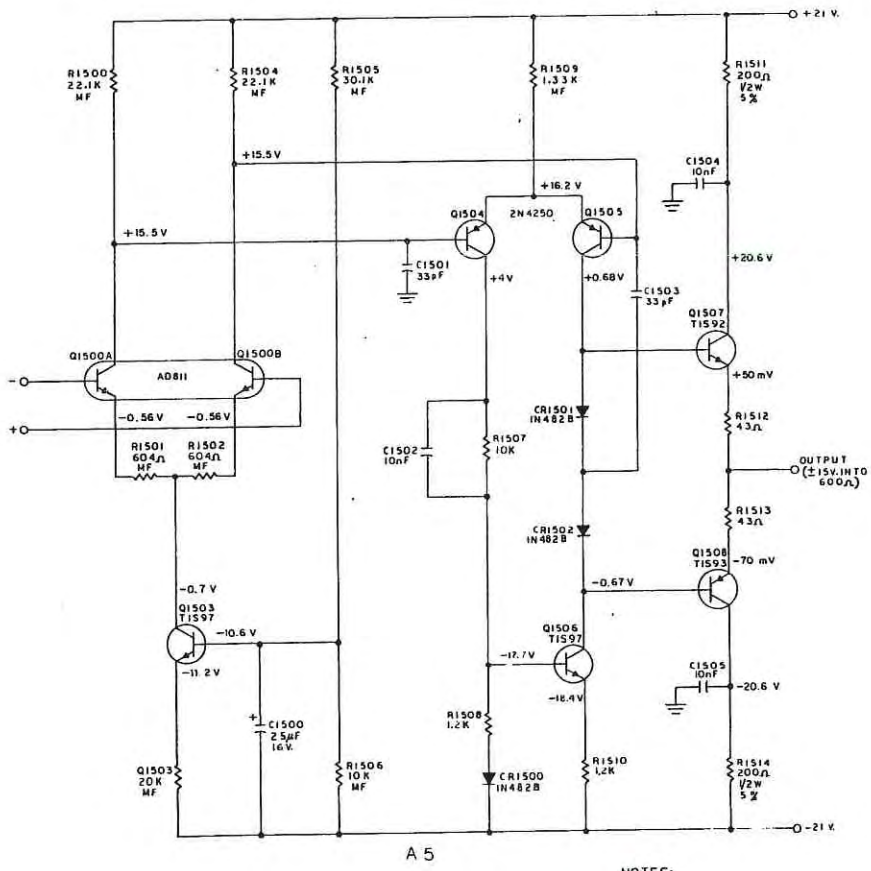


A1



A5

NOTES:

1. ALL RESISTORS ARE 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. ALL GND ROUTED TO SHELL OF OUTPUT BNC.

OPERATIONAL AMPLIFIERS A1 & A5
SIGNAL AMP. BD.
SUB-ASSEMBLY #1240-2500-09 (PARTIAL)

MODEL 124 & 124A

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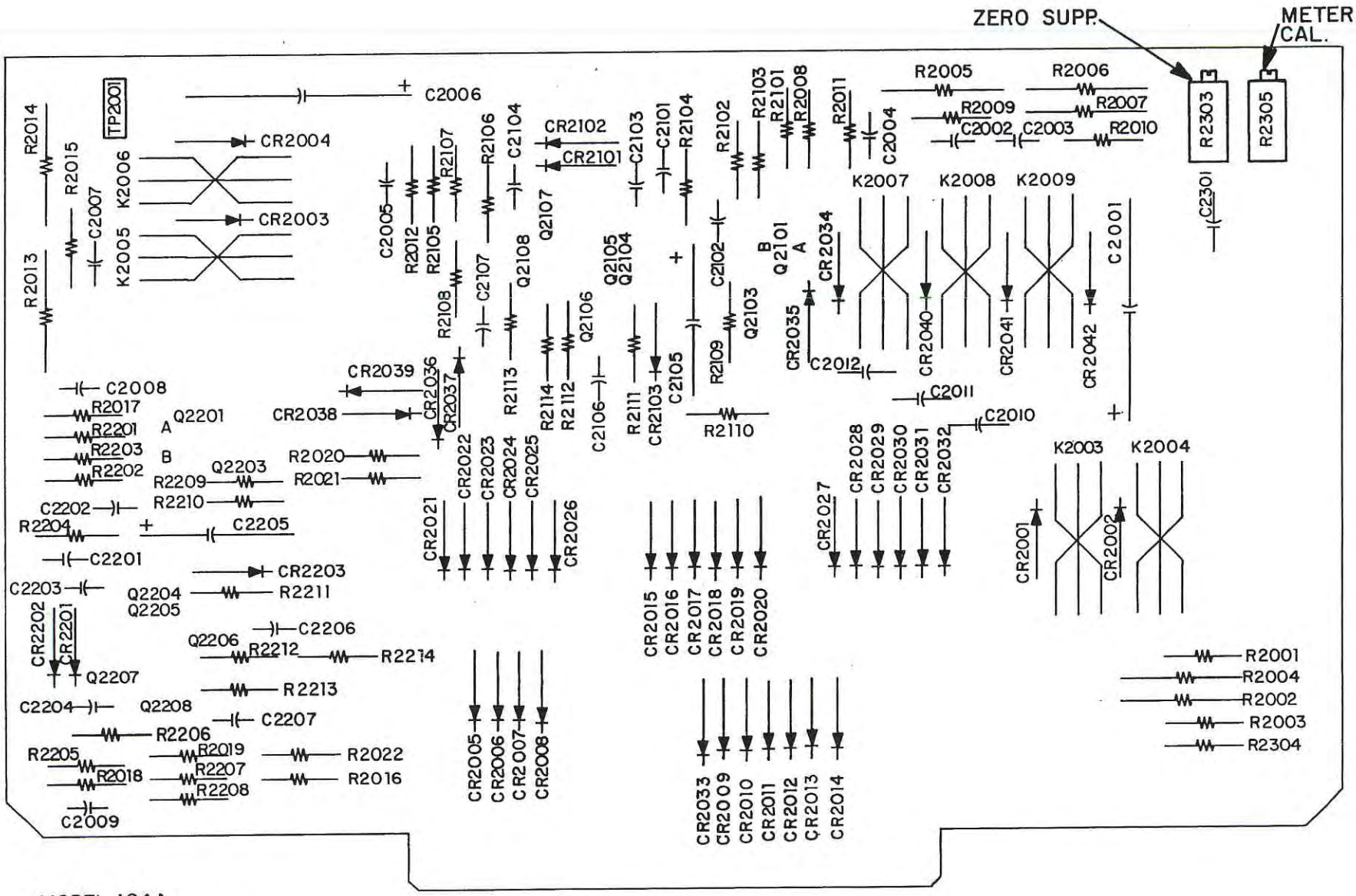
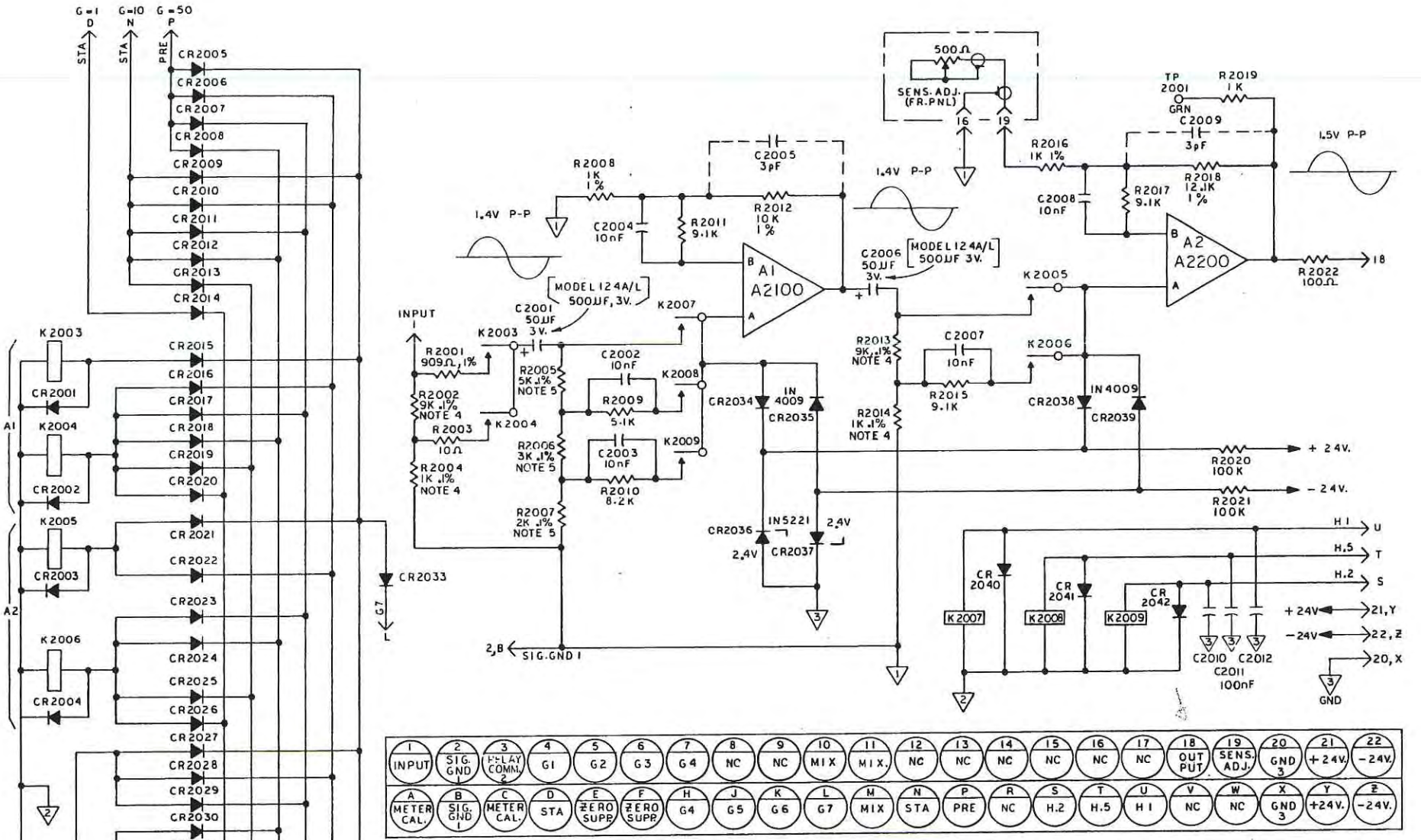


MODEL 124A
INTERMEDIATE AMP. BOARD



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
INPUT	SIG. GND	RELAY COMM. 2	G1	G2	G3	G4	NC	NC	MIX	MIX	NC	NC	NC	NC	NC	NC	OUT PUT	SENS. ADJ.	GND 3	+24V.	-24V.
A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z
METER CAL.	SIG. GND 1	METER CAL.	STA	ZERO SUPR.	ZERO SUPR.	G4	G5	G6	G7	MIX	STA	PRE	NC	H.2	H.5	H.1	NC	NC	GND 3	+24V.	-24V.

VOLTAGES AND WAVEFORMS MEASURED UNDER FOLLOWING CONDITIONS:

1) MODE -- BANDPASS.
2) SENSITIVITY -- 100mV.
3) CALIBRATE -- 100mV. (CONNECTED TO 'A' INPUT OF MODEL 116 PREAMPLIFIER).
4) TUNE TO 400Hz.

NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/2W METAL FILM.
3. ALL DIODES ARE IN482B UNLESS OTHERWISE NOTED.
4. MATCHED DIVIDER PAR SPEC. 691020.
5. MATCHED DIVIDER PAR SPEC. 700116.
6. ALL 1% RESISTORS 1/8W METAL FILM.

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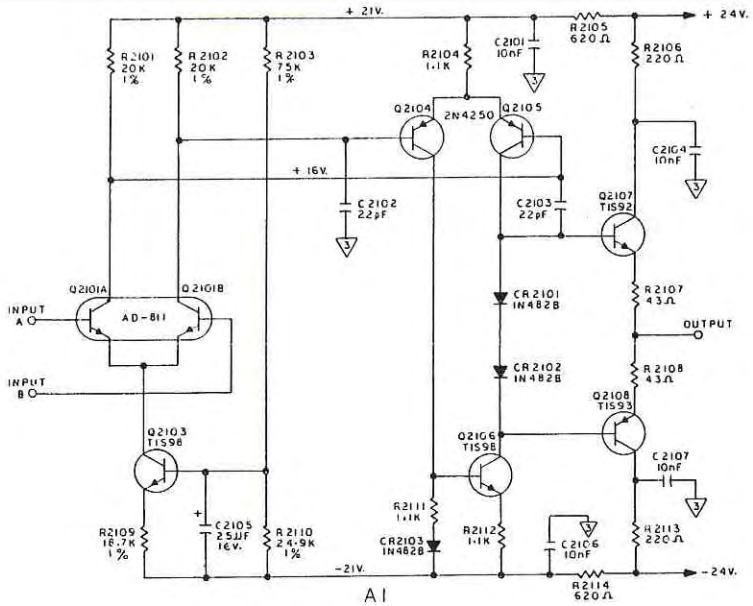
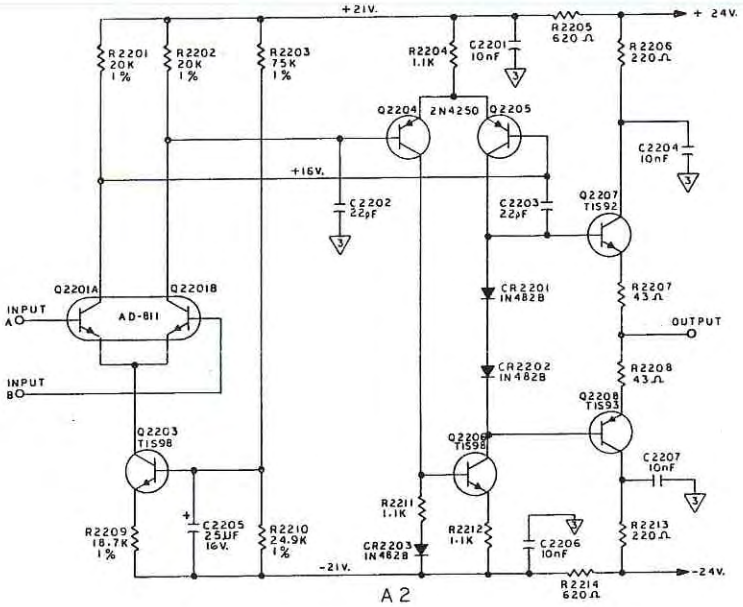
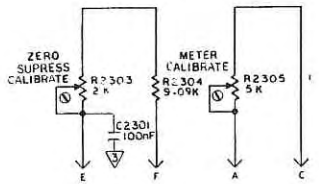
INTERMEDIATE AMPLIFIER BD
SUB ASSEBLY 1241-24-0009S (PARTIAL)

MODEL 124A







72

NOTES:
SEE SHEET 1

INTERMEDIATE AMPLIFIER BD
SUB ASSEMBLY 1241-24-00095 (PARTIAL)

MODEL 124A

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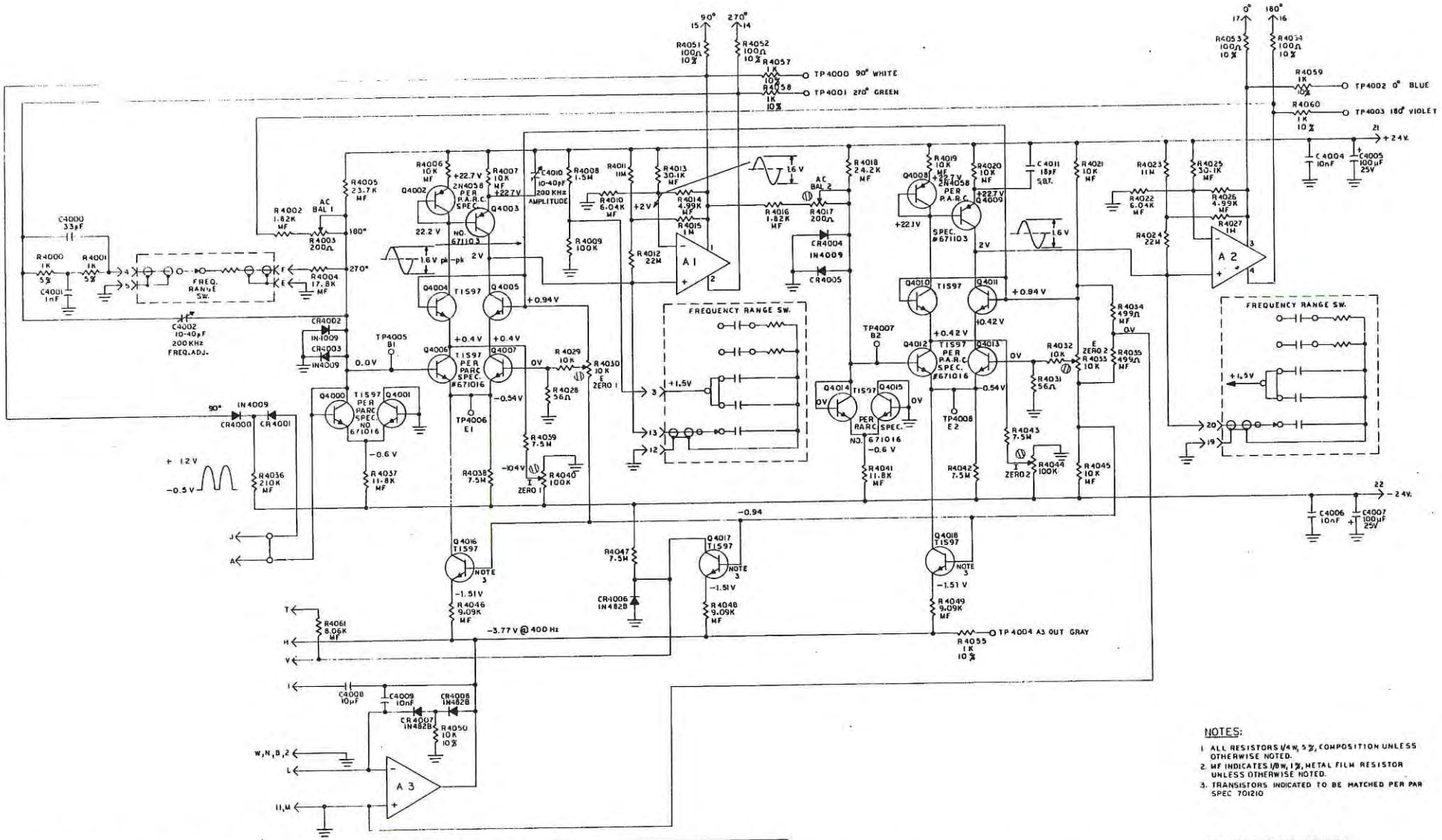

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
10μF	GND	+1.5V	AC FEED-BACK	GND	NC	NC	NC	NC	NC	GND	GND	TUNING CAPS	270°	90°	180°	0°	NC	GND	TUNING CAPS	+24V	-24V

A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z
MOD	GND	NC	NC	GND	AC FEED BACK	A3 OUT	MOD	NC	SUM. JCT.	GND	GND	NC	NC	NC	VCO IN	NC	DC FEED-BACK	GND	NC	+24V	-24V

REFERENCE OSCILLATOR BD. MODEL 124&124A

SUB-ASSEMBLY "1240-2200-02 (PARTIAL)

SEE 4870-D-SD FOR SHT 2 OF 3
SEE 4870-C-SD FOR SHT 3 OF 3.

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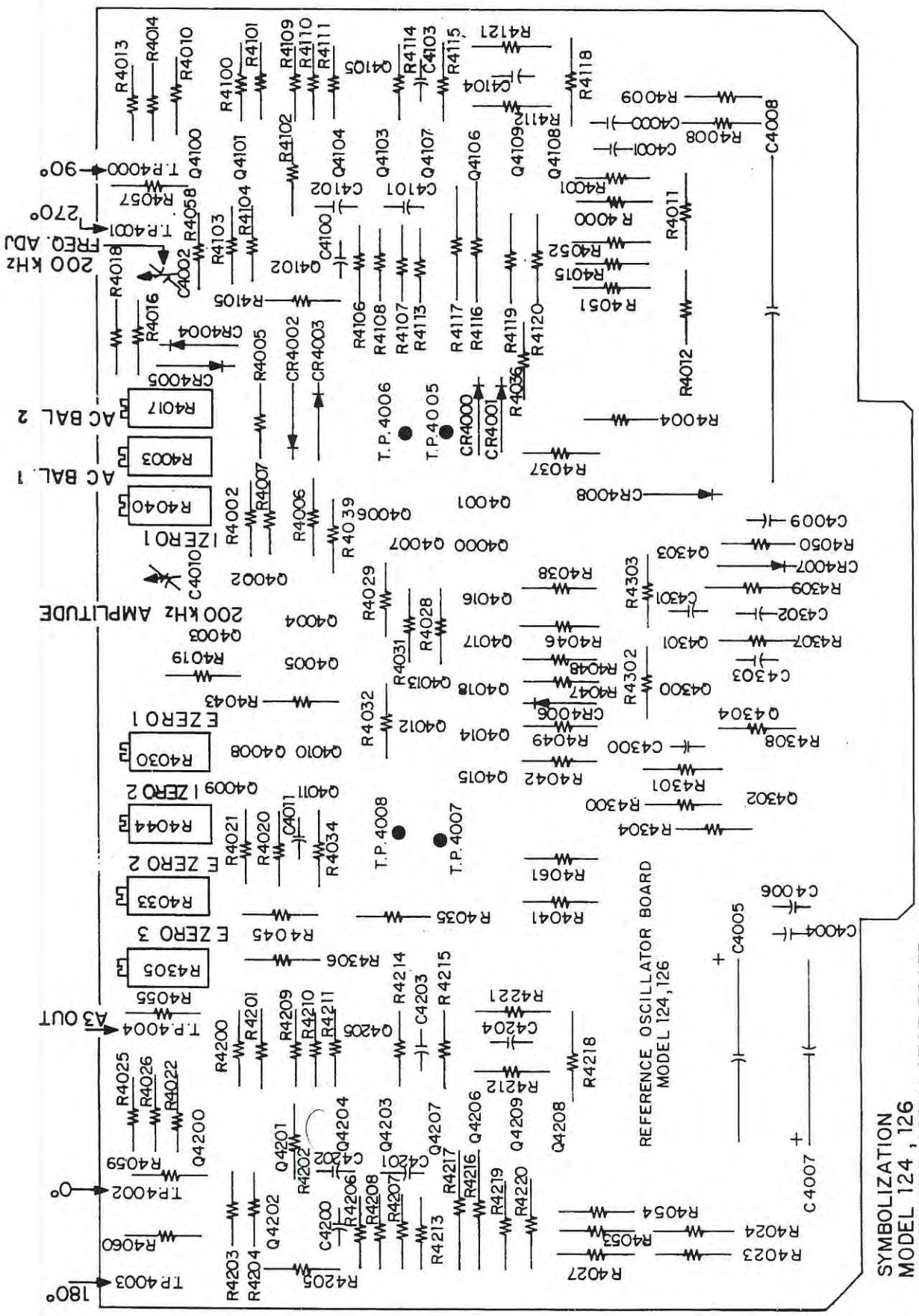
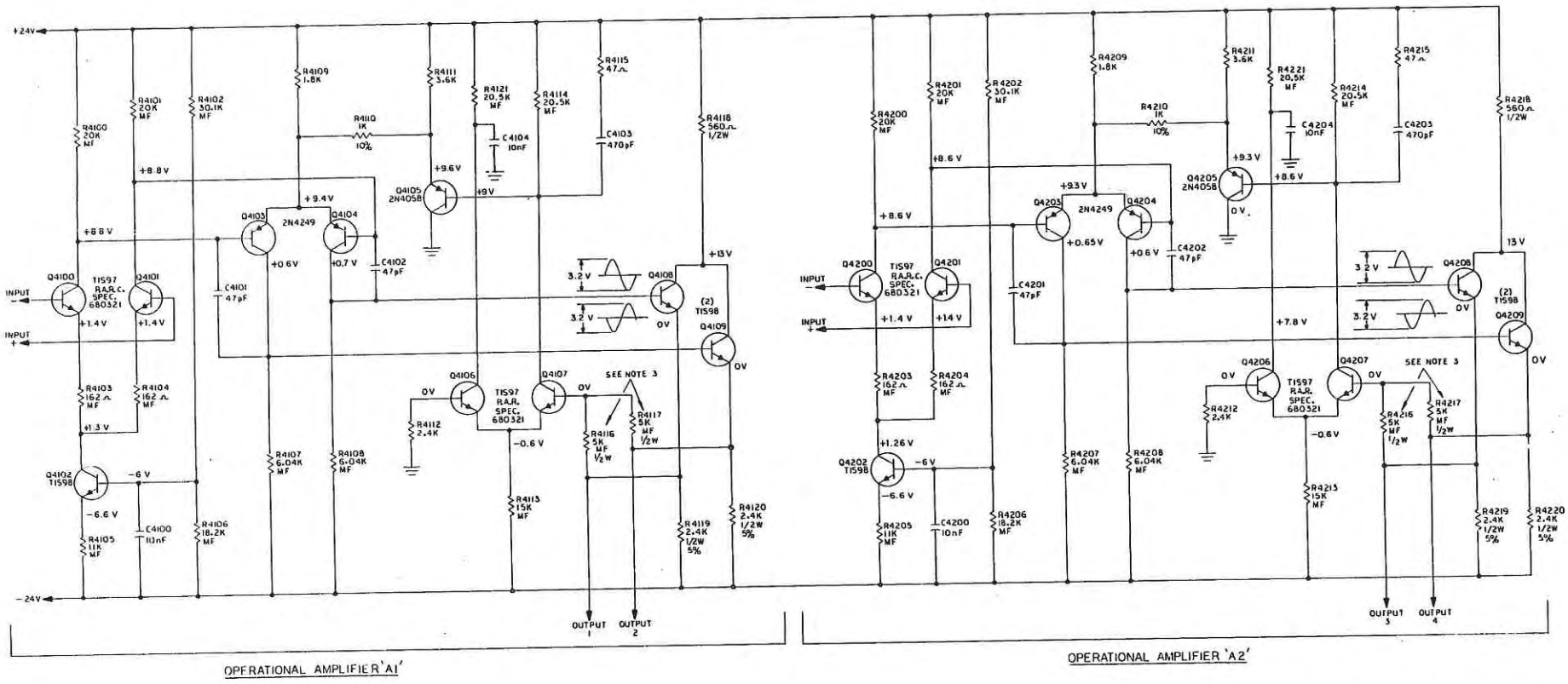
SHEET 1 OF 3 | 4870 | D | SD | G1


SYMBOLIZATION
MODEL 124, 126
REFERENCE OSCILLATOR BOARD
FAP. # 4980-MD-E
REFERENCE OSCILLATOR BOARD
MODEL 124,126
200 kHz AMPLITUDE
FREQ. ADJ
AC BAL 1
AC BAL 2
I ZERO 1
E ZERO 1
I ZERO 2
E ZERO 2
E ZERO 3
A3 OUT
0°
90°
180°
270°



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. MATCHED PAIR PER SPEC #700214

REFERENCE OSCILLATOR BD. MODEL 124 & 124A
SUB-ASSEMBLY #1240-2200-02 (PARTIAL)

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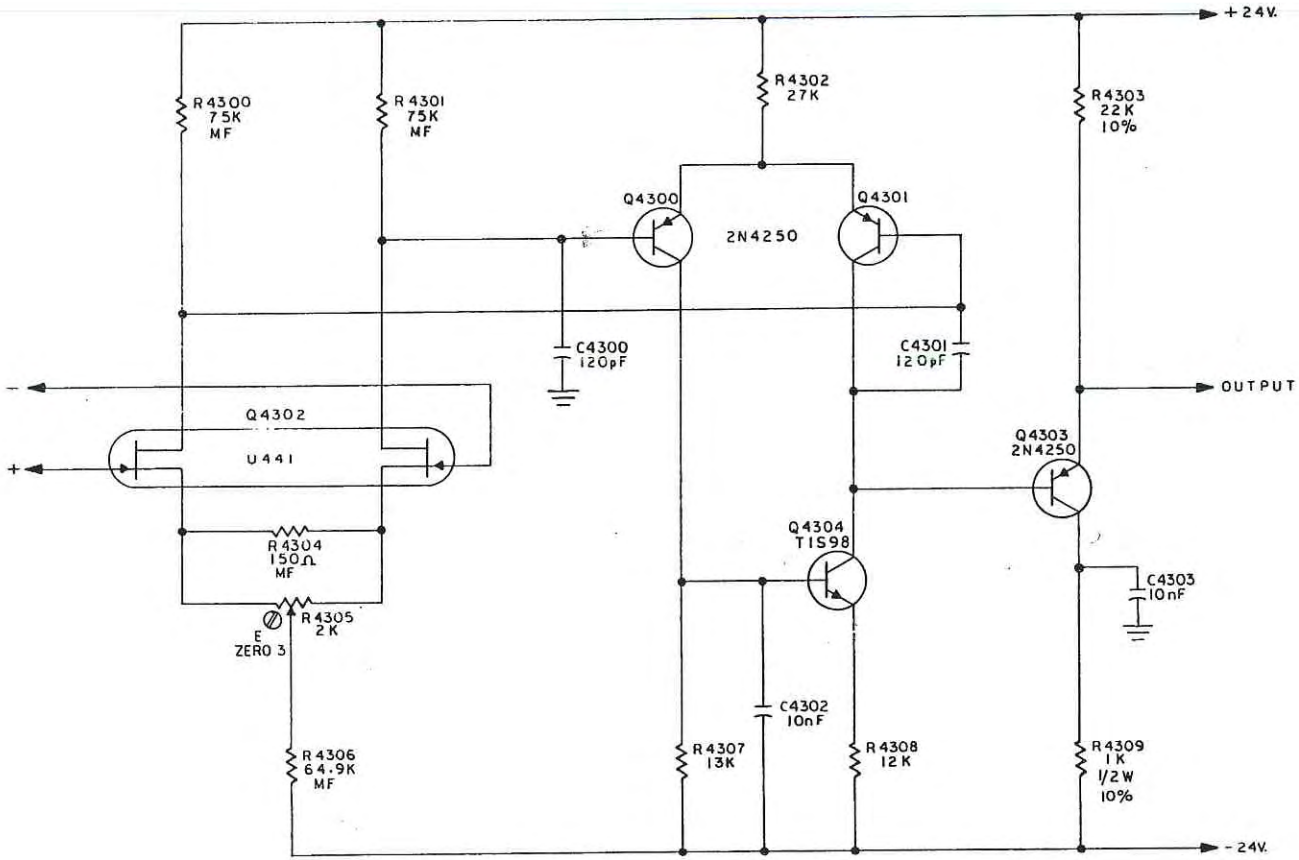

NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.

OPERATIONAL AMPLIFIER 'A3'

REFERENCE OSCILLATOR BD.
SUB-ASSEMBLY *1240-2200-02 (PARTIAL)

MODEL 124 & 124A

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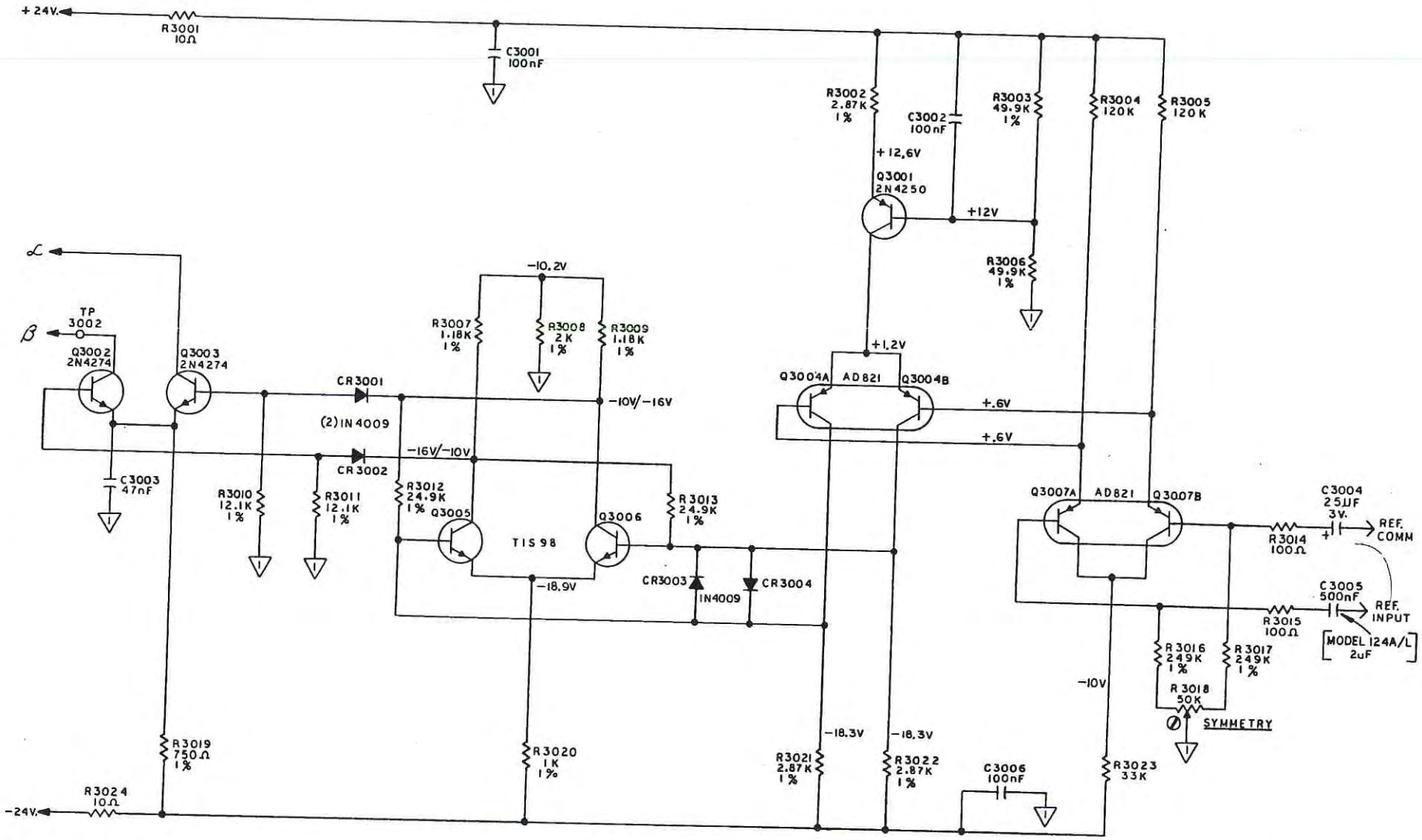
G1



MIXER BOARD

SCHMITT TRIGGER

SUB ASSEMBLY 1241-53-0003S (PARTIAL)

MODEL 124A

NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION, UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/8W METAL FILM UNLESS OTHERWISE NOTED.
3. ALL DIODES ARE IN482B UNLESS OTHERWISE NOTED.

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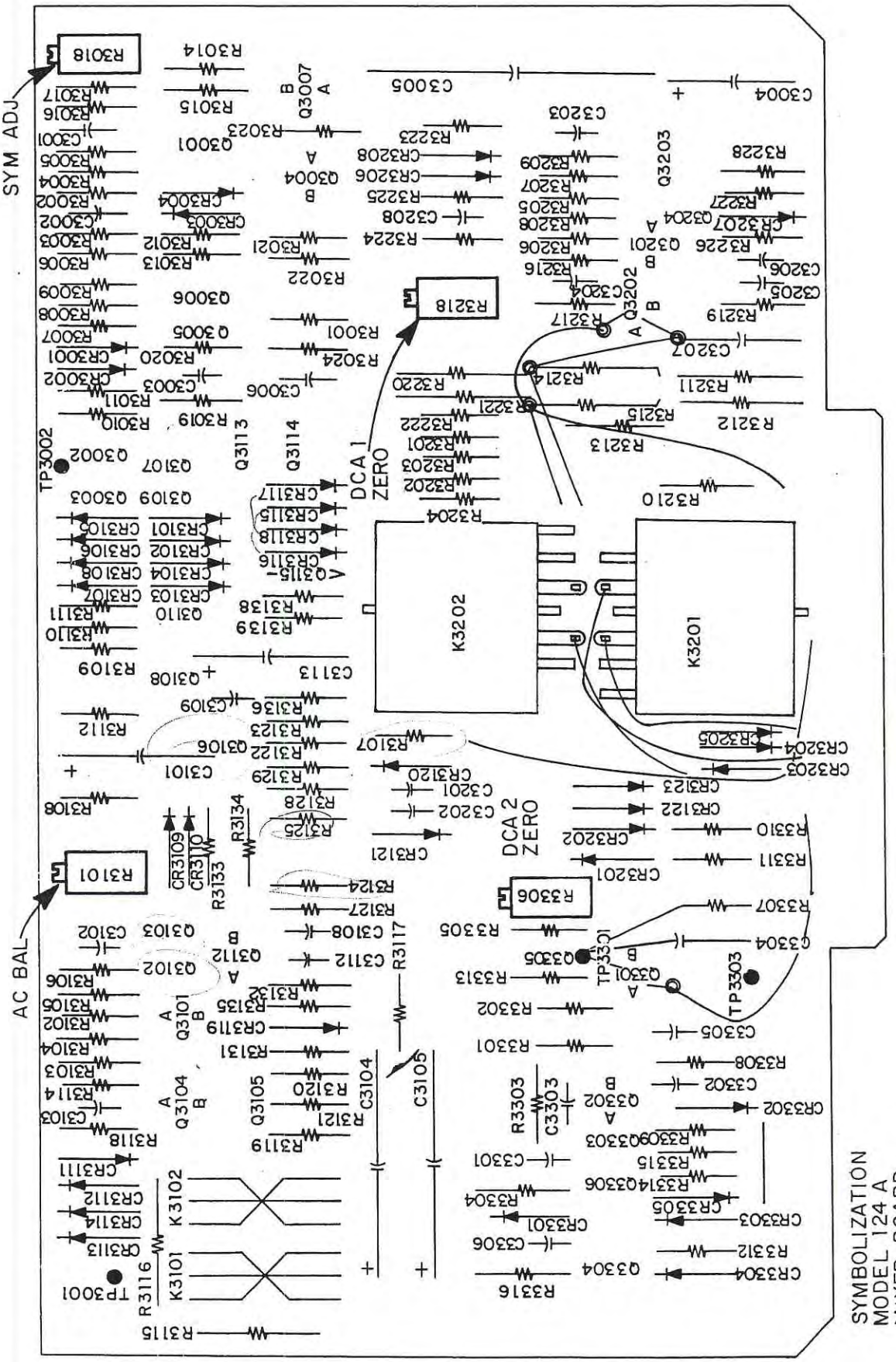
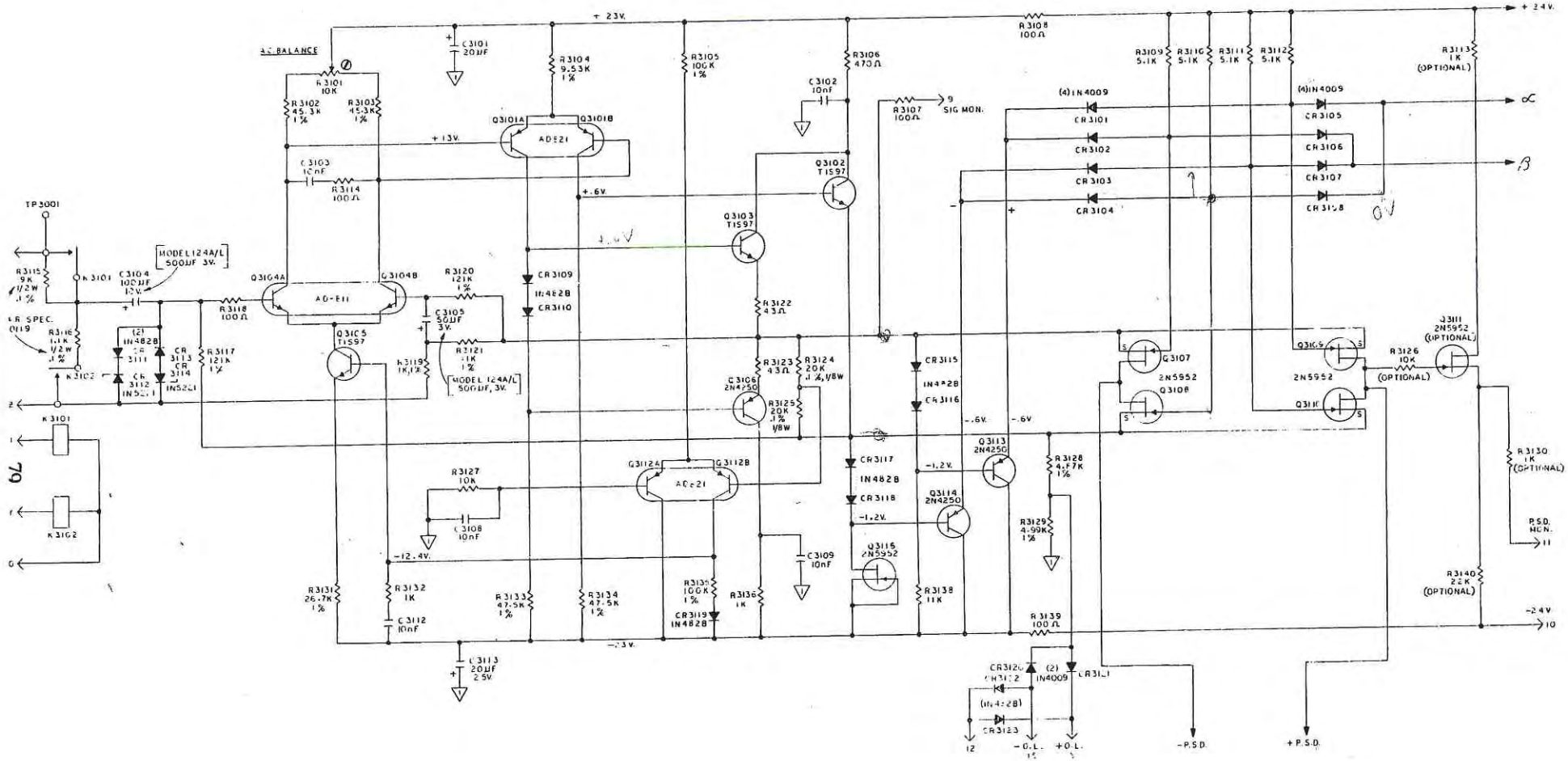


SYMBOLIZATION
MODEL 124 A
MIXER BOARD
FAB # 7230 — MD —



MIXER BOARD
FINAL A.C. AMPLIFIER
SUB ASSEMBLY 1241-53-0003S (PARTIAL)

MODEL 124A

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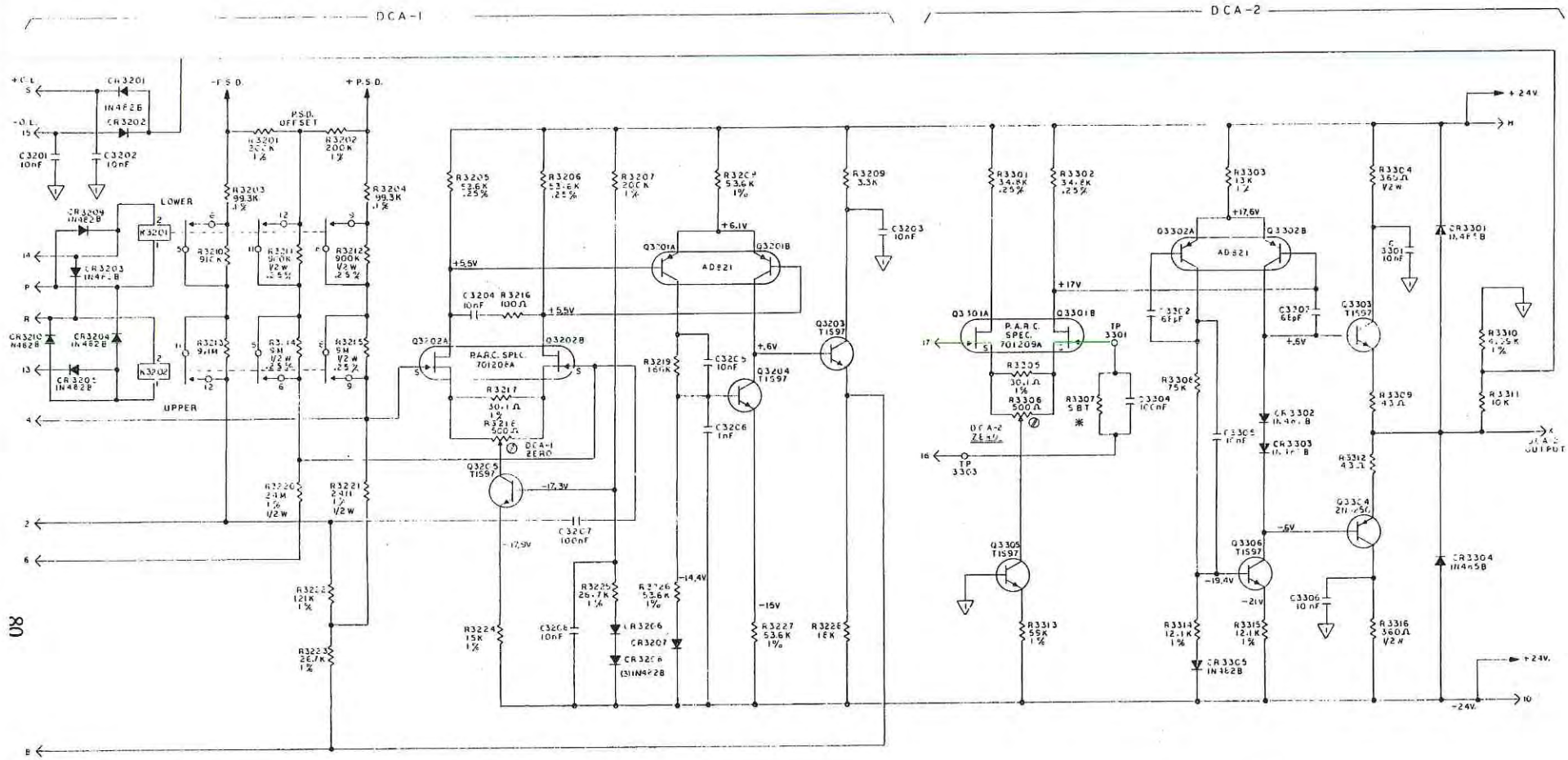

1 REF IN	2 DCA-1 COMM	3	4 DCA-1 INV. IN	5	6 ZERO SUPR	7 NC	8 NC	9 SIG HIGH	10 -24V	11 PSD MON.	12 DCA-1 OUT	13 N. REL RANGE	14 NORM LOCK	15 -O.L.	16 DCA-2 FOLLOW	17 DCA-2 INV. IN	18 NC	19 NC	20 RELAY COMM	21 MIX SIG	22 SIG IN.
A REF COMM	B DCA-1 OUT	C	D NC	E	F NC	H +24V.	J NC	K NC	L	M	N	P HI/LOW RANGE	R NORM LOCK	S +O.L.	T NC	U NC	V NC	W NC	X DCA-2 OUT	Y MIX SIG	Z SIG GND

MIXER BOARD
SUB ASSEMBLY 1241-53-00035 (PARTIAL)

MODEL 124A

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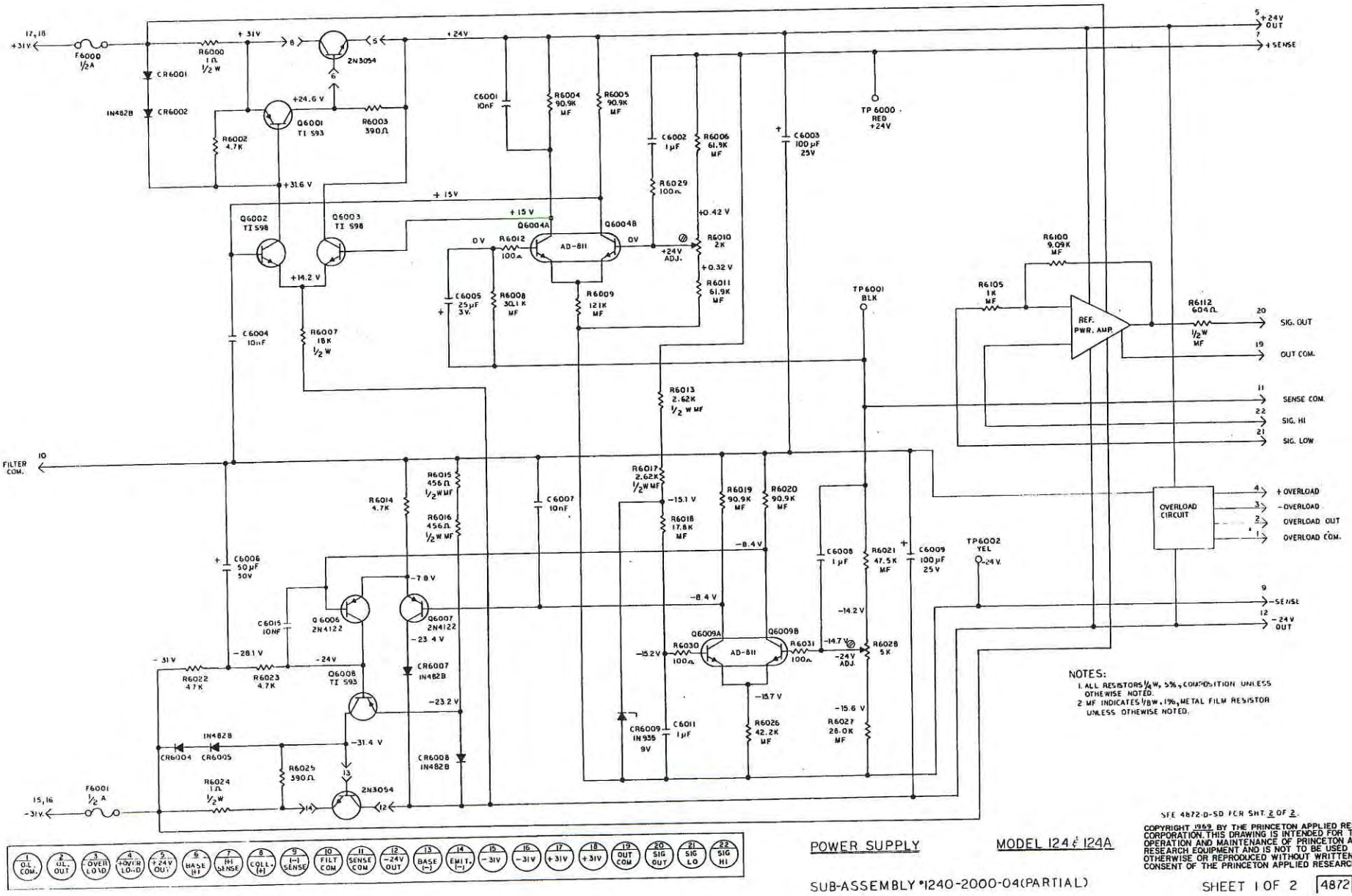

NOTES:
1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.

SEE 4872-D-SD FOR SHT. 2 OF 2.

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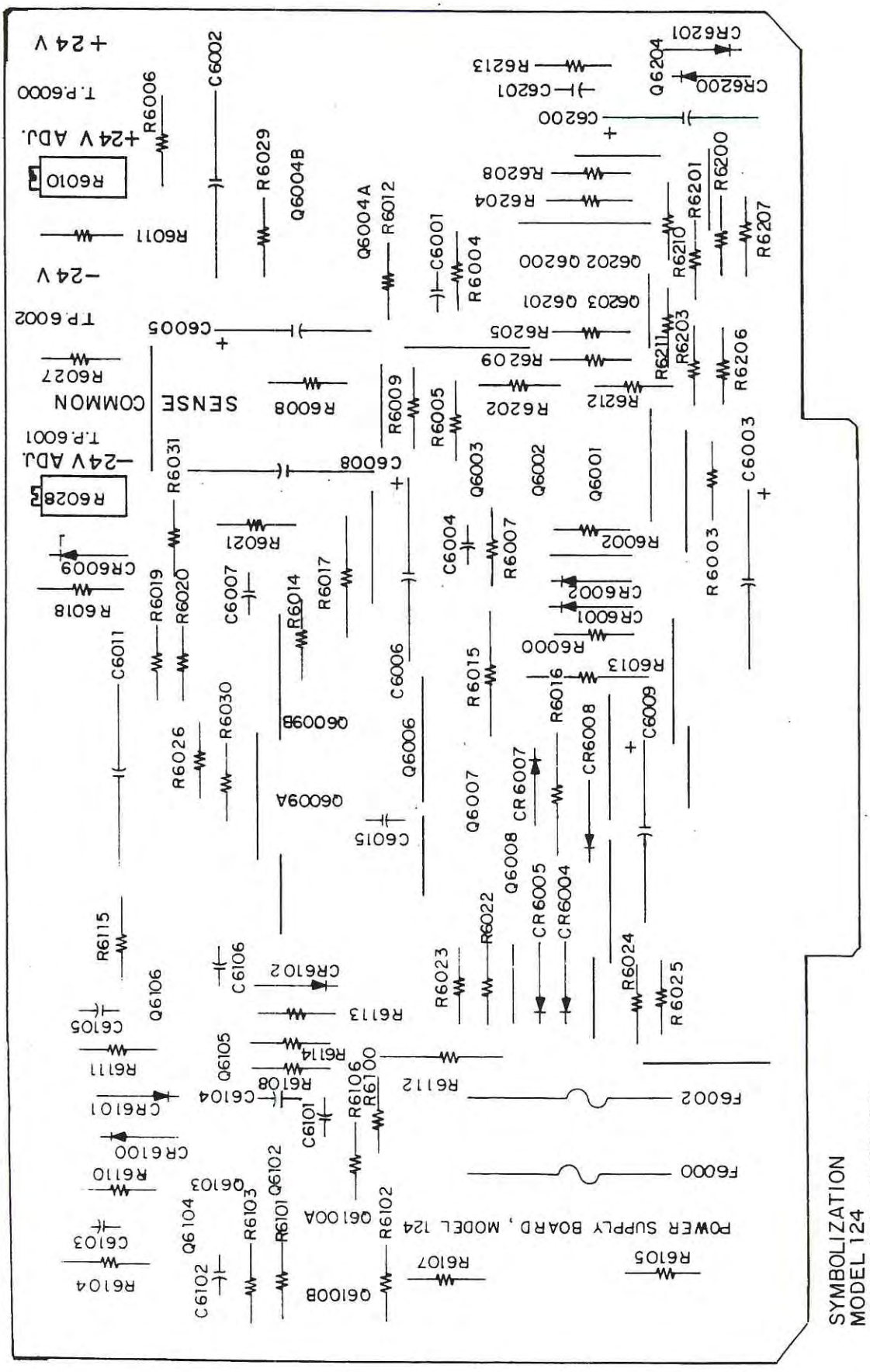
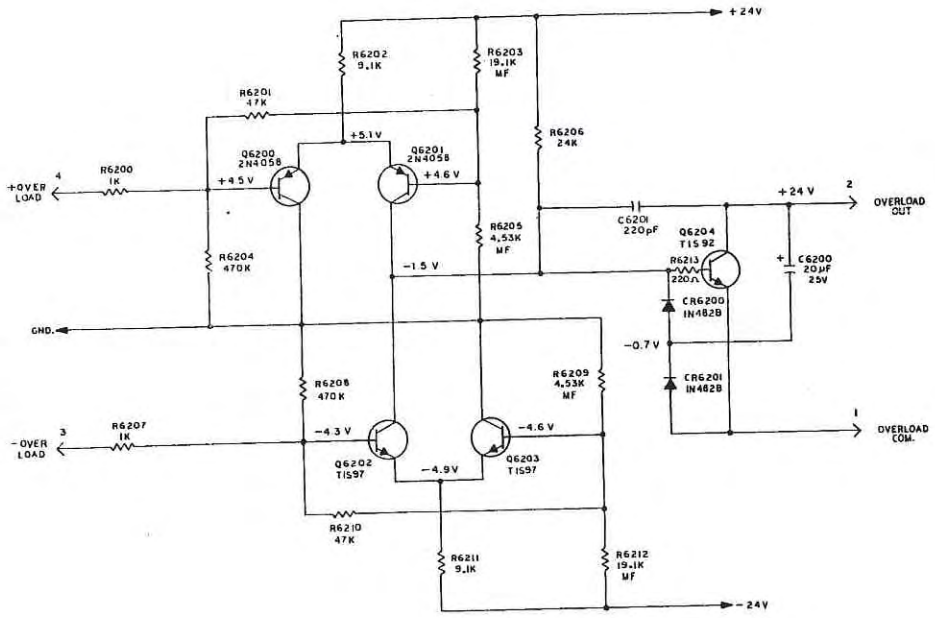
POWER SUPPLY MODEL 124 & 124A

SUB-ASSEMBLY #1240-2000-04 (PARTIAL)

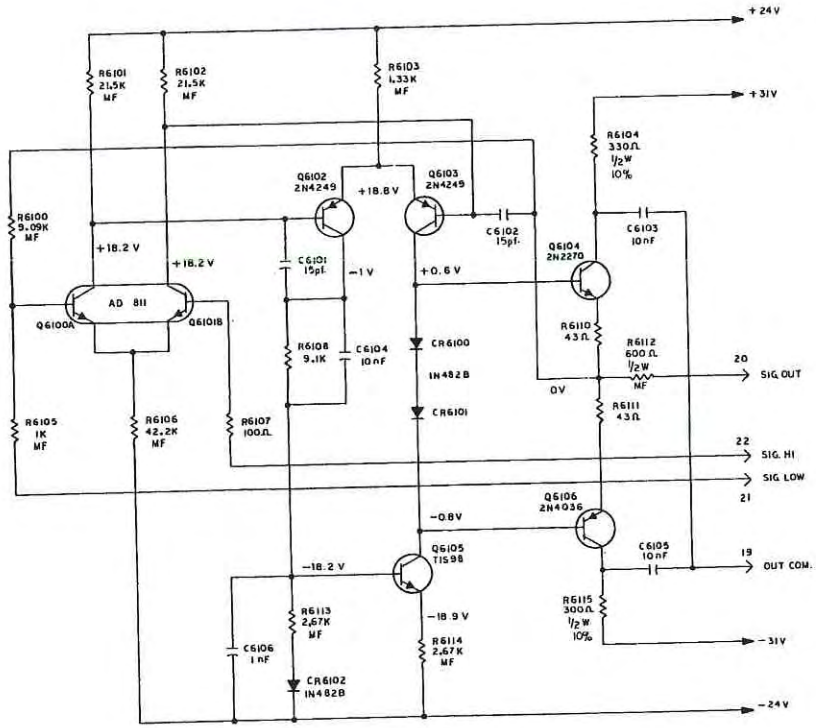
SHEET 1 OF 2 | 4872 | D | SD | E



SYMBOLIZATION
MODEL 124
POWER SUPPLY BOARD
FAB.# 4986-MD-D



OVERLOAD CIRCUIT



REFERENCE POWER AMP

NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.

POWER SUPPLY MODEL 124 & 124A
SUB ASSEMBLY 1240-2000-04 (PARTIAL)

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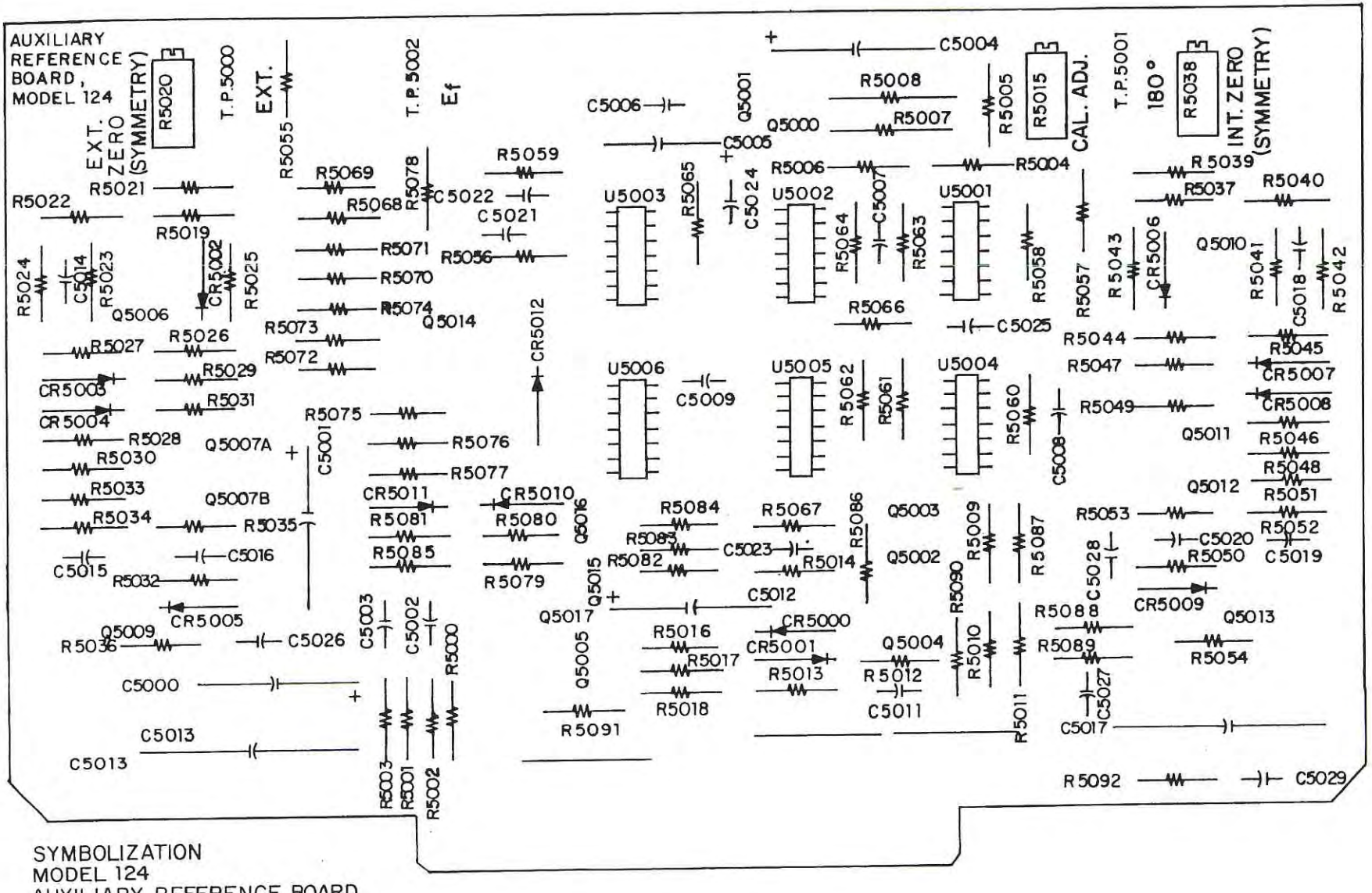
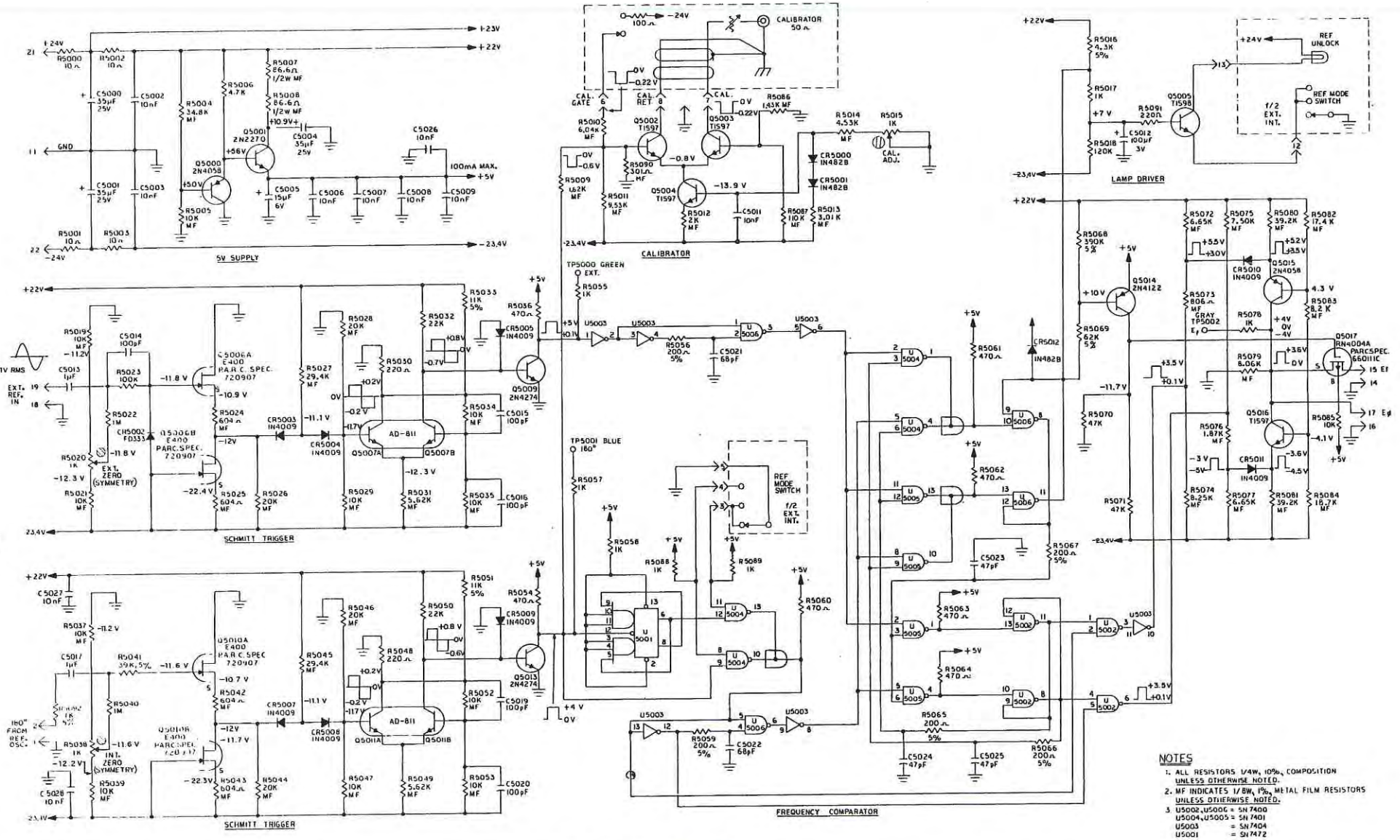


SYMBOLIZATION
MODEL 124
AUXILIARY REFERENCE BOARD
FAB. #4983-MD-D



NOTES

1. ALL RESISTORS 1/4W, 10%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTORS UNLESS OTHERWISE NOTED.
3. U5002, U5006 = SN 7400
   U5004, U5005 = SN 7401
   U5003 = SN 7404
   U5001 = SN 7472

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
GND	180° REF OSC	EXT. f	f/2	GND	CAL GATE	CAL.	CAL REF	GND		GND	LAMP GND	LAMP DR.	GND	E_f	GND	E_g	GND	EXT REF IN	+23V	+24V	-24V

A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z
																					OPT MOD

AUXILIARY REFERENCE BOARD
SUB-ASSEMBLY #1240-2100-03

MODEL 124 & 124A

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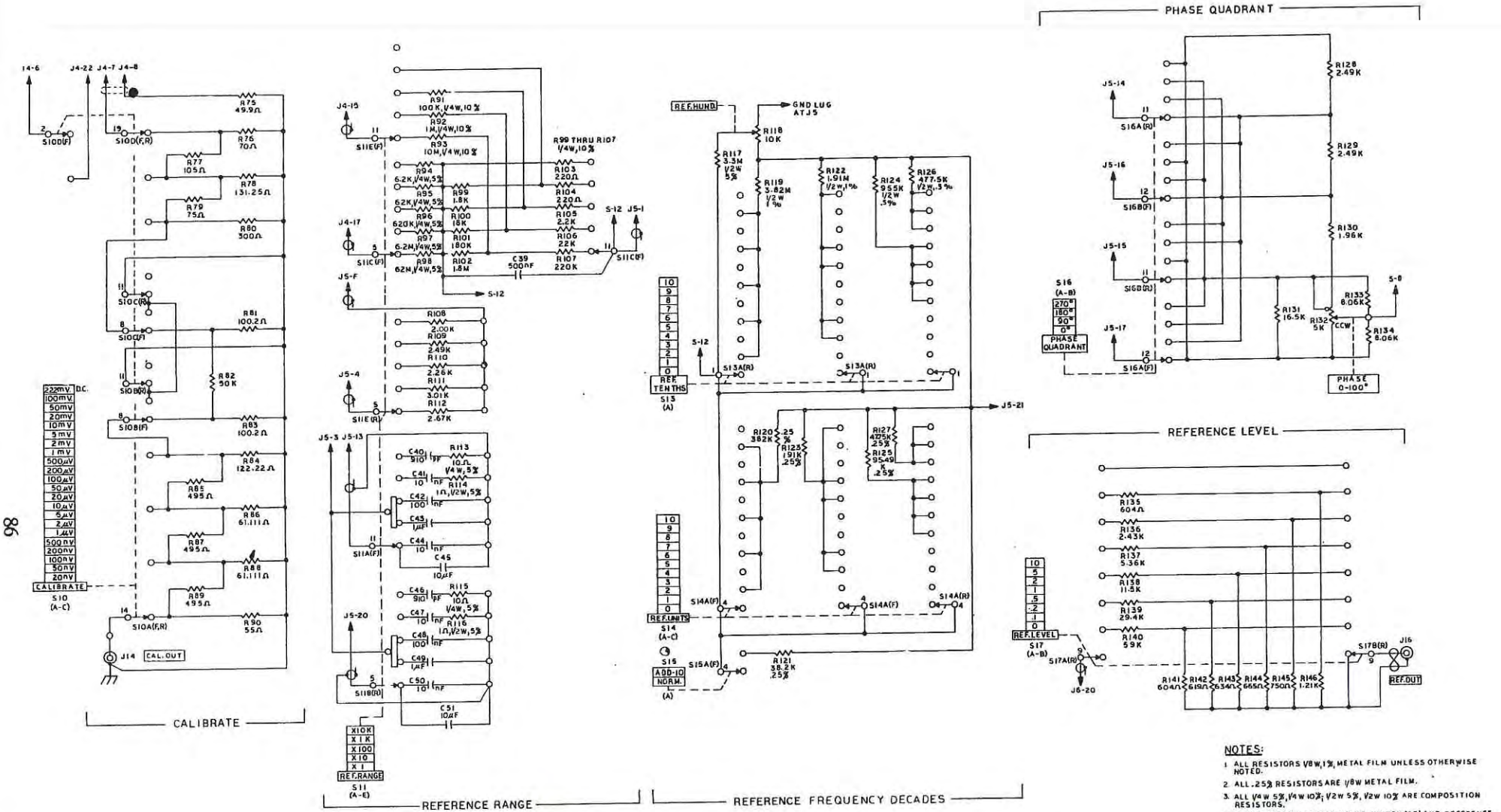
4871 | D | SD | 1



SWITCH SCHEMATIC

MODEL 124A

NOTES:

1. ALL RESISTORS 1/8W, 1%, METAL FILM UNLESS OTHERWISE NOTED.
2. ALL .25% RESISTORS ARE 1/8W METAL FILM.
3. ALL 1/4W 5%, 1/4W 10%; 1/2W 5%, 1/2W 10% ARE COMPOSITION RESISTORS.
4. CAPACITORS ON SIGNAL RANGE SWITCH (S3) AND REFERENCE RANGE SWITCH (S11) ARE SET PER PAR. SPEC. #70012.
5. R76 THRU R90 ARE 1%, 1/2W, METAL FILM.

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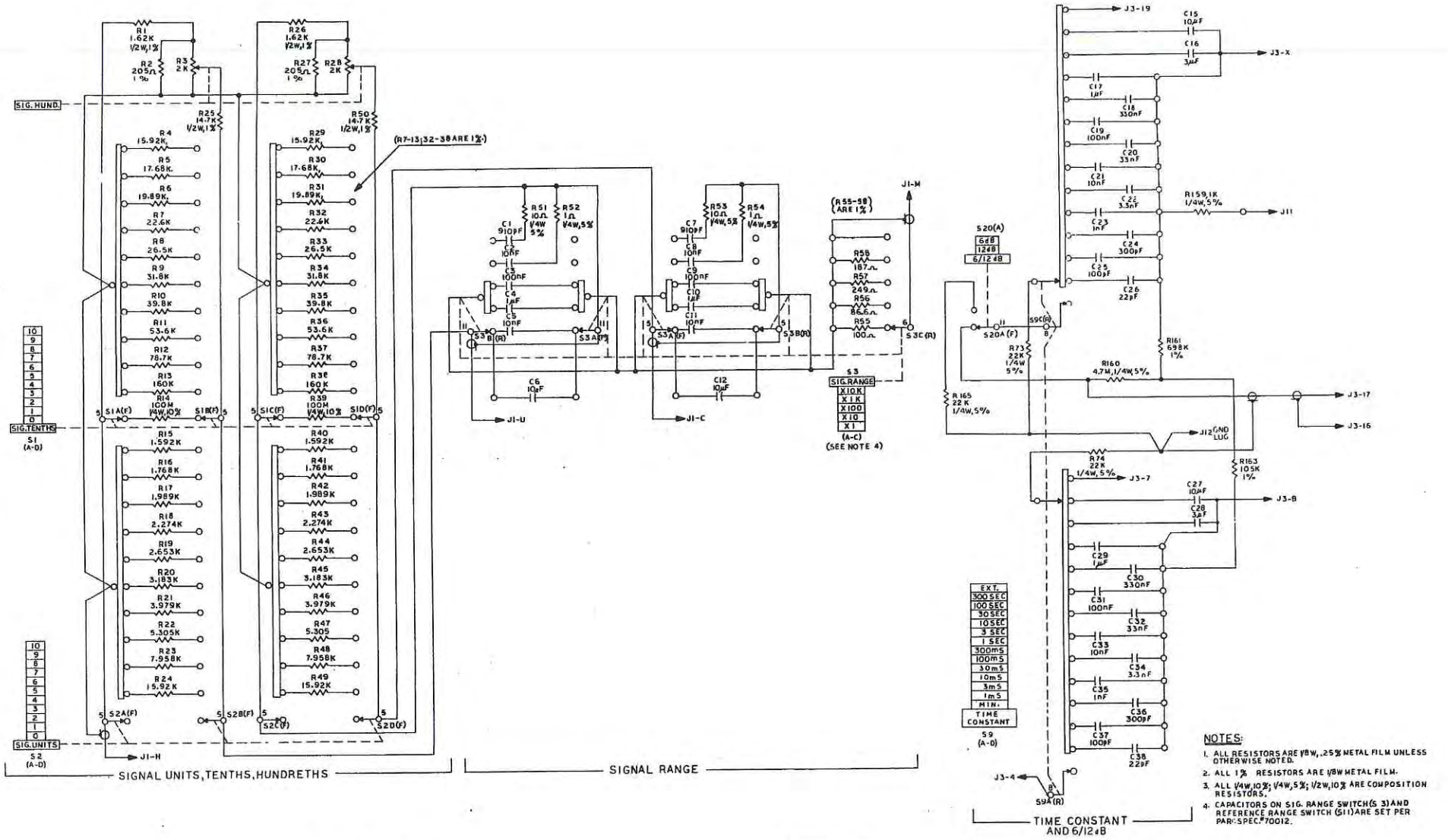

SWITCH SCHEMATIC

MODEL 124A

NOTES:

1. ALL RESISTORS ARE 1/8W, .25% METAL FILM UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/8W METAL FILM.
3. ALL 1/4W, 10%; 1/4W, 5%; 1/2W, 10% ARE COMPOSITION RESISTORS.
4. CAPACITORS ON SIG. RANGE SWITCH(S 3) AND REFERENCE RANGE SWITCH (S11) ARE SET PER PAR. SPEC. #70012.

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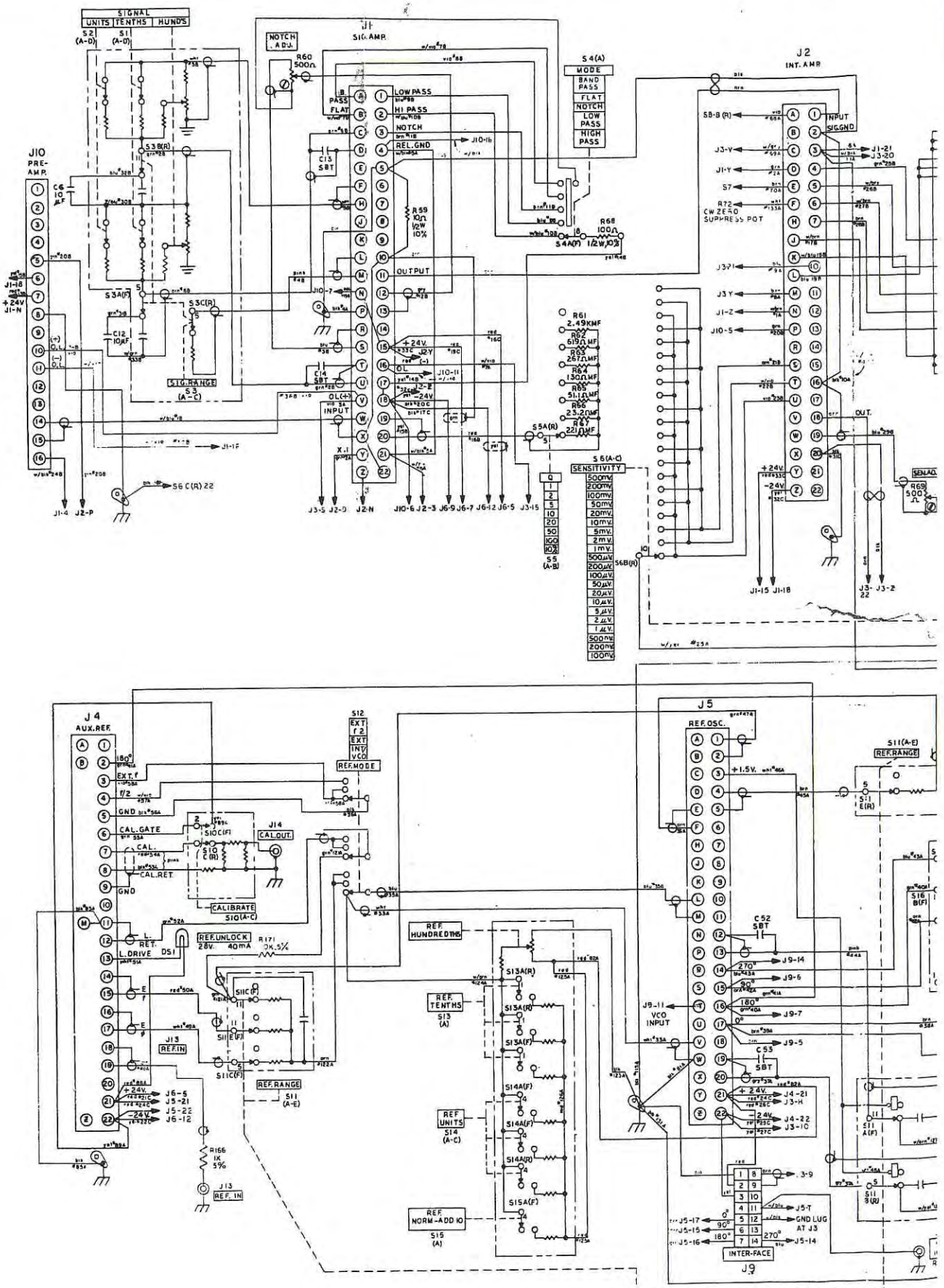
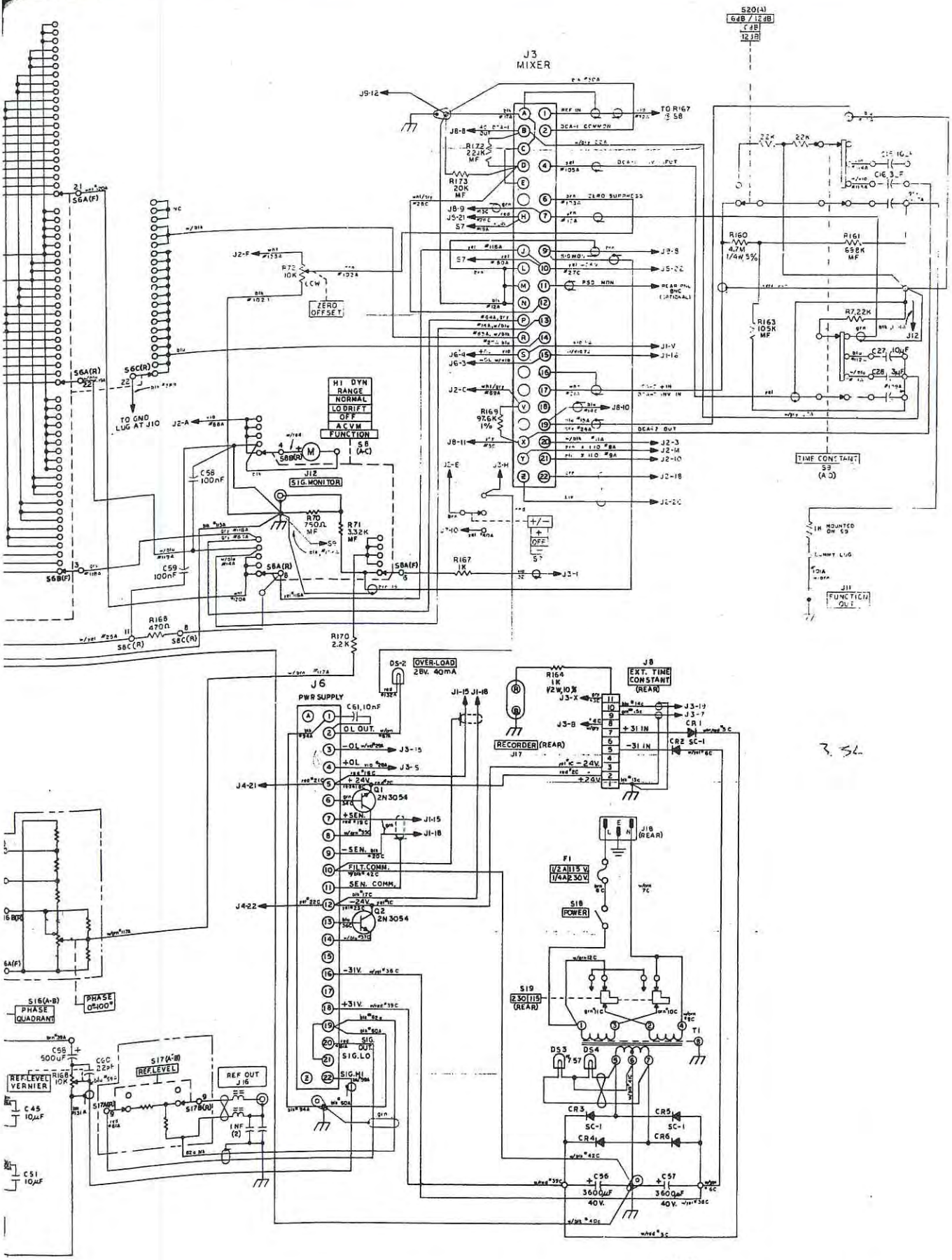


CHASSIS WIRING SCHEMATIC



MODEL 124A

NOTES:

1. ALL RESISTORS 1/4W, 10%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.

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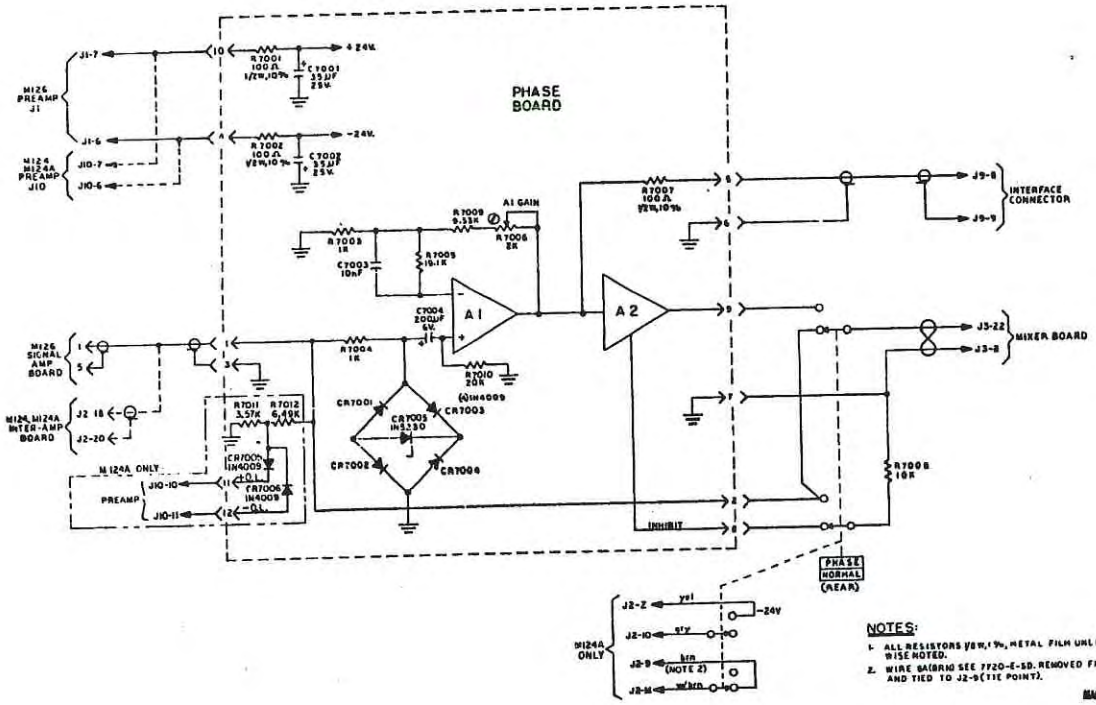
REV.	ZONE	DESCRIPTION	DATE	BY	APPD.
E1		REDRAWN W/O CHANGE	6-3-83	ECF	ECF



NOTES:

1. ALL RESISTORS 1/8W, 1%, METAL FILM UNLESS OTHERWISE NOTED.
2. WIRE BA(BRN) SEE 7720-E-SD. REMOVED FROM J2-M AND TIED TO J2-9(TIE POINT).

MAR 27 1974

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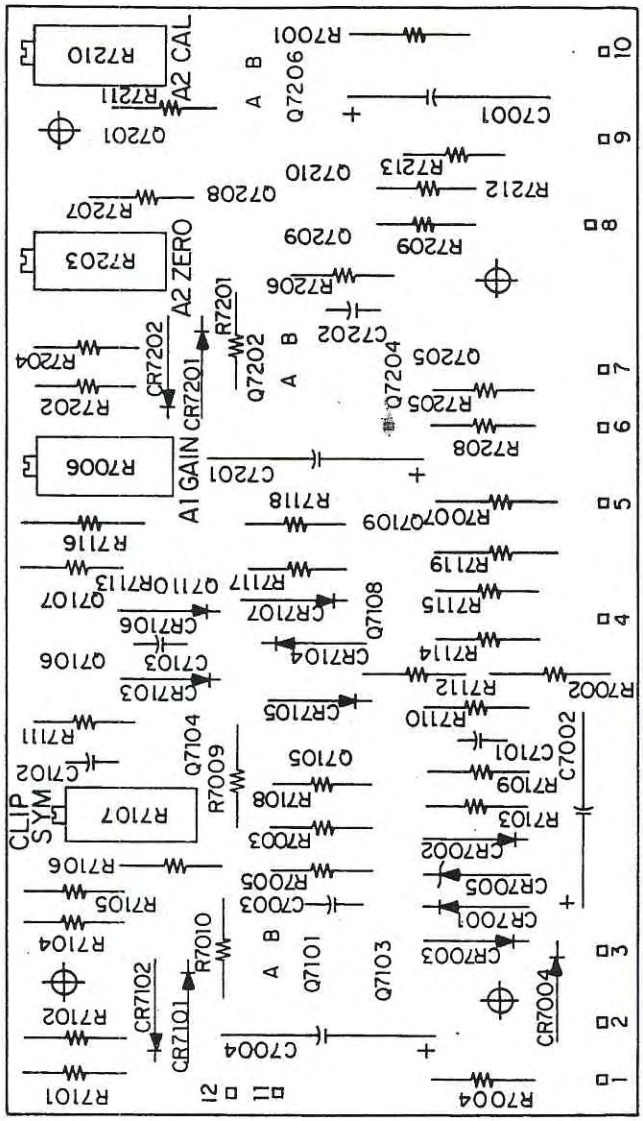
SHEET 1 OF 2 | 6084 | C | SD | E

PHASE METER MODIFICATION
126/99, 1240/85, 1241/85

MODEL 126
124, 124A

UNLESS OTHERWISE NOTED		TITLE: PHASE METER MOD.	EG&G PARC
DEC. .00 ±.01	METRIC		
DEC. .000 ±.005	FRAC. ±1/64		
SCALE	ANG. ±1/2°	MODEL NO. 126, 124, 124A	EG&G PRINCETON APPLIED RESEARCH P. O. BOX 2565 PRINCETON, N. J. 08540
DRWN.	DATE	DWG. APPROVED FOR PROD.	
CHKD.	"		
APPD. DM	6-3-71	PT. NO. ASSIGNED PROD. APPROVAL	DWG. NO. 6084-C-SD SHT. 1 OF 2 REV. E1

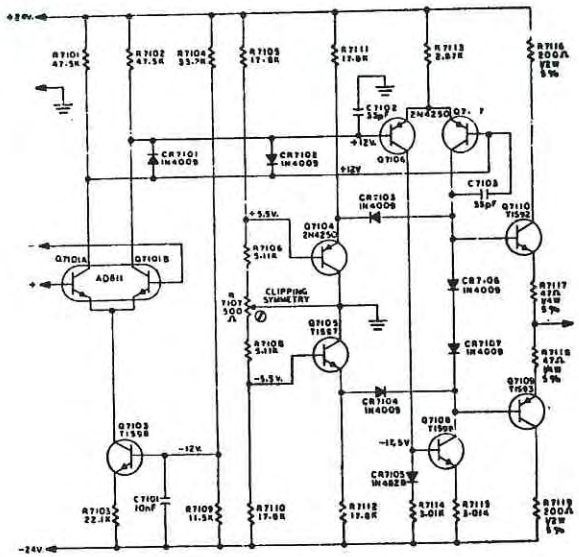
DWG. NO.	SHT.	REV.
6084-C-SD	1 OF 2	E1



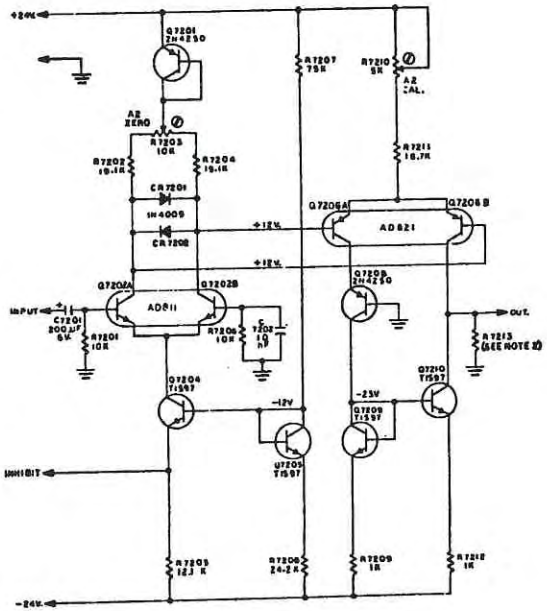
MODEL 126
PHASE METER OPT. AMPLIFIER BOARD

REV.	ZONE	DESCRIPTION	DATE	BY	APPD.

OP AMP



AMP LIMITER



NOTES:

1. ALL RESISTORS 1/8W, 1%, METAL FILM UNLESS OTHERWISE NOTED.
2. MODEL 126 = 15Ω
   MODEL 124 = 150Ω
   MODEL 124A = 75Ω.

MAY 2 7 1978

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SHEET 2 OF 2 | 6084 | C | SD

AMPLIFIERS

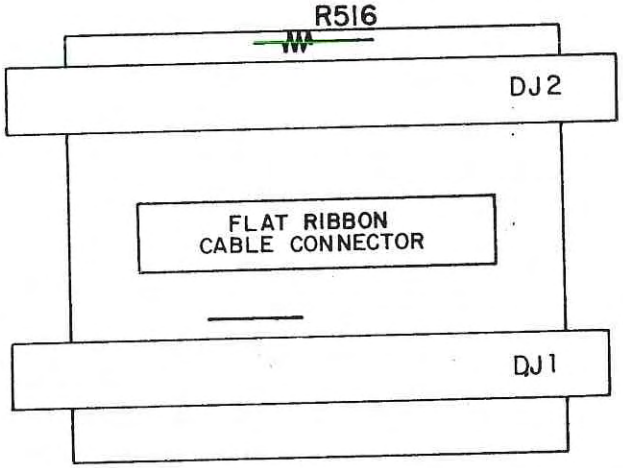
PHASE METER MODIFICATION
1260/99, 1240/85, 1241/85

MODEL 126, 124, 124A

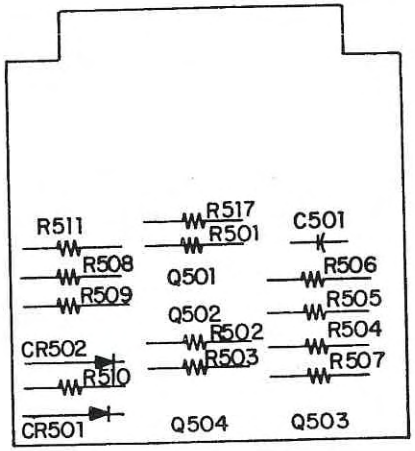
UNLESS OTHERWISE NOTED		TITLE: AMPLIFIERS PHASE METER MOD.	EG&G PARC
DEC. .00 ±.01	METRIC		
DEC. .000 ±.005	FRAC. ±1/64		
SCALE	ANG. ±1/2°	MODEL NO. 126, 124, 124A	EG&G PRINCETON APPLIED RESEARCH P. O. BOX 2565 PRINCETON, N. J. 08540
DRWN.	DATE	DWG. APPROVED FOR PROD.	
CHKD.	"		
APPD.	"	PT. NO. ASSIGNED PROD. APPROVAL	DWG. NO. 6084-C-SD SHT. 2 OF 2 REV. E

6084-C-SD E

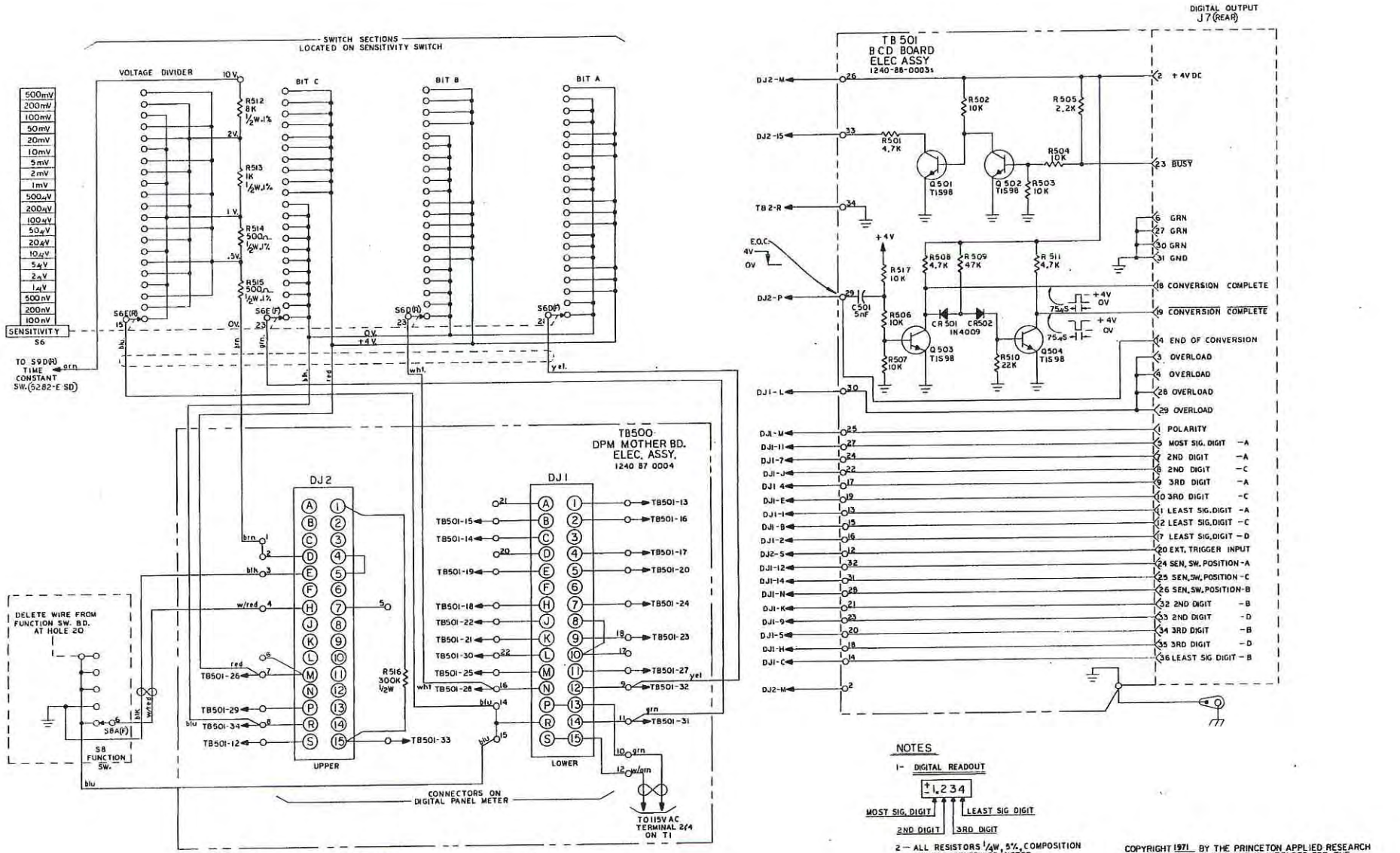
91



MODEL 124, 127, 156
DPM MOTHER BOARD



MODELS 124, 127, 156
DVM OPTION BOARD



CHASSIS WIRING DIAGRAM
DIGITAL PANEL METER WITH BCD OUTPUT.

MODEL 124/98 (SERIAL NO. 476 & UP)

NOTES

1- DIGITAL READOUT

2 — ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.

3 — ALL 1% RESISTORS 1/2W, METAL FILM

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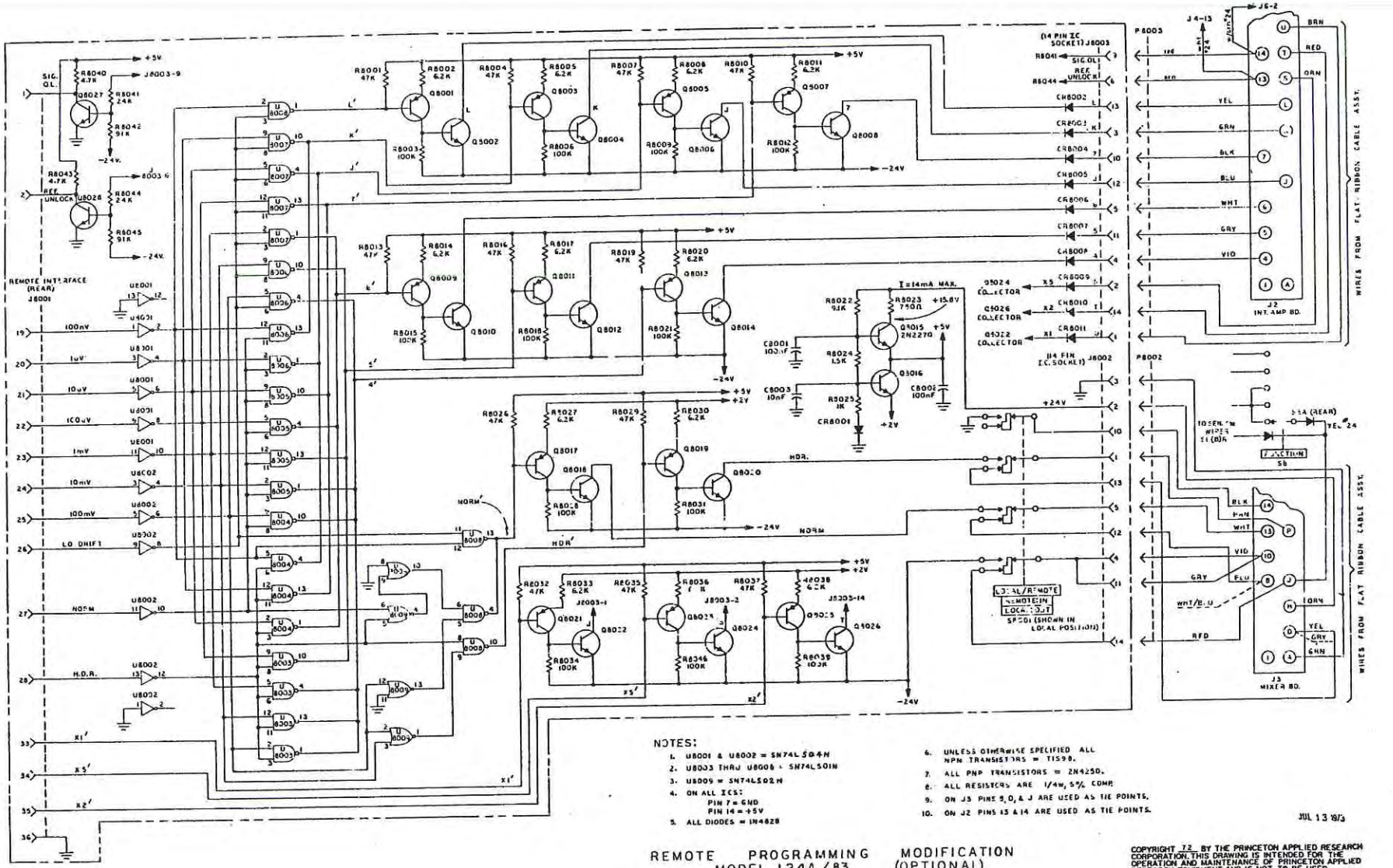
6725 D SD C



NOTES:

1. U8001 & U8002 = SN74LS04N
2. U8003 THRU U8006 = SN74LS01N
3. U8005 = SN74LS02N
4. ON ALL ICS:
   PIN 7 = GND
   PIN 14 = +5V
5. ALL DIODES = IN4828
6. UNLESS OTHERWISE SPECIFIED ALL NPN TRANSISTORS = TIS98.
7. ALL PNP TRANSISTORS = 2N4250.
8. ALL RESISTORS ARE 1/4W, 5% COMP.
9. ON J3 PINS 9, O, & J ARE USED AS TIE POINTS.
10. ON J2 PINS 13 & 14 ARE USED AS TIE POINTS.

JUL 13 1973

REMOTE PROGRAMMING MODIFICATION (OPTIONAL)

MODEL 124A/83

1241-83-0007S

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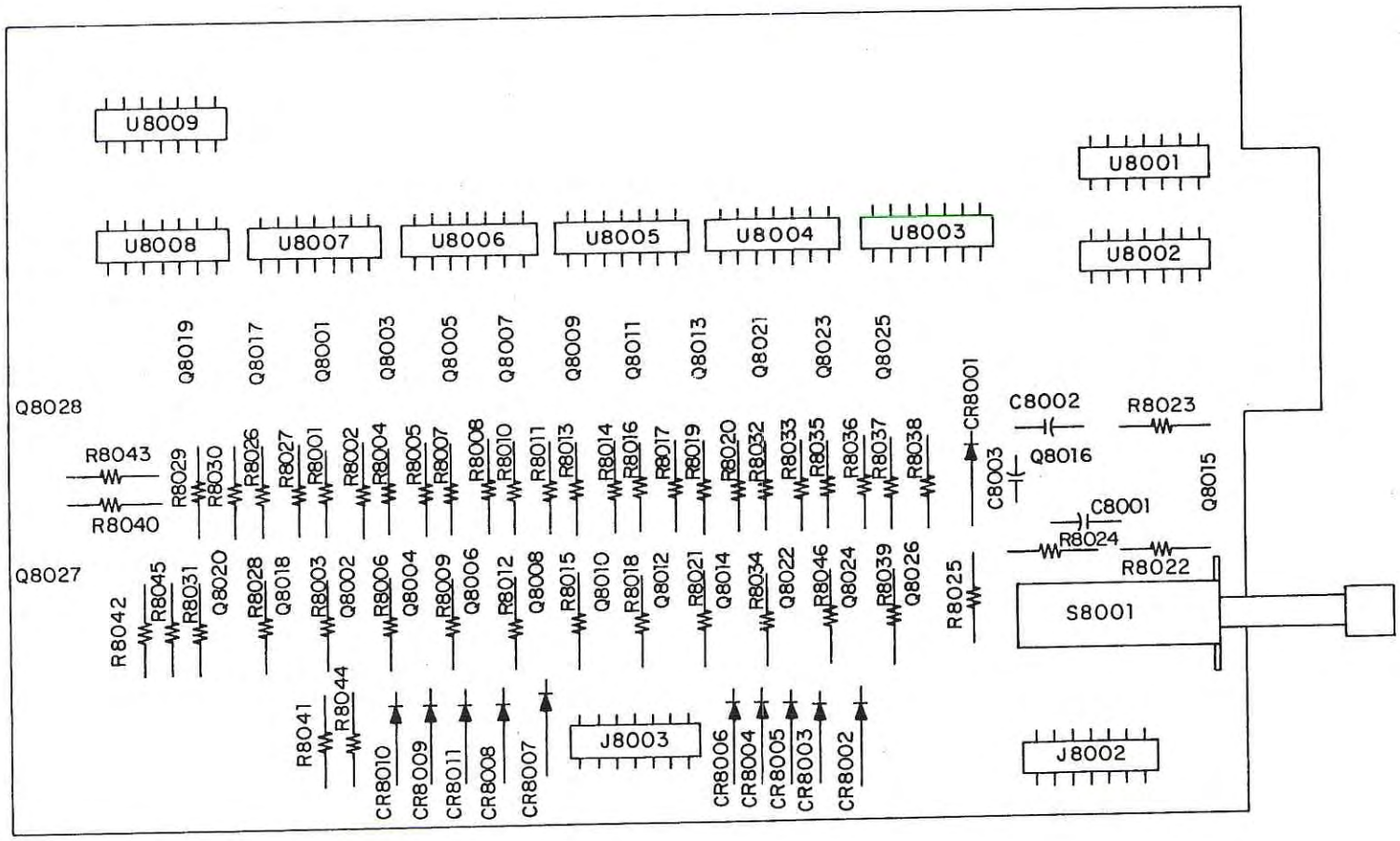
7877D1SD1A1



SYMBOLIZATION
MODEL 1241/83
REMOTE PROGRAMMING BOARD
FAB. # 7862-MD-A

WARRANTY

EG&G Instruments Corporation warrants each instrument of its own manufacture to be free of defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, shipment prepaid, to our Service Department for that purpose within ONE year of delivery to the original purchaser, provided prior authorization for such return has been given by an authorized representative of EG&G Instruments Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control. This Warranty shall not apply to any instrument or component not manufactured by EG&G Instruments Corporation. When products manufactured by others are included in EG&G Instruments Corporation equipment, the original manufacturer's warranty is extended to EG&G Instruments Corporation's customers.

EG&G Instruments Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF. THIS WARRANTY IS IN LIEU OF, AND EXCLUDES ANY AND ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESSED, IMPLIED OR STATUTORY, INCLUDING MERCHANTABILITY AND FITNESS, AS WELL AS ANY AND ALL OTHER OBLIGATIONS OR LIABILITIES OF EG&G INSTRUMENTS CORPORATION, INCLUDING, BUT NOT LIMITED TO, SPECIAL OR CONSEQUENTIAL DAMAGES. NO PERSON, FIRM OR CORPORATION IS AUTHORIZED TO ASSUME FOR EG&G INSTRUMENTS CORPORATION ANY ADDITIONAL OBLIGATION OR LIABILITY NOT EXPRESSLY PROVIDED FOR HEREIN EXCEPT IN WRITING DULY EXECUTED BY AN OFFICER OF EG&G INSTRUMENTS CORPORATION.

SHOULD YOUR EQUIPMENT REQUIRE SERVICE

A. Contact the Service Department (609-530-1000) or your local representative to discuss the problem. In many cases it will be possible to expedite servicing by localizing the problem to a particular plug-in circuit board.

B. If it is necessary to send any equipment back for service, we need the following information.

1. Model number and serial number.
2. Your name (instrument user).
3. Your address.
4. Address to which the instrument should be returned.
5. Your telephone number and extension.
6. Symptoms (in detail, including control settings).
7. Your purchase order number for repair charges (does not apply to repairs in warranty).
8. Shipping instructions (if you wish to authorize shipment by any method other than normal surface transportation.)

C. **U.S. CUSTOMERS** - Ship the equipment being returned to:

EG&G PARC
375 Phillips Blvd.
Trenton, NJ 08618

D. **CUSTOMERS OUTSIDE OF U.S.A.** - To avoid delay in customs clearance of equipment being returned, please contact the factory or the nearest factory distributor for complete shipping information.

E. Address correspondence to:

EG&G PARC
P.O. Box 2565
Princeton, New Jersey 08543-2565

Phone: (609) 530-1000
TELEX: 84-3409
FAX: 883-7259