SECTION I

SPECIFICATIONS

INTRODUCTION:

The PAR Model HR-8 Precision Lock-In Amplifier is essentially a detection system capable of operating with an extremely narrow equivalent noise bandwidth. Its function is to select a band of frequencies from a signal spectrum applied to its input circuit and to convert the information therein to an equivalent bandwidth at dc. The basic element of a Lock-In Amplifier is a phase-sensitive detector in which the signal voltage is mixed with a reference voltage, producing sum and difference frequencies. A low-pass filter at the output of the mixer rejects the high frequency components corresponding to sum frequencies, and passes the difference frequencies that lie within its passband. In particular, the difference frequency due to components of the signal at the reference frequency is zero or dc. Difference frequencies resulting from components of the signal spectrum at frequencies differing from the reference frequency by more than the cut-off frequency of the low-pass filter will be attenuated. Consequently, the output from the low-pass filter will be due to that portion of the signal spectrum which lies about the reference frequency within a passband determined by the low-pass filter.

MAIN FRAME SPECIFICATIONS

FREQUENCY RANGE: Continuously tunable from 1.5 Hz to 150 kHz in 5 ranges. Calibration accuracy within ±5%.

NOISE REJECTION: A signal 59 dB below ambient white noise in a 1 kHz bandwidth centered about signal frequency can be recovered with a signal-to-noise ratio of 1.

EQUIVALENT NOISE BANDWIDTH: 0.00125 Hz minimum (100 seconds maximum internal RC integrating time, 12 dB/oct.)

FILTER TIME CONSTANTS: 0, 1, 3, 10, 30, 100, 300 milliseconds; 1, 3, 10, 30, 100 seconds and EXT. position which allows capacitance to be added to rear connector to obtain any desired time constant. 6 or 12 dB/octave roll-off selectable by front panel switch.

ZERO SUPPRESS: Calibrated control permits off-setting zero by ±1000% of full scale on any range.

LINEARITY: ±0.1% of full scale.

SIGNAL CHANNEL CHARACTERISTICS: Active notch filter in negative feedback loop with nominal Q of 10. Calibrated front panel adjustment allows Q to be varied from 5 to 25 with no change in gain.

REFERENCE CHANNEL CHARACTERISTICS: The reference signal, by which the signal to be measured is demodulated, is obtained by four modes of operation.

INTERNAL: Internal oscillator drives the demodulator and presents a continuously variable 0-1 V rms (open circuit) signal at the REF. IN/OUT Connector. The source impedance is a constant 600 ohms.

EXTERNAL: Phase control not operable. Requires externally generated signal of 1 V peak-to-peak minimum level which crosses its mean value only twice each cycle with equal time between crossings.

SELECTIVE EXTERNAL: Externally generated reference signal filtered by tuned amplifier with a Q of 10, phase shifted and applied directly to demodulator. Minimum of 25 mV rms signal required.

AUTOMATIC: Any waveform which crosses its mean value only twice each cycle, and for which the smaller of the two mean-to-peak excursions is at least 500 mV. The instantaneous value of the waveform must not exceed ±100 volts.

PHASE ADJUSTMENT: Calibrated 360° phase shifter, accurate to ±5°. Differences in phase shift between signal and reference channels may be in excess of 5° on the X1 and $X10^4$ frequency ranges.

DC OUTPUT STABILITY: 0.1% of full scale in 24 hours with constant ambient temperature.

OUTPUT (located on rear): Single-ended with respect to ground. Panel meter (½% mirror scale with either center or optional left-hand zero) full scale corresponds to ±10 volts at output terminal. Adjustment allows output source impedance to be varied from 7K-22K ohms which permits driving either ±½ ma recorders with internal resistance less than 10 K or ±1 ma recorders with internal resistance less than 3 K as well as servo-type recorders.

MONITOR: A five position switch allows the panel meter and monitor output terminals to be switched to SIGNAL, REFERENCE, OFF, MIXER (OUTPUT) and OUTPUT to allow monitoring and adjustment of critical points.

INTERNAL CALIBRATOR: Provides 21 square wave output levels extending from 20 nanovolts to 100 millivolts, accurate to within 1%.

NOTE: At frequencies above 50 kHz, calibrator outputs below 1 μV may be in error by more than 1%. The use of external decade attenuators is recommended for applications where this might present difficulty.

POWER REQUIREMENTS: 105-125 volts or 210-250 volts; 50-60 Hz; 25 watts.

SIZE: 19" wide x 7" high x 15¾" deep.

WEIGHT: 41 lb.

WARRANTY: 1 year.

PREAMPLIFIER SPECIFICATIONS:

GENERAL: These preamplifiers are intended for use with the Model HR-8 Lock-In Amplifier. They can be plugged directly into the Model HR-8 main frame or operated remotely (with the purchase of a remote adapter kit.) In either case, the preamplifier is powered from and controlled by the Model HR-8. The following specifications refer to the performance of the individual preamplifier when used with the Model HR-8.

TYPE A PREAMPLIFIER: The Type A Preamplifier is a high input impedance low noise front end for the Model HR-8 used to obtain optimum signal-to-noise ratios for source impedances above 3 K.

SENSITIVITY: 21 ranges, from 100 nanovolts rms full scale to 500 millivolts rms full scale, in a 1-2-5 sequence.

FREQUENCY RANGE: 1.5 Hz to 150 kHz.

INPUTS: Differential or single-ended. Common mode rejection is in excess of 60 dB at 1 kHz.

INPUT IMPEDANCE: Each input to ground, 10 megohms shunted by 20 pf.

NOISE: High sensitivity settings (100 nV to 50 μV), noise figure for either (single-ended) input shall be better than 0.5 dB for a 100 k source at 1 kHz. For low sensitivity settings (100 μV to 500 mV), the internally generated noise shall result in a meter deflection of less than 1% (RMS) of full scale with a time constant setting of 1 sec 6 dB/oct., at any operating frequency above 15 Hz. Refer to Fig. 1-1 for noise figure contours.

TYPE B PREAMPLIFIER:

The Type B Preamplifier is a transformer type front end for the Model HR-8. The standard Type B is supplied with a 100:1 voltage transformation ratio to obtain best signal-to-noise ratios for source impedances as low as several ohms. Other ratios (ranging from 50:1 to 350:1) are achieved by changing tap connections and other transformers are available which provide an even wider selection of ratios. The following specifications refer to the standard 100:1 ratio connection.

SENSITIVITY: 21 ranges, from 1 nanovolt rms full scale to 5 millivolts rms full scale in a 1-2-5 sequence.

FREQUENCY RANGE: Depends on source impedance. With a 10 ohm source the frequency range will be approximately 10 Hz to 10 kHz. Lower source impedances will extend the low frequency response.

INPUT: Differential or single-ended. The transformer primary is brought to a pair of input connector terminals which are isolated from chassis ground.

INPUT IMPEDANCE: The input impedance is complex, but at the lower frequencies it is the reactance of the transformer primary self inductance of approximately 0.25 Henry.

NOISE: The noise figure at 1 kHz with a 10 ohm source shall be less than 3 dB. Refer to Fig. 1-2 for noise figure contours.

TYPE B1 PREAMPLIFIER:

The Type B1 Preamplifier is similar in performance and specifications to the Type B, except that the B1 covers the frequency range from 1 kHz to 150 kHz. It is normally supplied with a fixed 100:1 voltage transformation ratio. Taps are not provided, but other ratios can be supplied on special order. The following specifications refer to the standard 100:1 ratio connection.

SENSITIVITY: 21 ranges, from 1 nanovolt rms full scale to 5 millivolts rms full scale in a 1-2-5 sequence.

FREQUENCY RANGE: Depends on source impedance. With a 1 ohm source the frequency range will be 1 kHz to 150 kHz. Lower source impedances will extend the low frequency response somewhat, and higher source impedances will sacrifice response at both low- and high-frequency ends.

INPUT: Differential or single-ended. The transformer primary is brought to a pair of input connector terminals which are isolated from chassis ground.

INPUT IMPEDANCE: The input impedance is complex, but at the lower frequencies is the reactance of the transformer primary self-inductance of approximately 250 microhenrys.

NOISE: The noise figure at 40 kHz with a 5 ohm source shall be less than 3 dB.

TYPE C PREAMPLIFIER:

The Type C Preamplifier has an input impedance of approximately 25 K ohms, and best noise performance is obtained for source impedances within the range 50 ohms to 10 K. Circuitry is completely solid-state. Voltage gain is ten times that of the Type A Preamplifier.

SENSITIVITY: 21 ranges, from 10 nanovolts rms full scale to 50 millivolts rms full scale in a 1-2-5 sequence.

FREQUENCY RANGE: 1.5 Hz to 150 kHz.

INPUTS: Differential or single-ended. Common-mode rejection is in excess of 80 dB at 1 kHz.

INPUT IMPEDANCE: Each input to ground, 50 K. Between inputs, 50 K. When using the preamplifier single-ended, the effective input impedance is the parallel combination of these two impedances, or 25 K. In addition, there is 20 pf from each input to ground.

NOISE: At 1 kHz, noise figure for a 2 K resistive source shall be less than 2 db. Also, at 1 kHz the equivalent short-circuit noise resistance shall be less than 500 ohms. Refer to Fig. 1-3 for noise figure contours.

EXPLANATION OF NOISE FIGURE AND NOISE FIGURE CONTOURS

NOISE FIGURE is a common method of specifying amplier noise and is defined as follows:

$$\text{NOISE FIGURE (db)} = 10 \, \text{LOG}_{10} \frac{Y}{Z}$$

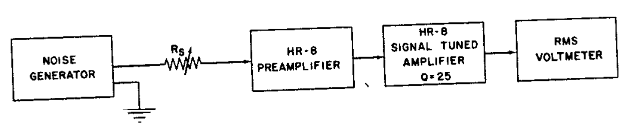
where:

y = Total Noise Power Per Unit Bandwidth Available At Amplifier Output

z = That Portion Of Numerator Attributable To Source Thermal Noise

The noise figure contours are essentially the loci of points of constant noise figure as a function of source impedance and operating frequency. They allow the user to determine the optimum points of operation as well as indicate regions of source impedance and operating frequency where it is not desirable to operate.

The noise figure contours are measured as follows*:



A noise generator is used to provide a calibrated white noise source (equal power per Hz of bandwidth.) The source impedance is determined by resistor R_S.

*For more detailed information, refer to "IRE Standards on Methods of Measuring Noise in Linear Twoports, 1959," 59 IRE 20 S1, **PROC. I.R.E.**, vol. 48, pp. 60-68; Jan. 1960.

The overall noise output with the output of the noise generator reduced to zero is first measured on the RMS voltmeter. The white noise signal from the generator is then applied to the amplifier under test, with the output signal of this unit being applied to a tuned amplifier which determines the noise bandwidth of the system. Since noise POWER adds directly and noise VOLTAGE adds vectorially (i.e., 1 mV of noise plus 1 mV of noise equals 1.414 mV of noise), the output of the noise generator is increased until the output as measured on the voltmeter is 1.4 times the value previously measured. The output of the noise generator is read from its front panel meter in microvolts—$Hz^{-1/2}$ and, in this measurement technique, equals the total noise referred to the amplifier input.

The magnitude of the Johnson noise, which would be present in the case of a noiseless amplifier, is given by

$$e_n^2 = 4KTB_nR$$

where:

e_n=rms noise voltage within bandwidth of measurements.

T=absolute temperature in degrees Kelvin.

k=Boltzmann's constant=1.38 x 10^{-23} joules/degree Kelvin.

B_n=bandwidth over which the noise voltage is measured.

R=resistive component of impedance across which voltage is measured.

By substituting these quantities in the noise figure equation, the noise figure at a particular source impedance and center frequency is determined. By varying R_s while maintaining a fixed center frequency of the tuned amplifier, noise figure as a function of source impedance is determined. By changing the center frequency of the tuned amplifier and maintaining a given source resistance, noise figure as a function of frequency is determined.

The contours shown represent the results of performing these measurements for a typical production Model HR-8 with various preamplifiers.

The HR-8 noise figure specifications refer to the more sensitive settings of the unit; namely, the ranges from 100 nV to 50μV. For ranges above 50 μV, the following specification shall be applicable:

"Internally generated noise shall result in a meter deflection of less than 1% rms with a filter time constant of 1 sec, 6 db/octave, at any frequency of operation above 15 Hz."

To maintain wide dynamic range for interfering signals, it is necessary to attenuate signal-plus-noise within or ahead of the preamplifier for sensitivity settings above 50 μV. The most pronounced effect of this aspect of the design is an increase in the output noise level of the instrument at the sensitivity setting of 1 mV, which results from the introduction of a 100:1 voltage attenuation ahead of the preamplifier. Less sensitive ranges still (2 mV, 5 mV, etc.) will show less noise because of the progressively lower source impedance presented by the attenuator to the preamplifier.

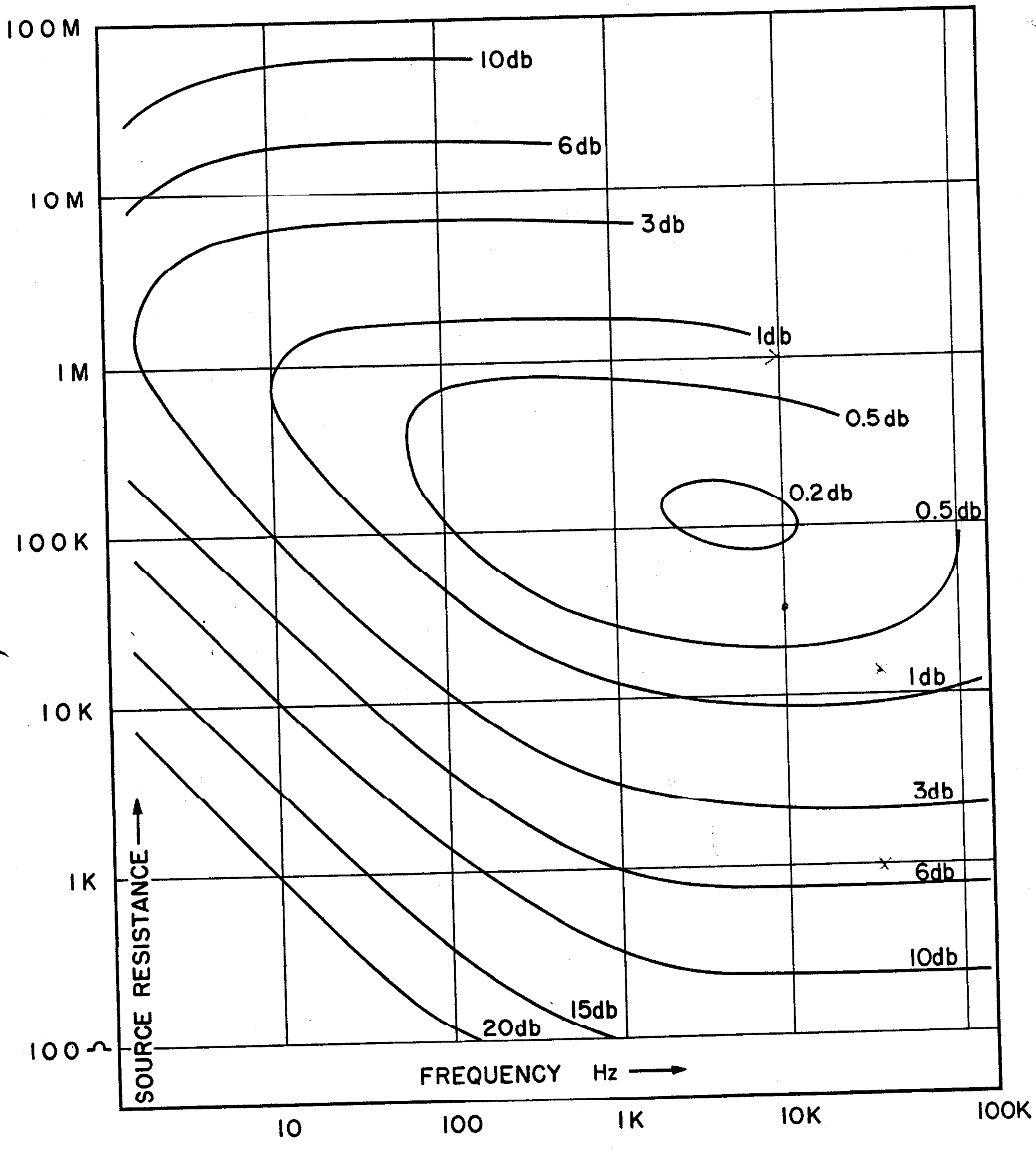


FIGURE 1-1

Contours of constant noise figure for a typical PAR Type A Preamplifier as a function of frequency and source resistance at 290°K. Amplifier operated single-ended.

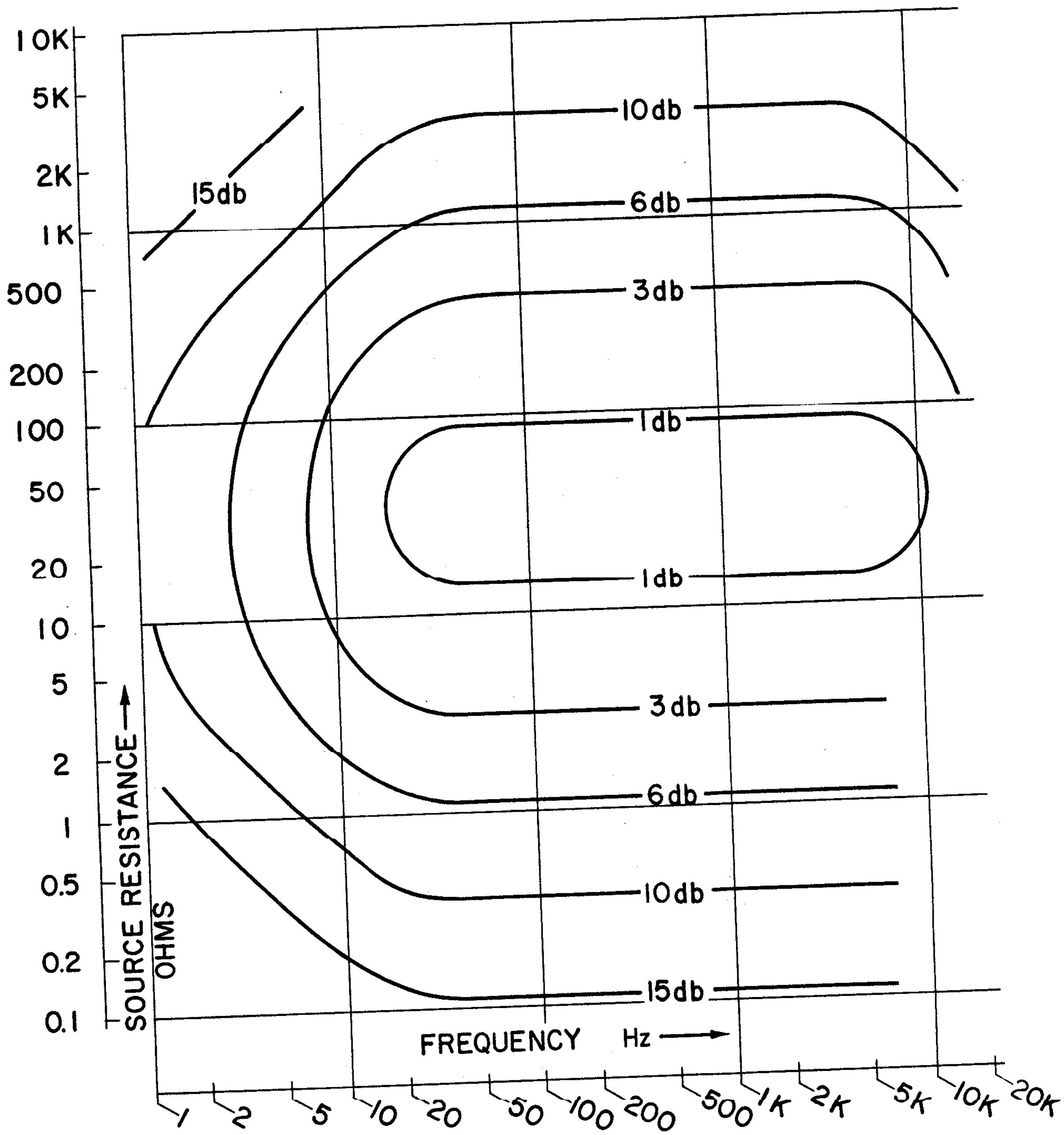


FIGURE 1-2

Noise figure contours for a typical Type B preamplifier. Source resistance assumed to be at 290°K.

NOTE: Transformer connected for standard turns ratio (N_o) of 100:1. For other than standard transformer ratio, the source resistance parameters given above should be scaled by the factor N_o^2/N_1^2 where N_1 is the non-standard turns ratio.

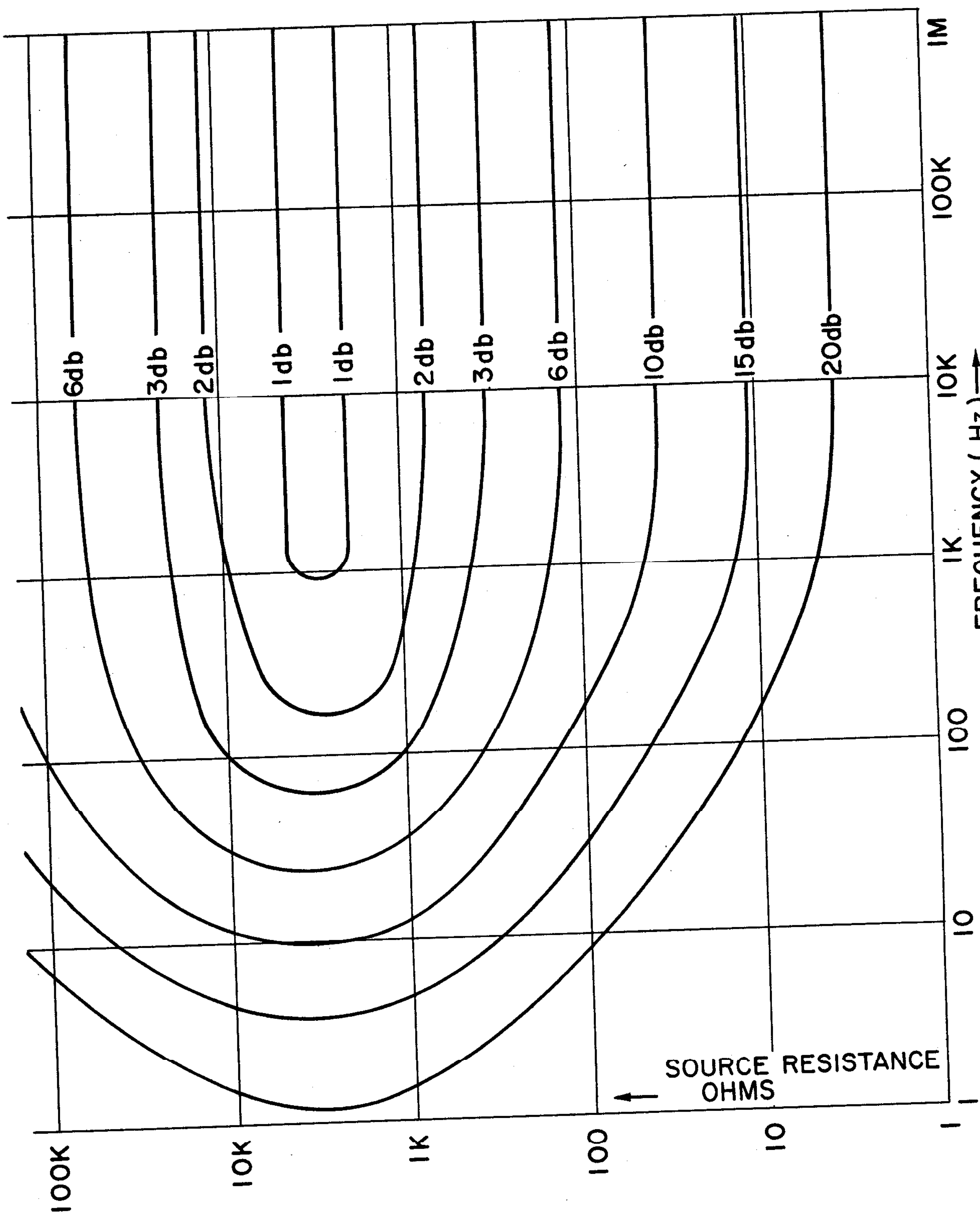


FIGURE 1-3

Contours of constant noise figure for a typical PAR Type C preamplifier as a function of frequency and source resistance at 290°K. Amplifier operated single-ended.

SECTION II

PRELIMINARY OPERATING INSTRUCTIONS

TEMPERATURE LIMITS:

This instrument should be located where the ambient temperature will not be above 45°C (113°F) nor below 10°C (50°F). Since the power consumption is small (25 watts), the instrument temperature will not rise more than 5°C above the ambient temperature.

POWER REQUIREMENTS:

Certain HR-8 Models are equipped with a 115-230 Voltage switch on the rear panel. If the switch position does not match the available line voltage, insert a screwdriver blade into the slot in the switch and snap the switch to the appropriate position. If the unit does not have a rear-panel voltage switch, the power transformer is normally wired for operation at 105-125 volts AC, 50-60 Hz, as illustrated in Figure 2-1A. However, the transformer primary winding can be reconnected as shown in Figure 2-1B for operation on 210-250 volts. If the instrument is shipped with the latter connection, a tag will be found attached to the line cord at the plug end indicating the 210-250 volts connection. A change from one connection to the other can be easily made at any time. To gain access to the transformer terminals, proceed as follows:

1) Remove the bottom sheet metal cover by removing 7 screws.
2) Locate the power transformer at the rear of the chassis in the input fuse area.
3) Remove the two screws holding the diode mounting board and swing the board such that the bottom of the transformer is fully exposed.
4) Change the primary connections to the proper configuration as shown in Figures 2-1A and 2-1B.
5) Reassemble the case by reversing the above procedure.

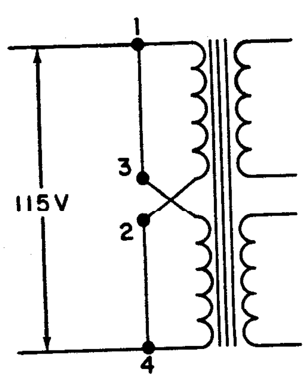


FIGURE 2-1A

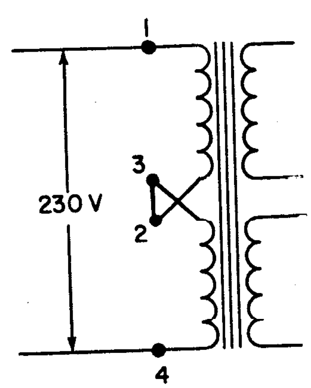


FIGURE 2-1B

FUSING:

A slo-blo 3AG 250 volt fuse is installed in the primary circuit of the power transformer. The fuse rating is 0.4 A in 115 volt operation, or 0.3 A in 230 volt operation. The fuse holder is mounted on the rear panel of the instrument case. Two slo-blo 3AG fuses rated at 0.4 A are mounted on each of the two power supply circuit boards, one in the +31 volt line and the other in the −31 volt line.

PREAMPLIFIERS:

A space is provided in the front panel for a plug-in preamplifier. The Type A Preamplifier is the normal complement of the Model HR-8, and its use will be assumed in the following instructions. The Type A Preamplifier has a low-noise high impedance differential input circuit, and its gain is coordinated with that of the main unit of the Model HR-8 so that the sensitivity values marked on the SENSITIVITY switch are correct.

FRONT PANEL CONTROLS AND CONNECTIONS
(Type A Preamplifier)
(HR-8 Main Frame)

A, A-B, -B Switch:

This switch selects the mode of operation of the preamplifier. The single-ended input positions, A or -B, are preferred when the signal source permits. A lower noise figure is obtained in single-ended operation because the output then contains the noise of only one input amplifier tube. Differential input is available when its use is advantageous but the output in this case contains the noise of two input amplifier tubes, and the noise figure is consequently higher. More precisely, if the signal source impedance is under 3K, the noise figure may be up to 3 dB higher in the differential connection. If the source impedance is greater than 3K, the noise figure is approximately the same in either connection.

AC BALANCE:

This screw-driver control adjusts the differential amplifier for maximum common mode rejection.

INPUT A, INPUT B:

These BNC connectors are the input connection points of the Type A Preamplifier.

POWER:

In the OFF position this switch opens one side of the AC power line.

SENSITIVITY:

This switch adjusts the gain of the preamplifier and the intermediate amplifier to give the sensitivity values marked on the panel. There are 21 ranges, extending from 100 nanovolts rms full scale to 500 millivolts rms full scale in a 1, 2, 5 sequence. When the Type B or B1 preamplifiers are used, sensitivity limits are 1 nanovolt and 5 millivolts; with the Type C preamplifier, 10 nanovolts and 50 millivolts.

GAIN ADJ.: (Screw driver adjustment):

This control adjusts the gain of the signal tuned amplifier. It is used for calibrating the instrument including preamplifier and has an adjustment range of 2:1.

FREQUENCY:

This control simultaneously tunes the signal channel and the reference channel. Tuning is continuous over a 1.5-to-15 range.

FREQUENCY RANGE:

This control selects the frequency decade within which the FREQUENCY control operates. The actual frequency in Hz is the product of the indicated values on the FREQUENCY control and the FREQUENCY RANGE switch. The accuracy of the frequency setting is ±5%.

FREQ. TRIM:

This control varies the tuning of the signal channel tuned amplifier only. It is used to peak the signal channel at any given frequency setting, thus compensating for errors in tracking between the signal and the reference tuned amplifiers. Total variation depends on the setting of the FREQUENCY dial. The lowest value, ±2.5% occurs at the low frequency end of the FREQUENCY dial.

SIG. Q:

This control varies the Q of the signal channel tuned amplifier between 5 and 25. The normal operating value is 10. At higher Q values gain stability is sacrificed, and conversely there is an improvement in gain stability at lower Q values. When the instrument is operated in its highest frequency range (15 to 150 kHz) the gain may change by about 10 percent when the Q is adjusted over its full range.

MODE:

This switch is used to select one of the four modes in which the reference channel can be operated. (See OPERATING INSTRUCTIONS for a description of the four possible modes of operation).

REF. IN/OUT CONNECTOR:

In the internal reference mode, the internally generated reference voltage is available at this connector. In the other three reference modes it is the input connector for the externally generated reference voltage.

REF. ATTEN.

In the INT. mode, this switch controls the level of the sinusoidal output voltage appearing at the REF IN/OUT connector. In the SEL EXT or EXT modes of operation, this switch determines the fraction of the voltage applied to the REF IN/OUT connector which is actually applied to the amplifier. In the AUTO mode, this attenuator is inoperative.

VERNIER:

The red knob concentric with the REF. ATTEN. allows continuous variation of the reference level between steps of the REF. ATTEN. switch.

PHASE:

The phase knob adjusts the phase of the reference voltage. It provides a continuous phase adjustment over the full 360° range with ± 5° accuracy. The outer ring surrounding the phase knob is attached to a quadrant switch which advances the phase in 90° increments.

TIME CONSTANT:

This switch determines the time constant of the RC low-pass filter in the output circuit of the mixer. In the OFF position the time constant is approximately 100 microseconds. In other switch positions the time constant has its indicated value. In the EXTERNAL position the time constant is determined by external capacitors connected to an octal socket on the rear panel.

6 DB — 12 DB PER OCTAVE:

This switch (concentric with the TIME CONSTANT control) selects either a single RC filter stage, giving a roll-off rate of 6 db/octave, or two RC filter stages, giving a roll-off rate of 12 db/octave.

OVERLOAD:

This is a lamp which lights when the signal channel amplifier is subjected to a combination of signal-plus-noise whose peak amplitude is greater than the linear range of the amplifier output.

MONITOR CONNECTOR:

This connector provides for the monitoring (usually with an oscilloscope) of points selected by the METER/MONITOR switch.

METER/MONITOR:

This switch connects the panel meter to selected points in the instrument for monitoring signal voltages, and simultaneously connects the MONITOR connector for waveform monitoring. The five switch positions (see Fig. 2-3) are:

1. **SIGNAL:** The MONITOR connector and a peak-responding circuit driving the panel meter are connected to the output of the signal channel tuned amplifier (Fig 2-3A.) Full scale deflection of the meter corresponds to 4 volts peak-to-peak at the MONITOR connector. In the SIGNAL position of the METER/MONITOR switch the meter sensitivity is reduced by a factor of 100. For example in the 100 uV position of the SENSITIVITY switch an input signal of 10mV rms is required for a full scale meter reading.

   NOTE: With no signal input the panel meter stands at approximately 5% of full scale and it operates linearly in the upper 4/5 of the scale.

2. **REFERENCE:** The circuit connections in this switch position are affected by the Reference Mode switch. In the EXT. reference mode, the MONITOR connector and the AC voltmeter (panel meter) are connected to the mixer at the reference input point. In the other three reference modes, both are connected to the output of the reference channel tuned amplifier, ahead of the phase control potentiometer. Figure 2-3B shows this connection. Full scale deflection corresponds to 2 volts rms applied to the phase potentiometer. (The reference voltage required to operate the mixer is in the range of 0.5 to 2 volts rms, or ¼ scale to full scale on the panel meter.)

   NOTE: With no reference input the panel meter stands at approximately 5% of full scale and it operates linearly in the upper 4/5 of the scale.

3. **OFF:** Panel Meter and MONITOR connector are disconnected. In this switch position the mechanical zero of the meter can be checked and adjusted.

4. **MIXER:** The panel meter is connected as a DC voltmeter at the output of the DC amplifier that drives the recorder terminals. Full scale is ±10 volts. The MONITOR terminal is connected to the output of the mixer, ahead of the circuit in which the time constant is applied, to permit oscilloscope observation of the demodulated signal waveform before it is affected by the time constant filter. Connections are shown in Figure 2-3C.

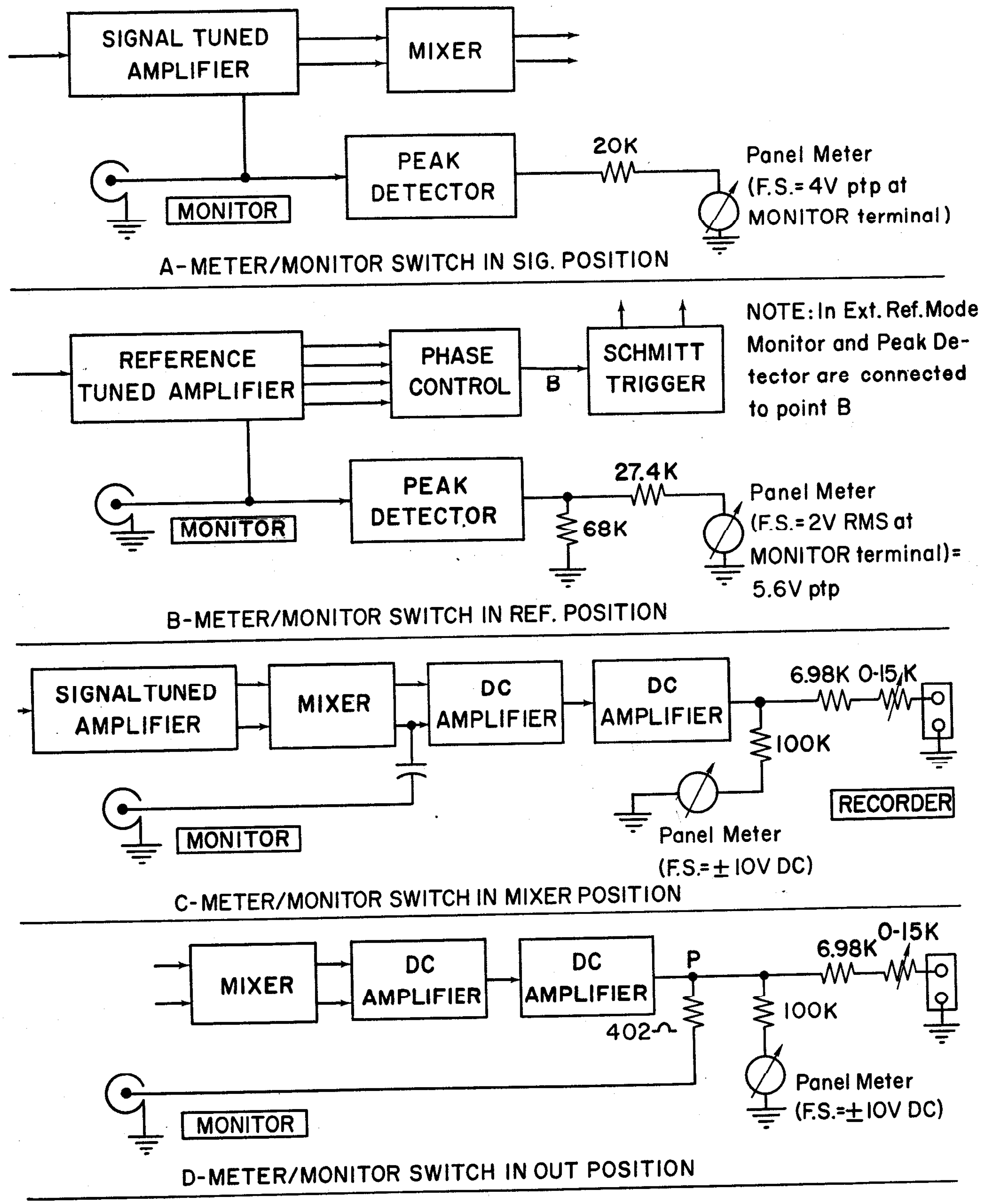


FIG. 2-3 METER/MONITOR SWITCH CONNECTIONS

5. OUT: The panel meter connection is the same as in the MIXER switch setting. The MONITOR terminal is connected to the same point at the output of the buffer amplifier, through a 402 ohm resistor, (Fig. 2-3D).

ZERO OFFSET:

This is a calibrated ten-turn precision potentiometer which permits offsetting the zero of the panel meter (in the OUT or MIXER positions of the METER MONITOR) and that of the recorder circuit by any amount up to 10 times full scale.

+/− SWITCH:

Either + or − polarity of offset can be selected with this switch.

CALIBRATE SWITCH and CONNECTOR:

This switch provides, from an internal square wave generator, 21 square wave voltages which can be impressed on the signal circuit for calibrating the signal amplifier gain. The maximum voltage is 222 millivolts peak-to-peak, which is then subdivided to the different switch positions by precision resistors. However, because of the selectivity of the signal channel tuned amplifier and the synchronous demodulator, only the fundamental frequency component of the square wave calibrating voltage is detected. Therefore, the switch positions are marked with the RMS voltages of the fundamental frequency sine wave component. The relation between the square wave amplitude and the fundamental frequency component is found by examining the Fourier series representing a symmetrical square wave. This is:

$$y = \left[\frac{2V}{\pi} \cos(2\pi f)t - \frac{1}{3}\cos 3(2\pi f)t + \frac{1}{5}\cos 5(2\pi f)t \ldots\right]$$

where: y = instantaneous amplitude
V = peak-to-peak square wave amplitude
f = fundamental frequency

The harmonics at frequencies 3f, 5f, etc. are filtered out and have no effect. The peak amplitude of the fundamental frequency component is $y = \frac{2V}{\pi} = .636V$, and the corresponding rms value is 0.45V = V/2.22. In the Model HR-8, V is 222 millivolts, and the rms value of the fundamental component is 100 millivolts, as marked at the top switch position. In one switch position the square wave generator is turned off, and 222 millivolts dc is presented at the output terminal. This can be measured with an accurate dc voltmeter, and if the correct value is obtained, all the calibrating voltages are known to be correct.

The calibrating circuit operates in all reference modes except the EXT. mode. In the EXT SEL. and AUTO reference modes the calibrator output is available only if required reference signal is supplied to the REF IN/OUT connector.

OUTPUT:

The OUTPUT binding posts are located on the rear panel. One binding post is grounded to the chassis. The other is normally at ground potential when there is no signal input and no zero offset. Full scale on the panel meter when the Meter/Monitor switch is set in the OUT position corresponds to ±10 volts. This is the open circuit voltage at the point P in Figure 4D, ahead of the 6.98K resistor and the OUTPUT ADJ. potentiometer. The OUTPUT binding posts are permanently connected, and are not changed when the panel meter is switched.

OUTPUT ADJ.

This potentiometer is located on the rear panel and allows the output source impedance to be varied from 7K to 22K ohms for adjusting recorder deflection to match the panel meter deflection. The range of adjustment is sufficient to accommodate either a ±1 milliampere recorder with less than 3K internal resistance or a ±½ milliampere recorder with less than 10K ohms internal resistance. Servo-type recorders with high input impedance can also be accommodated but the OUTPUT ADJ. potentiometer will be ineffective unless the OUTPUT binding posts are shunted by a resistance.

SECTION III

OPERATING INSTRUCTIONS

INTRODUCTION:

The PAR Model HR-8 Precision Lock-In Amplifier is essentially a detection system capable of operating with an extremely narrow equivalent noise bandwidth. Its function is to select a band of frequencies from a signal spectrum applied to its input circuit and to convert the information therein to an equivalent bandwidth at dc. The basic element of a Lock-In Amplifier is a phase-sensitive detector in which the signal voltage is mixed with a reference voltage, producing sum and difference frequencies. A low-pass filter at the output of the mixer rejects the high frequency components corresponding to sum frequencies, and passes the difference frequencies that lie within its pass-band. In particular, the difference frequency due to components of the signal at the reference frequency is zero or dc. Difference frequencies resulting from components of the signal spectrum at frequencies differing from the reference frequency by more than the cut-off frequency of the low-pass filter will be attenuated. Consequently, the output from the low-pass filter will be due to that portion of the signal spectrum which lies about the reference frequency within a passband determined by the low-pass filter.

The internal organization of the Model HR-8 Precision Lock-In Amplifier is shown in the block diagram, Figure 3-1. The signal is amplified first in a broadband amplifier in a plug-in sub-assembly, then again in a broadband intermediate amplifier which amplifies the entire signal spectrum from 1.5 Hz to 150 kHz. Following amplification in the two untuned amplifiers, a portion of the signal spectrum centered about the desired signal frequency is selected and amplified by the signal channel tuned amplifier. This amplifier effects an initial narrowing of the received frequency band, thus increasing the ratio of the desired signal to the total peak voltage input. The output of the amplifier is impressed on the phase-sensitive mixer (so named because its output is proportional to the cosine of the phase angle between signal and reference voltages). The output of the mixer is passed through the time constant circuit, which might be termed a Miller-Integrator-Amplifier. In this circuit the upper sideband produced in the mixing process is rejected and the lower sideband (including the zero-frequency component corresponding to the exact signal frequency) is amplified, and the frequency bandwidth selected by the signal channel tuned amplifier is further narrowed by the low-pass filter. Following this circuit, a unity gain isolating amplifier drives the panel meter and chart recorder output.

The mixer requires as a reference voltage a symmetrical square wave of nominally one volt peak-to-peak amplitude. This is provided by a Schmitt trigger which is driven by the reference signal in one of the four reference modes shown in Figure 3-2A through D. The phase angle between signal and reference is adjustable in three of the reference modes by means of a phase control.

REFERENCE CHANNEL:

The operation of the reference channel depends on the mode being used. Consequently the four available modes will be treated separately.

EXTERNAL (Fig. 3-2A):

This reference mode is intended for use in situations in which there is available a reference voltage which has suitable amplitude (1 volt peak-to-peak) and waveform, and which is either inherently in phase with the signal or can be phased by an adjustment in either of the sources supplying the signal or reference inputs. For example, if the signal source is a detector which responds to radiation chopped by a rotating shutter, and the reference is provided by a chopper on the same shaft, the phase can be adjusted mechanically. A chopper or commutator which is used in this way to generate a reference voltage should ordinarily be constructed so that the open and closed circuit time intervals, or the positive and negative voltage time intervals, are equal.

Sine waves and symmetrical square and triangular waves are suitable reference waveforms. In general, any waveform can be used if the zero crossings are equally spaced, if there are only two zero crossings in each cycle, and if the voltage rises steeply at each crossing.

In this reference mode the only adjustment provided in the Lock-In Amplifier is that of amplitude. The level required is one volt peak-to-peak and the preferred instrument for making the measurement is an oscilloscope. With the instrument power turned on, the following control settings are made:

REFERENCE MODE	EXT.
METER/MONITOR switch	REF.
REF. ATTEN.	OFF.
REF. ATTEN. VERNIER	FULLY C.W.

Connect the reference source to the REF IN/OUT connector and the oscilloscope to the monitor connector. Adjust the REF. ATTEN and vernier until 1 to 5 volts peak-to-peak is seen on the scope. The waveform should be observed to verify that it is satisfactory according to the criteria above.

SELECTIVE EXTERNAL REFERENCE MODE (Fig. 3-2C):

This reference mode can be used when the reference voltage is too small or too distorted for the EXT mode, or when variable phase adjustment is needed. The fundamental frequency component of the waveform should have an amplitude of at least 25 millivolts rms. Sinusoidal, square, triangular, and sawtooth waves are suitable and exact symmetry is not essential.

With the instrument power turned on, set the instrument controls as follows:

REF MODE	SEL. EXT.
METER/MONITOR switch	REF.
FREQ. RANGE	DESIRED REF. FREQ.
FREQUENCY dial	DESIRED REF. FREQ.
REF ATTEN.	OFF
REF ATTEN. VERNIER	FULLY C. W.

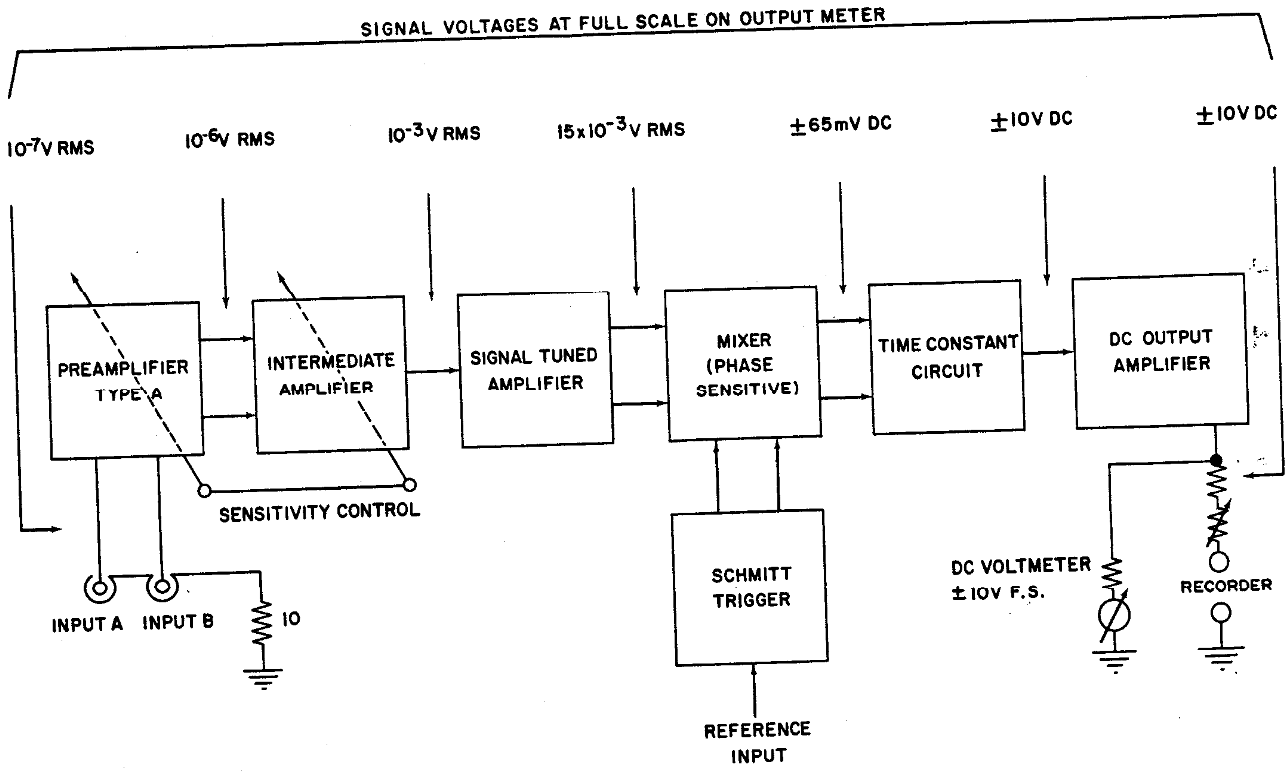


FIGURE 3-1 INTERNAL ORGANIZATION OF MODEL HR-8

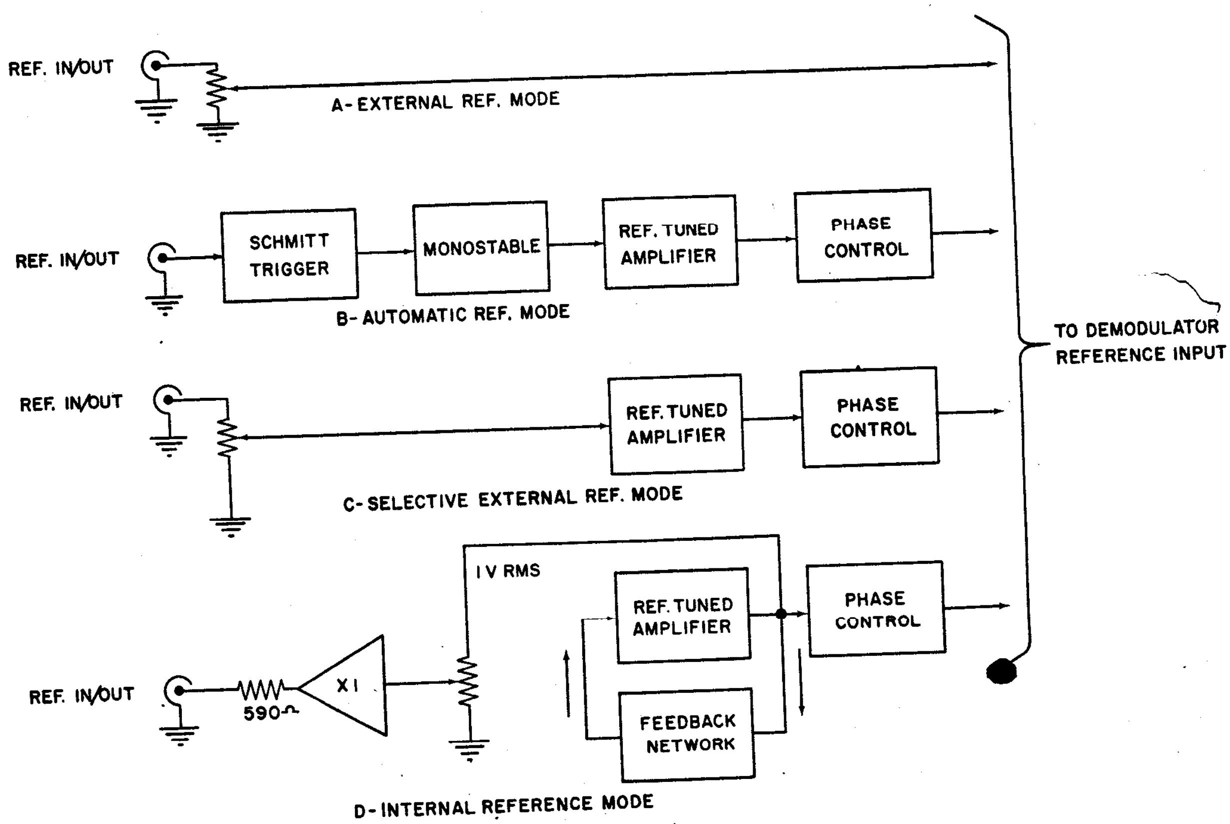


FIGURE 3-2 REFERENCE CHANNEL MODES

Connect the reference source to the REF. IN/OUT connector and adjust the REF. ATTEN. for a small deflection on the panel meter. Adjust the FREQUENCY dial to maximize the meter reading. Finally adjust the REF. ATTEN. switch for 0.5 to 2.0 volts rms on the panel meter (full scale corresponds to 2 volts rms.) With an oscilloscope connected to the MONITOR terminal, inspect the reference waveform, which should be a reasonable approximation of a sinusoid.

AUTOMATIC REFERENCE MODE (Fig. 3-2B):

This reference mode is used when the reference waveform does not satisfy the requirements for operation in the EXT or the SEL EXT reference mode. Pulse signals, sawtooth waves, and almost any irregular and unsymmetrical waveform will operate the reference circuit satisfactorily. The only limitations are that the waveform cross its mean only twice each cycle, and that the smaller of the two mean-to-peak excursions must be at least 500 mV. In this reference mode the REF ATTEN is omitted from the circuit and the only adjustment required is to tune the reference channel tuned amplifier.

With instrument power applied, set the instrument controls as follows:

REF MODE ....AUTO

METER/MONITOR switch ....REF

Connect the reference source to the REF IN/OUT connector and adjust the FREQUENCY dial to tune the reference channel tuned amplifier to the reference input frequency. The meter will read approximately one volt rms for all reference voltage levels within the specified range (full scale on the meter is two volts rms).

INTERNAL REFERENCE MODE (Fig. 3-2D):

In this mode of operation a feedback circuit is connected to the reference channel tuned amplifier, causing it to oscillate at the frequency to which the amplifier is tuned. The proper voltage for operating the switching circuits in the mixer (approximately one volt rms) is automatically provided by limiting action in the feedback circuit. Proper operation of the internal oscillator is indicated if the panel meter deflects to approximately half scale when the METER/MONITOR switch is set at REF. The waveform can be examined on an oscilloscope connected to the MONITOR connector.

The internal reference mode of operation is applicable when the signal source does not itself generate a suitable reference signal, but can be synchronized or driven by an injected voltage. A sinusoidal voltage at the reference frequency whose maximum amplitude is one volt rms is available for this purpose at the REF IN/OUT connector. This amplitude of this signal can be adjusted by the REF ATTEN. and REF ATTEN. VERNIER.

SIGNAL CHANNEL INPUT CONNECTION:

The Type A and C Preamplifiers are equipped with two BNC connectors for feeding a balanced signal voltage to the differential input. Either input connector may be used alone for single-ended input. The maximum DC voltage that can be applied to either input is 100 volts. (Voltage steps in excess of 10 volts should not be applied.)

When the Lock-In Amplifier and the signal source are both operated by the same AC power source, which of course is the usual arrangement, spurious signals can be injected into the signal circuit by "ground loop" currents. When low-level signals are being measured it is important to suppress the ground loop currents, or to divert them from the signal circuit. A circuit which is designed to accomplish this result is shown in Figure 3-3A. In this diagram, the conductors A and B are the signal wire and the shielding braid respectively of the signal cable connecting signal source and preamplifier. Conductor C represents the common connection to the power line, including a small voltage difference between the two power supplies. Conductor D is a ground strap connecting the signal source chassis to the amplifier chassis (or the preamplifier chassis, if the latter is remote from the main unit of the Model HR-8). This conductor, which should be of substantial size, provides a low impedance path (the lower the better) for ground currents, thereby minimizing power frequency voltage between the signal common and the Model HR-8 chassis. Conductor D may be the braid of the reference cable, the power line ground, a metallic rack in which the signal source and the Lock-In Amplifier are mounted, or a combination of any of these. Otherwise, a conductor of substantial size should be connected between the amplifier chassis and the signal common point at the signal source. Attention is directed to the fact that the shells of the BNC input connectors are not grounded directly to the preamplifier chassis, but instead are grounded through a 10 ohm resistor. This resistor discourages the flow of ground loop currents through the A and B conductors, and forces them to flow instead through D, where they are isolated from the signal input circuit.

When using the differential input feature of the Type A or Type C Preamplifiers, best common-mode rejection is achieved by adjusting the AC BAL screwdriver adjustment at the same frequency and sensitivity setting that will be used in the measurement. This adjustment can be accomplished by feeding the same signal to both A and B inputs (the calibrator is a convenient signal source), then adjusting AC BAL for minimum indicated signal in either MIXER or OUT positions of the monitor switch.

In the Type B and B1 Preamplifiers the input circuit is the primary circuit of a transformer, neither end of which is grounded at the amplifier chassis. Input connections for these units are shown in Figure 3-3B. One (either) end of the transformer is grounded at the signal source common point through the braid of the coaxial connecting cable, and the amplifier chassis is connected to the same point by a separate low resistance (and low inductance) ground strap.

NOTE: NO DC CURRENT SHOULD BE ALLOWED TO FLOW IN THE TRANSFORMER PRIMARY. COMMON MODE DC VOLTAGE APPLIED SHOULD BE LIMITED TO ± 50 VOLTS.

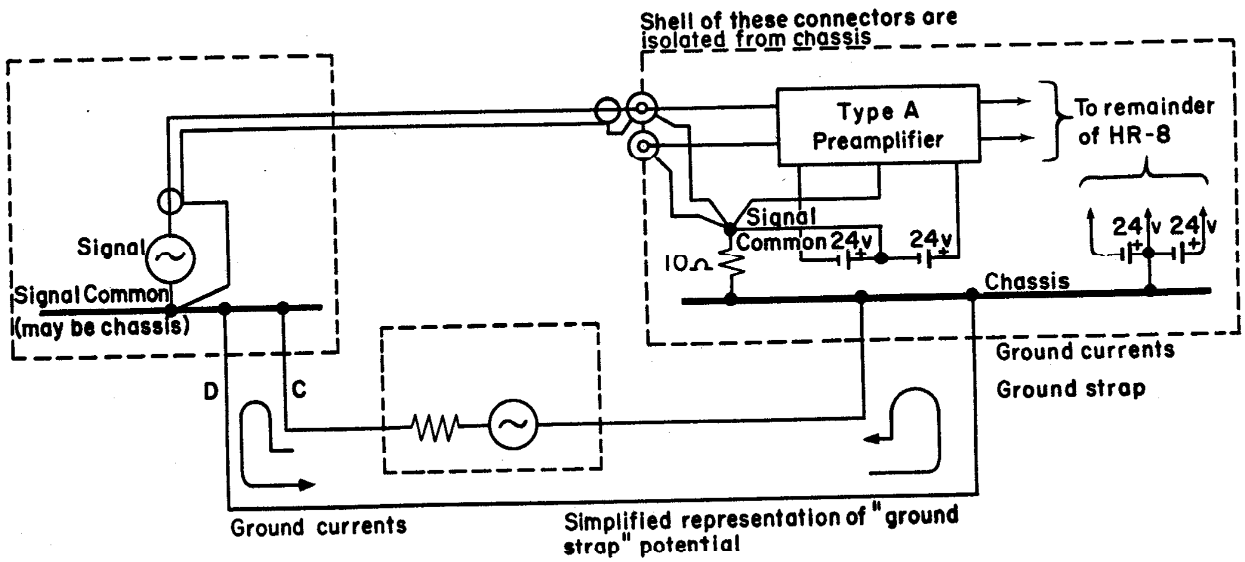


FIGURE 3-3A

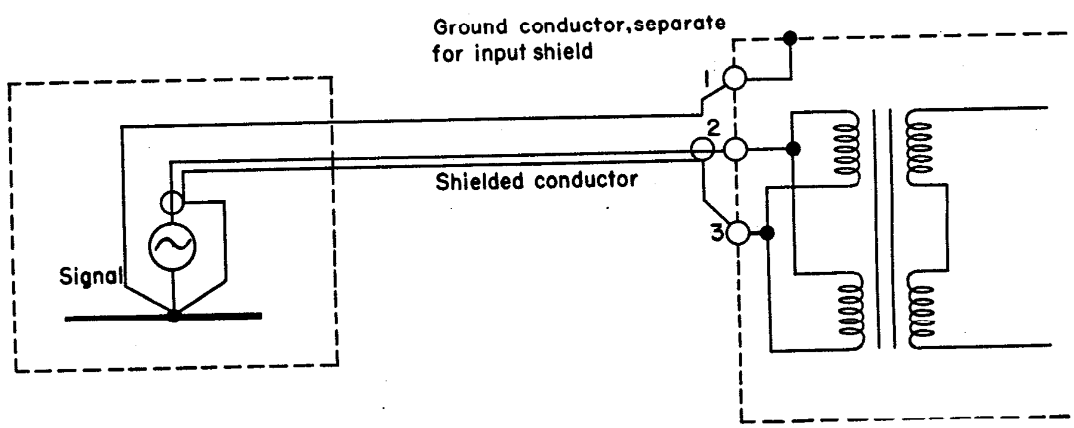


FIGURE 3-3B

SIGNAL CHANNEL:

SIGNAL CHANNEL TUNING:

It is assumed now that the reference channel is set up and operating in the desired mode and at the correct frequency, and that the connections have been made to the signal input connectors. Set the METER/MONITOR switch at SIG. and adjust the SENSITIVITY control to obtain an on-scale reading of the panel meter. If the reference channel is operating in the EXT mode set FREQ TRIM to "0" and adjust the FREQUENCY dial to maximize the meter reading. If the reference channel is operating in th SEL. EXT, AUTO or INT mode, the meter reading should be maximized by adjusting the FREQ TRIM control only.

OPERATION ON XI FREQUENCY RANGE:

When the amplifier is operating in its lowest frequency range, the time it takes to reach steady state after any change in signal level or frequency is long enough to be perceptible. The behavior of the tuned amplifier is similar to that of a parallel RLC circuit having the same Q. The rise time (0 to 63%) of such a circuit whose resonant frequency is f_0 is given by:

$$t_r = \frac{Q}{\pi f_0}$$

Taking an extreme example, In the Model HR-8 the normal value of Q is 10, and at a frequency of 1.5 Hz the rise time is 2.12 seconds. The time required to reach steady state is several times this figure, and is long enough to interfere with the processes of tuning and level setting. Furthermore, any noise impulse accompanying the signal will set up a ringing response which will take a time of this order to decay. As a result, adjustment of the amplifier at very low frequencies becomes a test of patience. In the low frequency range, some advantage may be gained by adjusting Q to a lower value to shorten rise time or increasing Q to enhance selectivity.

REMOTE OPERATION:

The preamplifier can be removed from the main frame of the Model HR-8 and operated in close proximity to the signal source. A remote preamplifier kit is available as an accessory for connecting the preamplifier to the main frame. The length of the cable normally supplied with this kit is 10 feet, but longer cables can be supplied on special order.

OUTPUT FILTERING:

The principle of operation of the time constant circuit is illustrated in Figure 3-4. There are two stages of low-pass filtering. The first stage comprises the push-pull amplifier A and the RC feedback elements R_f and C_f. The DC amplification (X 310) is determined by the ratio R_f/R_i. The product R_fC_f determines the cut-off frequency and hence the bandwidth of the signal passed to the output circuit. Following the feedback amplifier, a simple low-pass circuit, R_2C_2, provides additional filtering. C_2 is varied simultaneously with C_f for adjustment of time constant, and R_2C_2 is always equal to R_fC_f. The roll-off rate in the attenuation region is 12 dB/octave, however, C_2 can be disconnected (by the 6 dB/OCT - 12 dB/OCT switch), and the roll-off rate then is only 6 dB/octave.

The equivalent noise bandwidth of the first RC filter circuit is

$$(\Delta B)_1 = \frac{1}{4RC}$$

and the rise time (10% to 90%) is

$$(T_r)_1 = 2.2RC$$

When both RC circuits are in use, the equations become:

$$(\Delta B)_2 = \frac{1}{8RC} \qquad (T_r)_2 = 3.4RC$$

Comparing the two sets of equations it is seen that:

1. For a given time constant (RC) the equivalent noise bandwidth of the double-section filter is one half that of the single-section.

$$(\Delta B)_2 = \tfrac{1}{2} (\Delta B)_1$$

2. For a given noise bandwidth the rise time of the double-section filter is about 23% less than that of a single-section filter

$$(T_r)_2 = \frac{2.2}{3.4} \times \frac{1}{2} \times (T_r)_1 = .772\ (T_r)_1$$

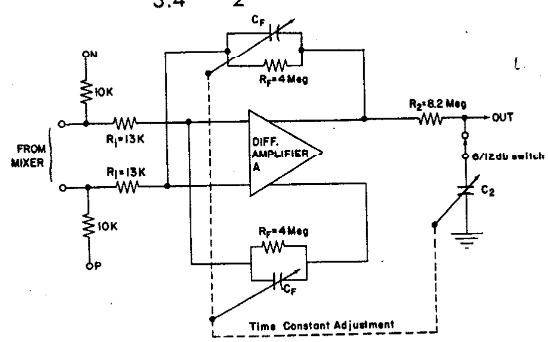


FIGURE 3-4

For most measurement applications of the Lock-In Amplifier, it is advantageous to use the 12 dB/octave filter so as to have the shortest response time for a given noise bandwidth. However, if the Lock-In Amplifier is being used as a component in a closed servo loop, the 6 dB/octave roll-off may be preferred.

EXTERNAL TIME CONSTANT:

The EXT. position on the TIME CONSTANT switch allows the operator to obtain any desired time constant by connecting the appropriate capacitors to the octal socket on the rear of the Model HR-8 (Figure 3-5.)

USE OF EXTERNAL CAPACITORS:

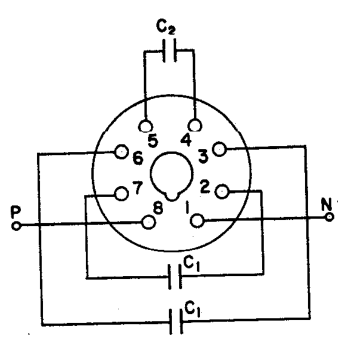


FIGURE 3-5

Socket on rear panel for connection of external time constant capacitors (viewed from outside.)

NOTE: Capacitor rating = 50 volts.

The required capacitance may be calculated from the following relationships:

$$C_1 = \frac{N}{4}\,\mu f$$

$$C_2 = \frac{N}{8}\,\mu f$$

where N = Required time constant in seconds.

NOTE: C_2 is required only when operating at 12 db/octave.

Only non-electrolytic capacitors should be used in the time constant circuits. Mylar, polystyrene, or polycarbonate film types are preferred.

Pins No. 1 and No. 8 on the external capacitor socket, marked N and P respectively, are connected to the mixer output just before the time constant circuit, as indicated in Figure 3-4, and as shown in detail in the mixer circuit board diagram. The N-P connection is used if it is desired for any reason to apply the mixer output unaffected by the internal filter to an external measuring circuit.

DETECTION OF SIGNALS AT A MULTIPLE OF THE REFERENCE FREQUENCY:

In some Lock-In Amplifier applications, the available reference frequency is a subharmonic of the signal frequency. In such cases, a reference frequency equal to the signal frequency must be produced in a harmonic generator. The Model HR-8 Lock-In Amplifier is ideally suited to this mode of operation because of its continuously tunable reference channel amplifier. In general, the reference signal (assumed to be sinusoidal, though this is not to be considered a restriction) is fed into a simple harmonic generator, the desired harmonic being selected by means of the tuned amplifier.

If even (2nd and higher) harmonics are of interest the following harmonic generator is useful:

The amplitude of the reference sine wave should be several volts peak to obtain efficient rectification.

The Fourier Series of an ideal waveform of this type is

$$E(t) = Eo\left[\frac{1}{\pi} + \frac{1}{2}\sin\omega t - \frac{2}{\pi}\sum_{k=2}^{\infty}\frac{\cos k\omega t}{k^2-1}\right] \text{(k even)}$$

where E (t) is the output waveform of the half wave rectifier and E_n is the peak value of the input voltage. Apart from the fundamental, the output contains only even harmonics.

For operation in the SEL. EXT. mode a minimum level (of the desired harmonic) of 70 millivolts peak-to-peak is required at the reference input terminals, i.e., we must have

$2A_2 \geq 70mV$. (A_2 = peak amplitude of second harmonic)

i.e. $\frac{4E_0}{3\pi} \geq 70mV$.

$$Eo = \frac{70 \times 3\pi}{4} = 165mV$$

Since this is below the minimum value for efficient rectification by a silicon diode it is clear that any reference voltage large enough to produce the output waveform of Figure 3-6 will be adequate to drive the Lock-In Amplifier.

For second harmonic operation, simply feed the reference signal to the Lock-In via a diode as shown in Figure 3-6. Set the FREQUENCY dial and FREQUENCY RANGE switch to the second harmonic of the reference frequency and proceed according to the instructions given above for operation in the SELECTIVE EXTERNAL reference mode.

Operation on even harmonics higher than the second is possible. The following considerations should be understood before such operation is attempted.

The reference channel tuned amplifier at full gain "1" can withstand an input of 1 v peak-to-peak without overloading. In order to assure proper operation, the maximum instantaneous peak input voltage must be kept below this level. (Of course for settings of the REFERENCE LEVEL control other than "1" this limiting value is proportionately higher). If a high order harmonic is used the level of the harmonic of interest will be considerably lower than the maximum instantaneous peak input level (E_0). If we assign a maximum value of 1 to E_0, the component parts of the rectified wave are:

fundamental	1.0V peak-to-peak
2nd harmonic	.424V peak-to-peak
4th harmonic	.085V peak-to-peak
6th harmonic	.036V peak-to-peak

Thus, operation at the fourth harmonic should be possible, but at the sixth and higher harmonics there is not enough voltage for operation of the reference circuit.

For the sixth and higher even harmonics, the circuit of Figure 3-7 can be used.

R_2 and C constitute a high-pass filter whose effect is to reduce the level of the lower order harmonics. A good choice of R_2C is a value such that

$$\omega_n = \frac{1}{R_2C}$$

where ω_n is the angular frequency of the desired harmonic. Of course more elaborate preselection methods may be used.

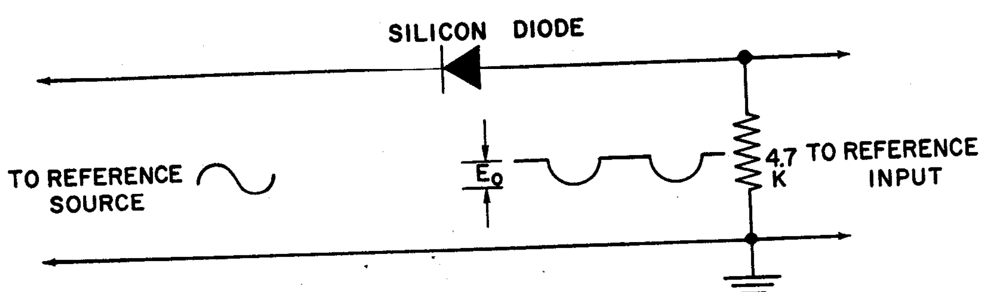


FIGURE 3-6

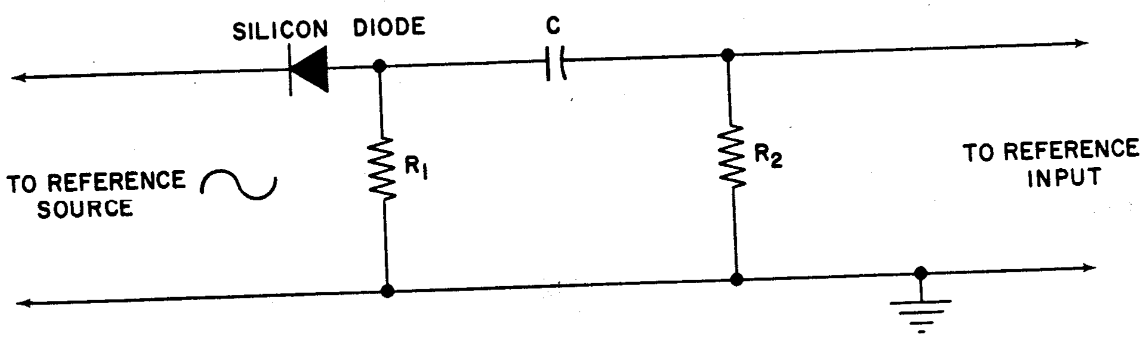


FIGURE 3-7

In any case the Lock-In is set to the frequency of the desired harmonic and set up as outlined in the SELECTIVE EXTERNAL section of OPERATING INSTRUCTIONS in this manual.

If odd (3rd and higher) harmonic operation is desired the following circuit can be used (Figure 3-8).

The resulting waveform has a harmonic structure given closely by:

$$E(t) = \frac{4\,E_o}{\pi} \sum_{K=o}^{\infty} (-1)^k \frac{\cos{(2k+1)\,\omega t}}{\cos(2k+1)}$$

where E_o is about ½ volt for silicon diodes without bias voltage. Using an argument similar to that of the preceding section it turns out that this arrangement will permit operation up to the 5th harmonic.

If operation at higher odd harmonics is desired the following circuit may be used. (Figure 3-9)

If $R_1C = \frac{1}{\omega}_n$ the voltage gain from A to B at a frequency ω_n will be approximately 0.7. At frequencies ω, below ω_n the gain is roughly proportional to ω. The amplitude of the harmonics in the input waveform is proportional to $\frac{1}{\omega}$.

Therefore up to ω_n the various odd harmonics appearing at B are all about the sample amplitude. If ω_n is chosen to be the highest harmonic of interest, then operation at all odd harmonics below this will be possible.

In any case the Lock-In is tuned to the harmonic of interest and set up according to the procedure in the SELECTIVE EXTERNAL section of OPERATING INSTRUCTIONS in this manual.

OPERATION WITHOUT REFERENCE VOLTAGE:

If no reference voltage is applied, the Model HR-8 can be used as a simple tuned voltmeter, with lower sensitivity and greater bandwidth than when used in the lock-in mode. The bandwidth is that of the signal tuned amplifier, normally one tenth of the signal frequency but adjustable between the limits of 1/5th

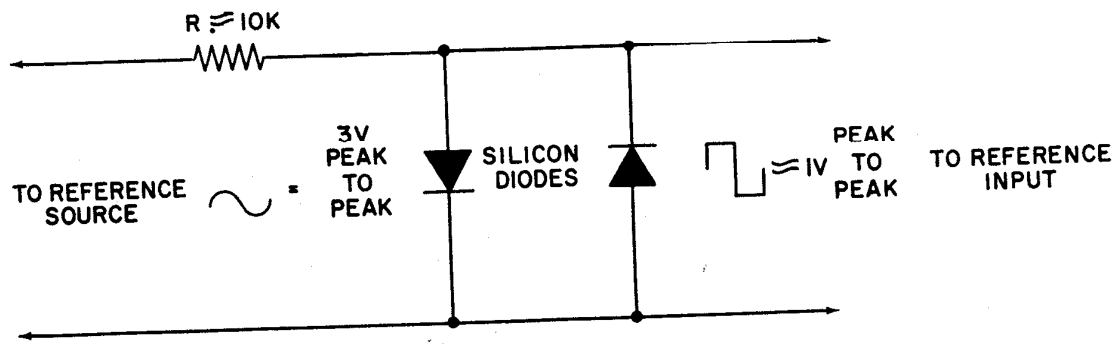


FIGURE 3-8

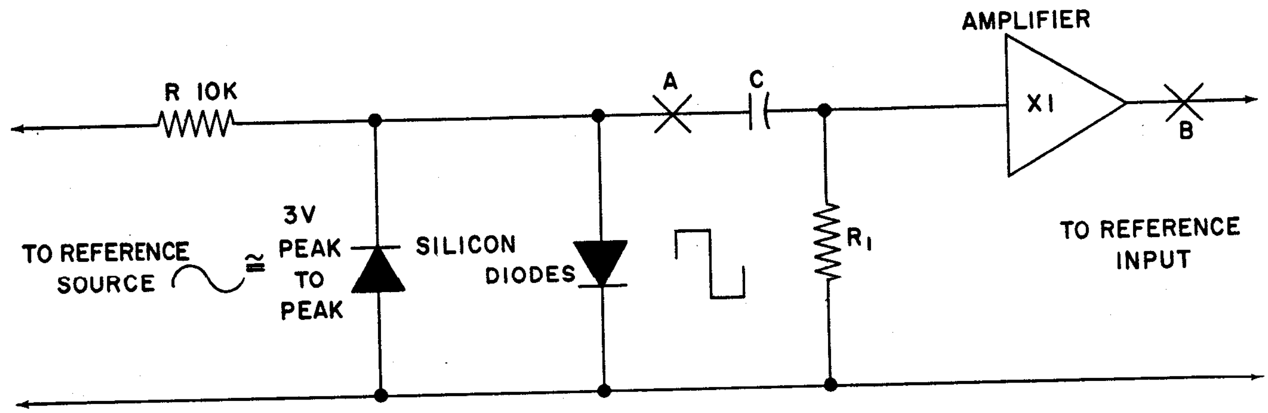


FIGURE 3-9

and 1/25th of the signal frequency. The sensitivity is reduced by a factor of 100. Thus, the voltage required for full scale deflection is 100 times the value indicated on the SENSITIVITY switch. A precise calibration can be made using the gain adjustment and the square-wave calibrating circuit. To operate the Model HR-8 in this manner, connect the signal source to the input connector on the preamplifier and place the METER/MONITOR switch in the SIG position. The instrument is then a selective peak-responding voltmeter calibrated in rms sine wave volts in the upper 4/5 of the meter scale. In this part of the meter range its deflection is a linear function of the applied voltage. This characteristic is obtained by applying a small forward bias to the rectifier which results in a meter deflection of about 5% of full scale with no signal applied. However, the spacing of steps on the SENSITIVITY switch is such that it is possible to make all measurements on the upper 60% of the meter scale.

OVERLOAD:

An overload condition can exist in three areas of the Model HR-8 Lock-In Amplifier.

1. TUNED AMPLIFIER INPUT OVERLOAD

The tuned amplifier input can be overloaded by interfering signals, significantly removed from the tuned frequency (factor of 10) with an amplitude of 1000 times the sensitivity setting in use. To test for this condition, set the MONITOR switch in the SIG position and observe the MONITOR connector output with an oscilloscope. Any modulation of the signal by the interfering signal indicates that an overload condition exists. If this condition exists, the interfering signal should be attenuated by pre-filtering prior to the Model HR-8 Lock-In Amplifier.

2. MIXER OVERLOAD:

When the signal-plus-noise at the mixer input is so large that a significant change in Lock-In indication results, the OVERLOAD indicator will light. Adjustment of the SENSITIVITY switch to a point where the lamp is extinguished will provide maximum sensitivity without overload.

3. OUTPUT DC AMPLIFIER OVERLOAD

The output DC Amplifier will become overloaded if the demodulated and filtered signal applied to it has peak amplitudes greater than ±12 volts relative to ground. To check for this condition, set the monitor switch in the OUT position and observe the waveform appearing at the MONITOR connector. If voltage peaks exceeding 12 volts relative to ground appear, the overload condition exists. To overcome this condition either or both the TIME CONSTANT and the input SENSITIVITY controls should be adjusted.

GALVANOMETER TYPE RECORDERS:

Two binding posts for connection to a recorder are located on the rear panel together with a 15K potentiometer whose purpose is to adjust full-scale deflection of the recorder to track that of the panel meter. Any galvanometer type recorder requiring one milliampere for full scale deflection can be driven if its resistance does not exceed 3000 ohms.

Circuit connections are shown in Figure 3-10. Open circuit output voltage at the recorder terminals is 10 volts when the panel meter (in the OUT position of the METER/MONITOR switch) indicates full scale. Short circuit current is limited to 1.43 milliamperes by the 6.98 K fixed resistor in series with the output circuit of the transistor emitter follower. The red recorder binding post is at chassis potential when the panel meter is at zero (i.e., when there is no signal and the ZERO OFFSET is at zero). The black binding post is connected to the instrument chassis. The range of recorder current and resistance within which the 15 K RECORDER ADJUST can match the recorder full scale to the panel meter full scale is given by

$$\frac{10V}{7K + R_{rec}} > I_{fs} > \frac{10V}{22K + R_{rec}}$$

SERVO TYPE RECORDERS:

This category includes recorders in which the impressed voltage is amplified before being applied to the pen-actuating mechanism. They have high input resistance and are usually calibrated in volts. A suitable circuit for connecting such recorders to the Lock-In Amplifier is shown in Figure 3-11. The shunt resistance R_1 is chosen so that the voltage across it will drive the recorder to full scale when the panel meter is at full scale (±10 volts).

In general, if the particular servo recorder has an input impedance greater than 100K ohms and reads ± full scale on ± V volts, the value of the shunt resistor in K ohms which will allow the potentiometer to provide reasonable adjustment range is given by:

$$\frac{10V}{10\text{-}V} < R_1 < \frac{20V}{10\text{-}V}$$

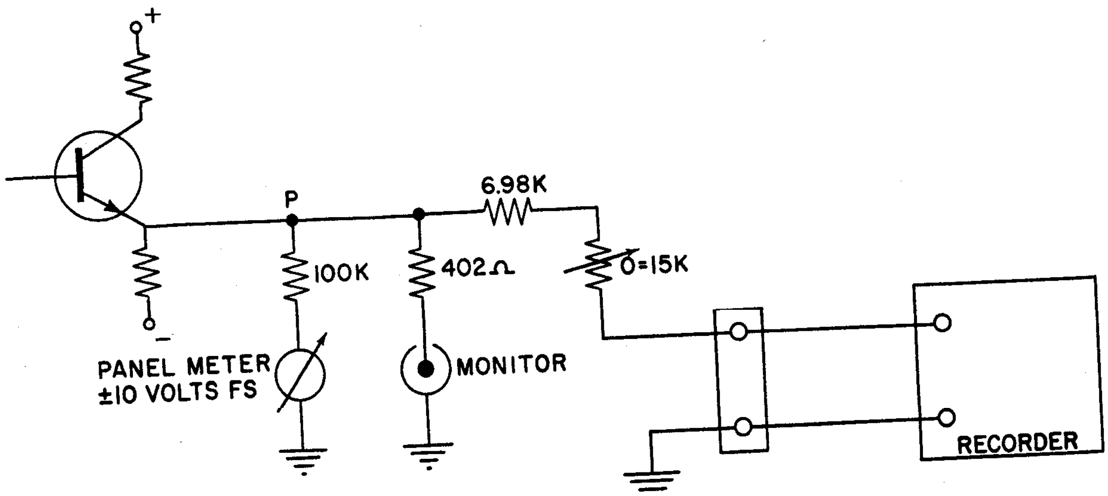


FIGURE 3-10
GALVANOMETRIC RECORDER USED WITH THE
MODEL HR-8

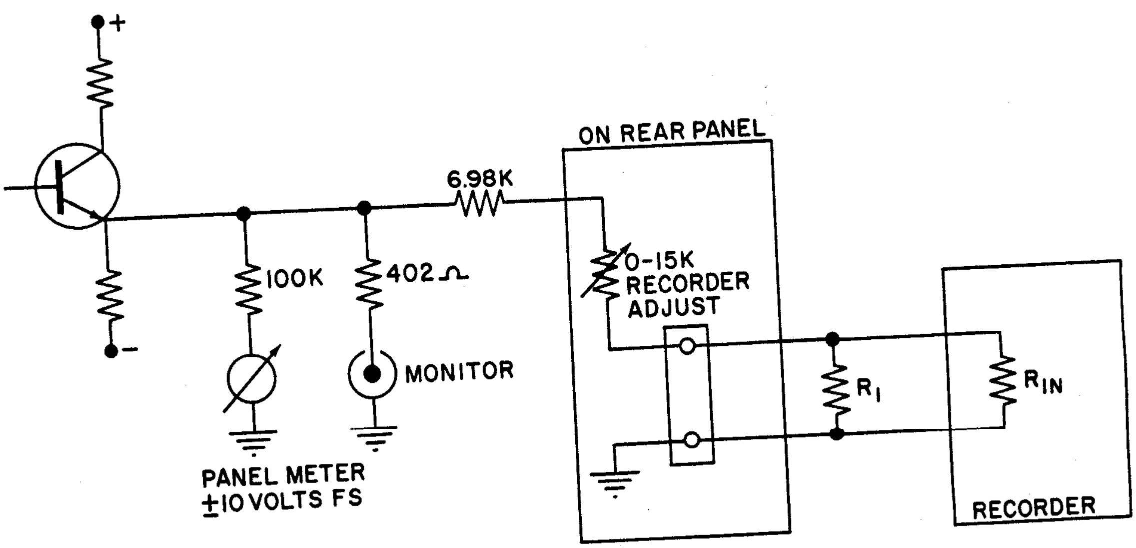


FIGURE 3-11
SERVO TYPE RECORDER USED WITH MODEL HR-8

RECORDER ADJUST:

A steady and noise-free signal should be used for adjusting the recorder so its full scale matches that of the panel meter. The ZERO OFFSET may be used for this purpose. To make the adjustment, disconnect the signal temporarily, set the METER/MONITOR switch at OUT, and rotate the ZERO OFFSET knob until the panel meter is at full scale. Then vary the RECORDER ADJUST until the recorder is also at full scale. Having made this adjustment, return the ZERO OFFSET to zero and lock the adjustment. Reconnect the signal.

ZERO OFFSET:

The ZERO OFFSET provides means of introducing an adjustable voltage of either polarity into the transistor amplifier which drives the recorder and the panel meter. The algebraic sum of the signal and the offset are amplified and appear at the output and drive the panel meter, the MONITOR output, and the recorder. Its purpose is best explained by an example. If the output signal never falls below a value V_1 and varies between that value and V_2, and furthermore if the significant range V_2-V_1 is very small compared with the steady component V_1, it is advantageous to suppress the steady component and expand the variable component V_2-V_1 so it fills the whole scale of the recorder. This is done by introducing an offset of magnitude V_1. The offset voltage is accurately indicated by a ten turn dial as a multiple of the panel meter full scale, so there is no loss of accuracy in using this facility. Maximum available offset amounts to ten times full scale.

The following procedure may be employed to determine suitable adjustments of SENSITIVITY and ZERO OFFSET. First, with no offset and with the signal at its maximum level, V_2, adjust the SENSITIVITY control for maximum on-scale deflection of the panel meter. Determine the minimum signal level, V_1, at the same SENSITIVITY setting. These values are shown graphically in Figure 3-12 where the horizontal bar represents the meter scale and the shaded section represents the useful signal range. The remainder of the procedure is most easily explained by using numerical values and, accordingly, a set of hypothetical figures has been added to Figure 3-12A. Making the calculation shown beside the diagram, it is found that the useful range of signal spans only 7% of the meter scale. By adjusting the SENSITIVITY control from its initial setting of 1000 microvolts (1.0 millivolts) to different values, the useful signal range can be expanded to 14%, 35%, or 70% of full scale. The next step would be 140%, which obviously is impractical, so 70% is chosen. The new full scale sensitivity V_o is 100 microvolts. Now the ZERO OFFSET must be adjusted to place the minimum signal, V_1, at the zero position on the meter. This is shown graphically in Figure 3-12. The required offset is found to be 8 turns of the 10-turn control. The measured voltage is the sum of the zero offset and the panel meter reading.

TIME CONSTANT ADJUSTMENT:

Noise accompanying the signal and appearing at the output can be reduced by increasing the time constant, but obviously the time constant should not be made so long that significant variations in signal level are not observed. The adjustment is made by observing the panel meter and/or the recorder, and gradually increasing the time constant until a satisfactory compromise between suppression of noise and speed of response is reached.

CALIBRATION:

To establish and maintain the specified accuracy of the instrument, it should be tested periodically with accurate calibrating signals derived from the internal calibration signal generator. For best accuracy, calibration should be performed at the same frequency, sensitivity, and signal Q as will actually be used for measurement. In the example that follows, these are 400 Hz, 500 μV, and 10 respectively. To perform this operation proceed as follows:

(1) Turn power ON.
(2) Connect a BNC cable from the CALIBRATE connector to INPUT A.
(3) Set preamp mode switch in "A" position.
(4) SENSITIVITY switch at 500 μV.
(5) FREQUENCY dial at 4.0.
(6) FREQ RANGE switch to $X10^2$.
(7) FREQ. TRIM to 0.
(8) SIG. Q to 10.
(9) Phase Quadrant switch to 0.
(10) PHASE control to 0.
(11) MODE switch to INT.
(12) REF. ATTEN. to OFF
(13) REF. VERNIER to max CCW.
(14) TIME CONSTANT to 100 mS.
(15) 6/12 dB switch to 6dB.
(16) Put METER/MONITOR switch in REF. position. Meter will read approximately 1V (full scale is 2V).
(17) METER/MONITOR to SIG.
(18) ZERO OFFSET to 0. (max. CCW and lock knob).
(19) CALIBRATE switch to 50 mV, (i.e., 100 x SENSITIVITY setting).
(20) A reading on the meter should be present at this point. The reference frequency is 400 Hz, and it is now necessary to trim the signal channel for a peak at this frequency. Adjust FREQ. TRIM. for a maximum reading. This reading should be approximately full scale.
(21) Put CALIBRATE switch to 500 μV position.
(22) Put METER/MONITOR in OUT position. Adjust PHASE control for maximum meter reading to the right. PHASE control should be approximately at 0°. The meter reading should be full scale. If it is not, adjust GAIN ADJ (screw driver adj.) for a full scale reading. This completes calibration of the Model HR-8 at 400 Hz.
(23) If the preamp is going to be used in the A-B mode, the AC BAL should be adjusted. This is done by feeding the same signal into the A and B simultaneously. To obtain the highest degree of common mode rejection, this adjustment should be made with the same frequency and SENSITIVITY switch settings that will be used in the experimental measurements. Put the METER/MONITOR switch in the OUT position. Adjust the AC BAL (screw driver adj.) for zero on the meter. Increase the input signal by a factor of 10 to determine if the zero was properly adjusted. (Note: The above adjustment should be made only after all the preceding steps (1 through 22) have been made.

NOTE: This completes the calibration procedure.

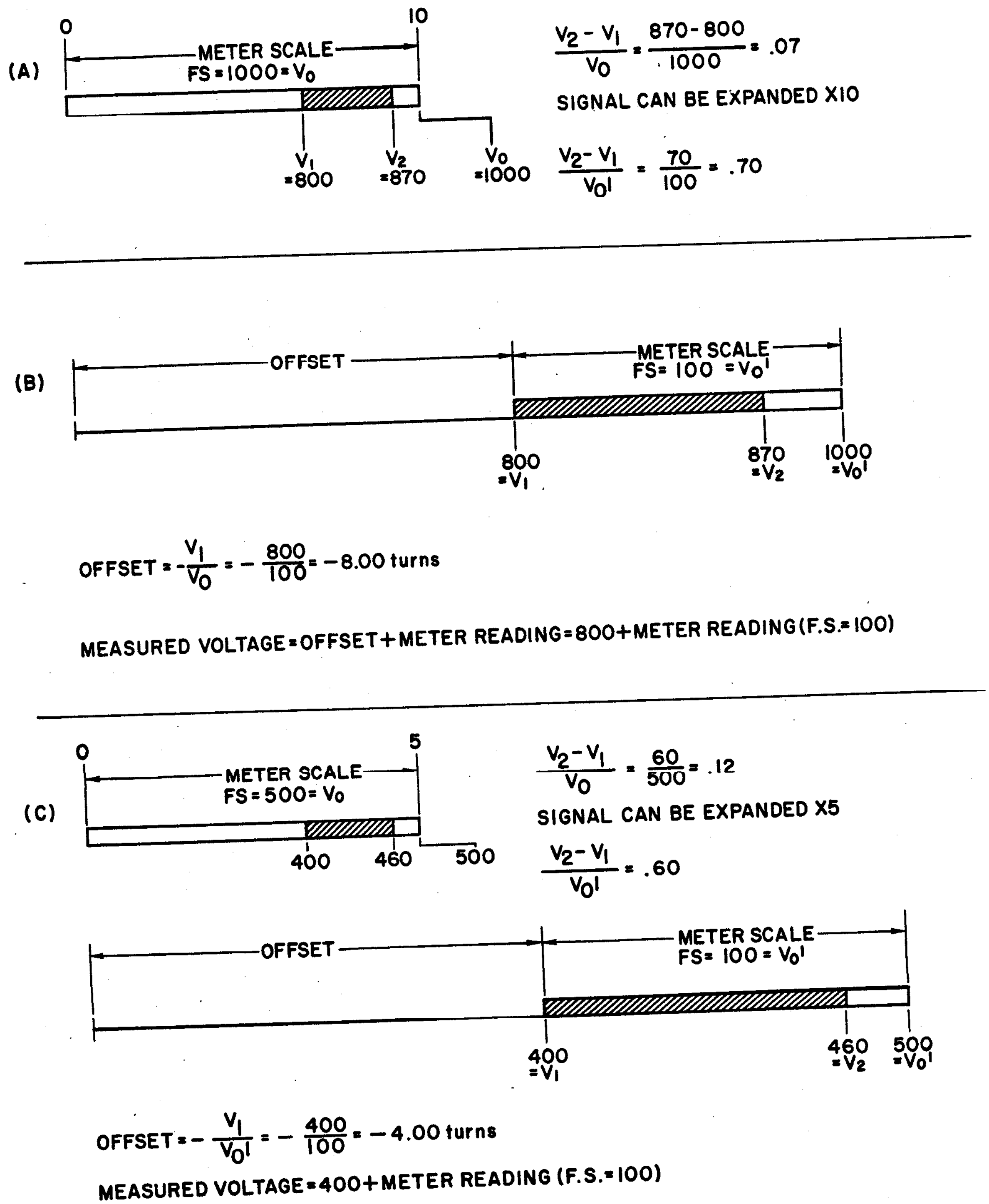


FIGURE 3-12

EXAMPLES OF ZERO OFFSET CONTROL APPLICATION

CIRCUIT DESCRIPTION

INTRODUCTION:

The various circuit elements that go together to make up this instrument are assembled on seven plug-in printed circuit boards, one printed circuit board mounted on the front panel and one board mounted underneath the main chassis. The different boards are identified as follows: (the identification numbers listed below appear on the printed wiring side of the boards.)

CIRCUIT	IDENTIFICATION NO.
INTERMEDIATE AMPLIFIER	IN 1395
SIGNAL CHANNEL TUNED AMPLIFIER	SI 1400
REFERENCE CHANNEL TUNED AMPLIFIER	RE 1393
AUXILIARY REFERENCE AMPLIFIER	AU 1394
POWER SUPPLY I	PO 1396
POWER SUPPLY II	PO 1396
MIXER DC AMPLIFIER	MI 1397

Access to the plug-in boards may be had by removing the top cover of the instrument. They are located as shown in Figure 4-1.

The circuitry will be discussed board by board in order to simplify the task of trouble shooting and to acquaint the interested user with the principles of operation.

The plug-in preamplifiers will be discussed as individual items and their relationship with the main frame circuitry will be detailed.

TYPE A PREAMPLIFIER (Circuit Boards PS 1398, PR 1399)

This is a differential input amplifier with low-noise input circuits provided by two nuvistor triodes operating as cathode followers. Each triode is followed by a transistor amplifier and a transistor emitter follower. Input may be either single-ended or differential, as selected by the A, A-B, -B switch. In the single-ended mode, either input connector may be used. In the differential mode, common mode output can be minimized by means of the A.C. BAL adjustment. The optimum adjustment varies slightly with frequency and sensitivity settings.

Amplifier gain (defined as the ratio of single-ended output to single-ended input) is either 10 or 1, as determined by the switch K-4. Additional gain variation is provided by input attenuators preceding the two cathode followers. By suitable combinations of the switches K-1, K-2, and K-3, the voltage at the triode grids may be reduced to 1/100 or 1/1000 of the voltage at the input connectors. The switches are relay operated, with the relays being controlled by contacts on the SENSITIVITY switch. The relays are programmed so that gain or loss ratios of 10.0, 1.0, 0.10, 0.010, and 0.0010 are selected in sequence and coordinated with gain changes in the intermediate amplifier.

Operating voltage for the amplifier passes through a voltage regulator, Q01 to Q04, whose main function is to prevent signal or reference leakage from high-level circuits into the preamplifier through the power supply circuit.

TYPE B PREAMPLIFIER (Circuit Boards PS 1398, PR 1574).

The Type B Preamplifier is characterized by low input impedance and high voltage gain. Input is differential through a transformer, and the output to the intermediate amplifier is balanced. The circuits in other respects are similiar to those of the Type A Preamplifier and gain variation is switch and relay controlled in the same manner.

In the normal input transformer connection, the voltage gain is approximately 100 times that of the Type A Preamplifier. Input impedance is low (dependent on frequency). The frequency range is approximate-

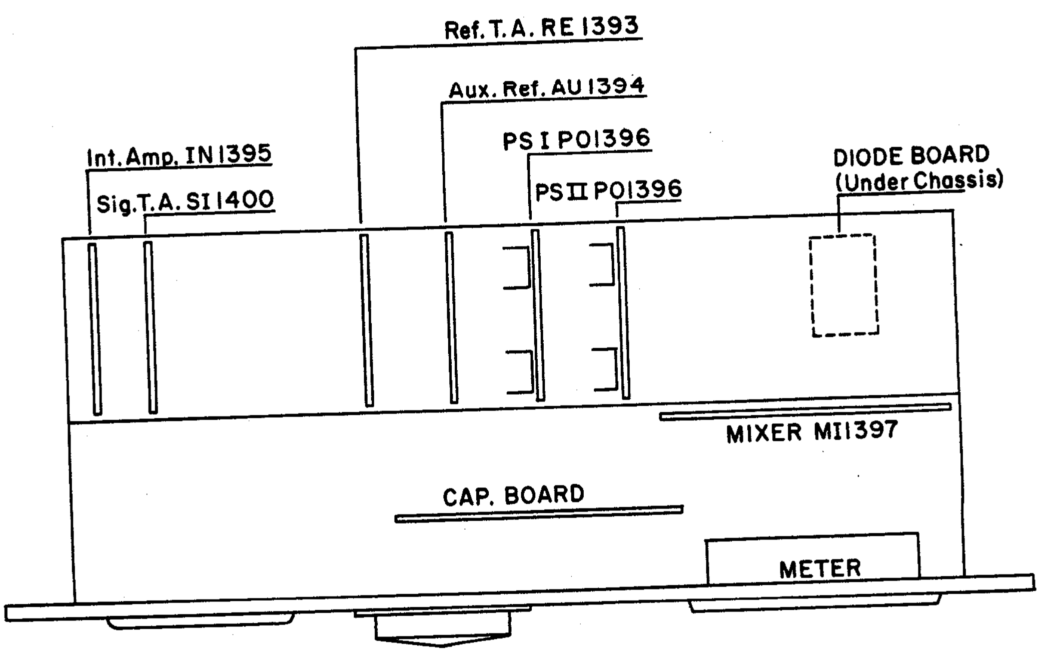


FIGURE 4-1
LOCATION OF PLUG-IN BOARDS

ly 10 Hz to 10 kHz, but the limits are affected somewhat by the source impedance.

Although the Type B Preamplifier is normally supplied with a 100:1 voltage transformation ratio, other ratios (ranging from 50:1 to 350:1) are easily achieved by changing transformer tap connections. Other transformers are available which provide an even wider selection of ratios.

TYPE B1 PREAMPLIFIER (Circuit Boards PS 1398, PR 1574)

The Type B1 Preamplifier is similar in design to the Type B Preamplifier. The Type B1, however, uses a higher frequency response transformer to provide coverage from 1 kHz to 150 kHz. These numbers apply for a source impedance of 1 ohm. Higher source impedances will restrict the passband. The Type B1 is normally supplied with a transformer having a 100:1 voltage transformation ratio, and taps are not provided.

TYPE C PREAMPLIFIER (Circuit Boards PR 1965, PS 1966)

The Type C Preamplifier uses a pair of low-noise silicon PNP junction transistors in a differential cascode circuit. Voltage gain is controlled by reed relays in the same manner as in the Type A Preamplifier, but the voltage gain of the Type C is always ten times greater than that of the Type A. Actual sensitivity of the HR-8/Type C combination ranges from 10 nV to 50 mV rms full scale. Frequency response is 1.5 Hz to 150 kHz.

INTERMEDIATE AMPLIFIER (Circuit Board IN1395)

The intermediate amplifier comprises three amplifying stages, each with a voltage gain of 10. (Gain is defined as the ratio of single-ended voltage output to single-ended voltage input). The first stage accepts balanced inputs from the preamplifier, and its output is single-ended. Its voltage gain can be reduced to 5 or 2 by switching in different emitter-coupling resistor values. The third stage, or both the second and the third, can be switched out of the circuit to reduce the gain by factors of 0.1 or 0.01, respectively. Both of these switching functions as well as those provided in the preamplifier are controlled by a six-wafer switch (the SENSITIVITY control) in such a way that the instrument sensitivity advances in a 1-2-5 sequence from 100 nanovolts rms to 500 millivolts rms for full scale deflection of the panel meter. The manner in which this is done is shown in Table 4-2. It is pointed out again that gain is defined and measured on the basis of single-ended input to the preamplifier, as illustrated in Figure 4-2.

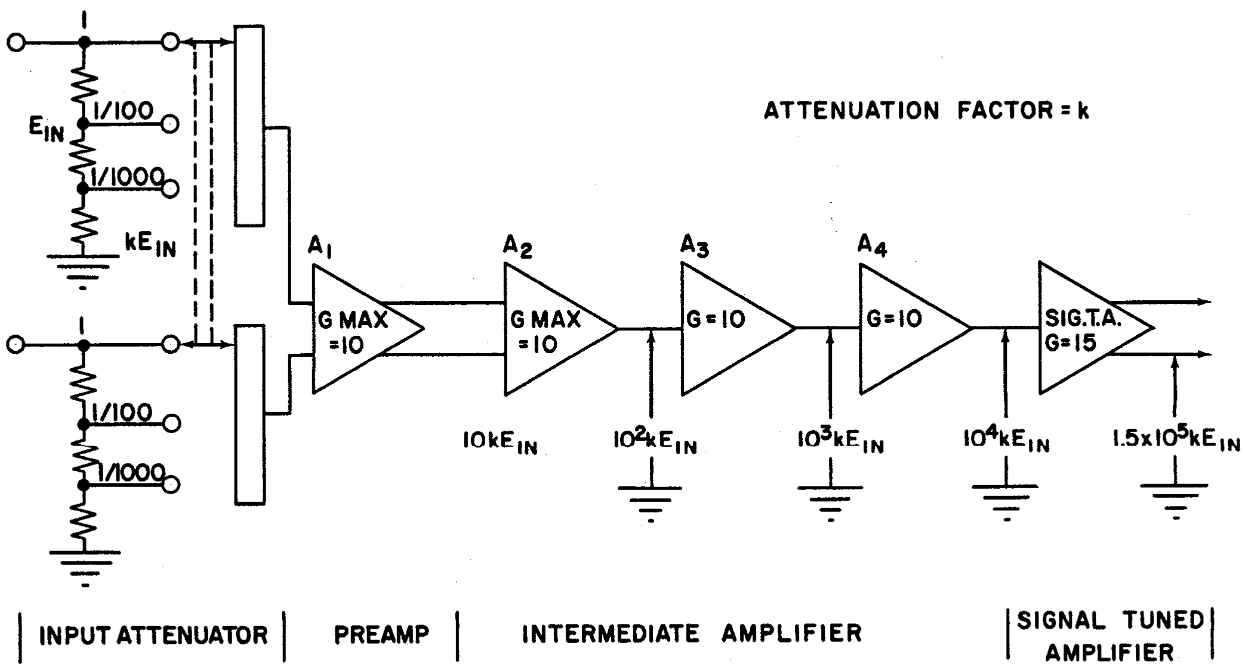


FIGURE 4-2 INPUT ATTENUATORS AND AMPLIFIERS

TABLE 1

INPUT ATTENUATOR AND AMPLIFIERS SETTINGS FOR VARIOUS SENSITIVITY SETTINGS

Sensitivity	Type A Preamplifier Input Atten.	V. Gain	Intermediate Amp. Voltage Gain	Net Gain
100 Nanovolts	1	10	10x10x10	10,000
200 Nanovolts	1	10	5x10x10	5,000
500 Nanovolts	1	10	2x10x10	2,000
1 Microvolt	1	10	10x10	1,000
2 Microvolts	1	10	5x10	500
5 Microvolts	1	10	2x10	200
10 Microvolts	1	10	10	100
20 Microvolts	1	10	5	50
50 Microvolts	1	10	2	20
100 Microvolts	1	1	10	10
200 Microvolts	1	1	5	5
500 Microvolts	1	1	2	2
1 Millivolt	1/100	10	10	1.
2 Millivolts	1/100	10	5	.5
5 Millivolts	1/100	10	2	.2
10 Millivolts	1/100	1	10	.1
20 Millivolts	1/100	1	5	.05
50 Millivolts	1/100	1	2	.02
100 Millivolts	1/1000	1	10	.01
200 Millivolts	1/1000	1	5	.005
500 Millivolts	1/1000	1	2	.002

SIGNAL CHANNEL TUNED AMPLIFIER (Circuit Board SI1400)

The tuned amplifier following the intermediate amplifier operates normally with a voltage gain of approximately 15 and a Q of 10. It is tunable over the frequency range of 1.5 Hz to 150 kHz by means of two RC low-pass circuits. Decade frequency steps are effected by switching the capacitors, and continuous tuning over an 11-to-1 range is by means of two potentiometers. Maximum amplification is obtained at the frequency at which the phase shift in each RC circuit is 45°, and the amplification falls to zero for signals of zero or infinite frequency. The selectivity characteristic is identical to that of a parallel RLC circuit. The Q of the RC tuned circuit is only 0.5 and to get a more useful value, negative feedback is utilized. The feedback factor can be varied (without affecting the gain) to give Q values from 5 to 25.

Gain may be adjusted between the limits of 10 and 20 by means of a front panel screw driver adjustment. This wide range of adjustment is provided in order that the instrument can be standardized to read either in volts as indicated by the SENSITIVITY switch, or in any units that may be appropriate to the measurement being made.

The input circuit is single-ended, and the output is balanced. The amplifier output circuit operates within its linear range up to 5 volts peak-to-peak output. A signal exceeding this value actuates an overload indicator which comprises the AC amplifier Q229 and Q230, the diodes D201-D204, the DC amplifier Q231, and a lamp in the collector circuit of Q231. The lamp is mounted behind a red jewel lens above the panel meter.

REFERENCE CHANNEL TUNED AMPLIFIER (Circuit Board RE 1393)

The frequency selective circuits in the reference channel tuned amplifier are similar in principle to those in the signal channel tuned amplifier, though slightly different in detail. In the output circuit, however, the arrangement is entirely different. In both amplifiers, one of the RC circuits produces a voltage with a phase lead of 45° from the input voltage, and the other RC circuit produces a phase lag of 45°. In the signal amplifier these two voltages are added, the result being an output voltage in-phase with the input. In the reference amplifier the two phase shifted voltages are manipulated to produce output voltages at 0°, 90°, 180°, and 270° respectively relative to the input voltage. The circuit by which this is accomplished is shown in simplified form in Figure 4-3. The sum of the two voltages at + and − 45° is passed through a phase splitter to produce voltages at 0° and 180°. In another part of the circuit one of the voltages is reversed and added to the other phase, the result after operation of a phase splitter being voltages at 90° and 270°. The four phases thus derived are applied to four equidistant points on a linear potentiometer, as shown in the diagram. By rotation of the contact point, any phase angle can be obtained with continuous adjustment from 0° to 360°. At odd multiples of 45° the output drops to 0.707 of the voltage at the input points, but this does not affect the operation of the mixer because the Schmitt trigger which drives the mixer responds only to zero-crossings of the waveform applied to its input.

In addition to the continuous variation of phase, phase changes in steps of 90° can be made by means of a 4-pole 4-position switch which connects the four output wires A, B, C and D to the four connection points. a, b, c and d on the potentiometer. By rotating this switch, the 90° wire (B) may be connected in turn to points b, c, d, and a; the other three wires are switched in the same way. Thus the phase of the voltage at the potentiometer rotor is changed in 90 degree steps.

AUXILIARY REFERENCE CIRCUITS (Circuit Board AU 1394):

This board includes a Schmitt trigger, a monostable multivibrator, a peak-responding ac voltmeter, a limiter, a square-wave generator, and an emitter follower. These circuits are used in different combinations in two of the reference modes, in the monitor voltmeter, and in the calibrator.

Automatic Reference Mode: This mode utilizes the Schmitt trigger and the monostable multivibrator. The reference voltage is applied to the Schmitt trigger. A reversed pair of diodes at the trigger input limits the peak voltage in each direction to about 0.6 volts. The output of the trigger is a rectangular wave of fixed

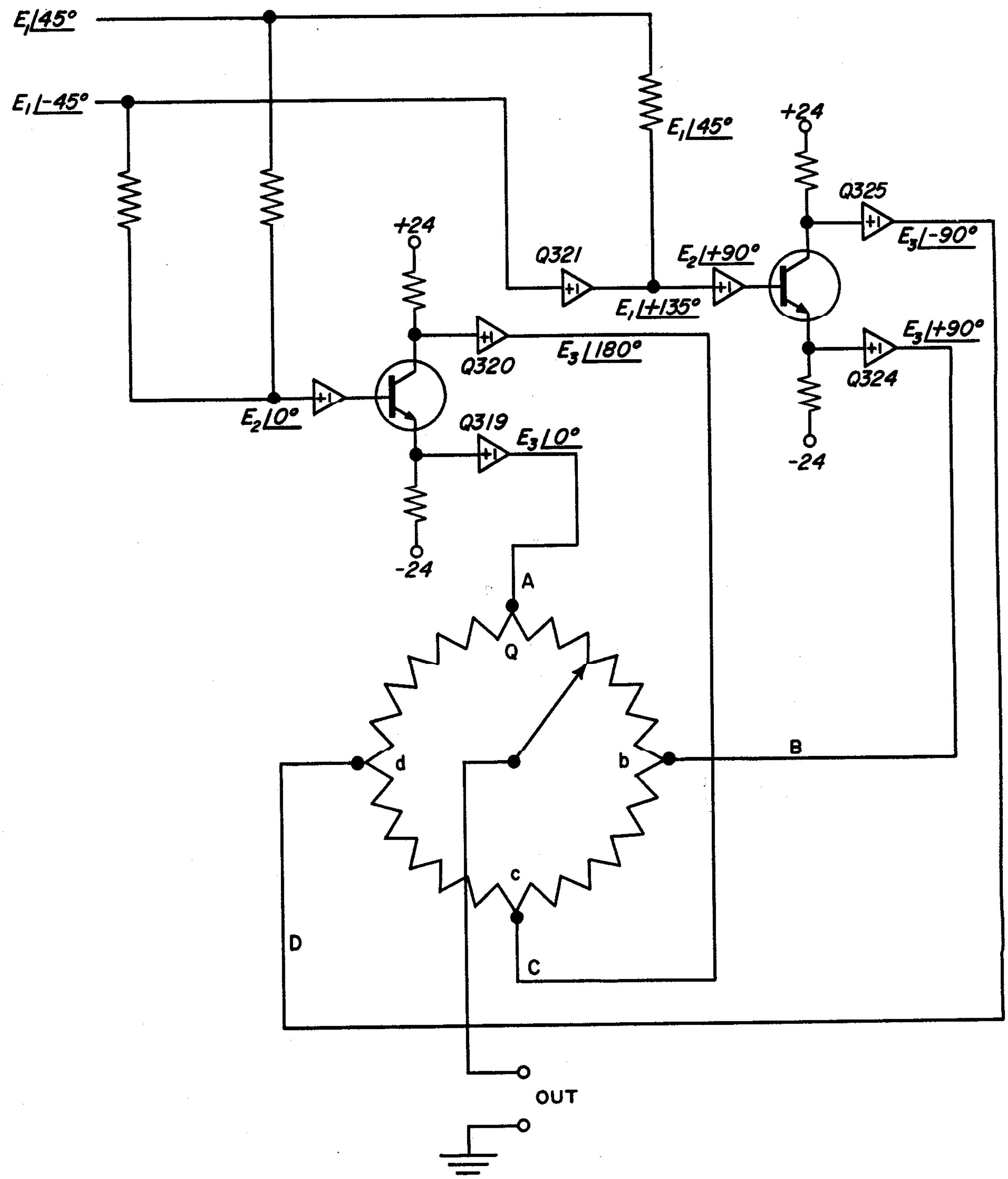


FIGURE 4-3

PHASE SHIFTER BLOCK DIAGRAM

amplitude which may be unsymmetrical depending upon the waveform of the input voltage. To make it symmetrical, it is passed through the multivibrator circuit. This circuit is switched into its quasi-stable state by the rectangular wave from the trigger, and it remains in this state for a time which depends only on the values of R and C in the timing circuit. The R and C are ganged with the corresponding elements in the signal and reference channel tuned amplifiers, and are in fact identical with those elements. The monostable returns to the stable state at the midpoint of the reference voltage cycle, thus generating a square wave that is relatively symmetrical. This square wave is amplified and filtered by the reference tuned amplifier, producing a relatively pure sine wave. The output amplitude of the multivibrator is 111 millivolts peak-to-peak. The fundamental frequency component is 50 millivolts rms. This is amplified to 1.0 volt rms by the tuned amplifier.

Internal Reference Mode: The limiter and the emitter follower are utilized in this reference mode. The reference channel tuned amplifier is made to operate as an oscillator by feeding back from output to input through the limiter. The voltage at the input of the limiter is a 1 volt rms sine wave, and its output is a 111 mV peak-to-peak square wave.

A fraction of the reference tuned amplifier output, as determined by the setting of the REF ATTENUATOR, is impressed on the emitter follower, and the output of this circuit is connected to the REF IN/OUT connector. The output impedance at this terminal is fixed at approximately 600 ohms by a 590 ohm resistor in series with the impedance of the transistor.

Monitor Voltmeter: In the SIG and REF positions of the METER/MONITOR switch, the signal and reference voltages are measured by the peak responding AC voltmeter. The voltage to be measured is impressed on a two-stage emitter follower, the purpose of which is to present a high impedance to the signal or reference circuit. The rectified output current, smoothed by the 50 microfarad capacitor C410, is fed to the panel meter. On the lowest frequency range, 1.5 to 15 Hz, the filter capacitance is increased to 150 microfarads.

Calibrator Circuit: A sine wave of approximately 1 volt rms amplitude taken from an isolating transistor Q317 in the reference channel tuned amplifier is impressed on the limiter (the same limiter that is used in the INT reference mode) where it is clipped to an amplitude of 1 volt peak-to-peak. The clipped sine wave is impressed on the calibrator square wave generator, a limiting amplifier whose output is a square wave of 222 millivolts peak-to-peak amplitude. This is subdivided by a ladder attenuator having input and output impedances of 50 ohms, in steps progressing in a 1-2-5 ratio from a minimum of 20 nanovolts to a maximum of 100 millivolts. These figures represent the rms amplitude of the fundamental frequency component of the square wave.

The attenuator switch also has two positions in which the base of the transistor Q414 can be connected through R445 to +24 or −24 volts. Either bias voltage is so much larger than the amplitude of the clipped sine wave that no square voltage appears in the output across the attenuator. When the bias is negative, the voltage across the attenuator is 222 millivolts, negative with respect to chassis. When the bias is positive, the voltage is zero. These voltages correspond exactly to the limits of the square wave swing when the circuit is generating calibrating voltage. In the negative bias position, the output terminal is connected to the highest point on the attenuator so that the DC level can be checked with an accurate DC voltmeter. If the specified value is obtained, it is then known that all the AC calibrating voltages are correct. If the DC voltage has any other value, it can be adjusted to 222 millivolts with the CAL. ADJ. potentiometer, R453.

MIXER (Circuit Board MI 1397)

The mixer is a switching circuit in which the output of a balanced amplifier is reversed in polarity at each half cycle of the reference waveform so that the applied ac signal is converted into a unidirectional current. The two pairs of transistors, Q701 and Q702, are operated as a double-pole double-throw switch by the square wave reference voltage applied at the point α and β. At any instant, one transistor of each pair is conducting, feeding current to the resistors R701 and R702; the other two transistors are cut-off. While Q701 and Q702 control the polarity of the current in the load resistors, the linear transistors Q703 control the magnitude of the currents in proportion to the balanced signal voltage applied to their bases. Leakage of the reference voltage into the signal output circuit is suppressed by the two AC BALANCE adjustments R704 and R712. Q704 acts as a current source, permitting a precisely fixed amount of current to flow to the load resistors. This helps to maintain a condition of exact balance in the mixer output, since whatever increment of current is added to one load resistor must be subtracted from the other.

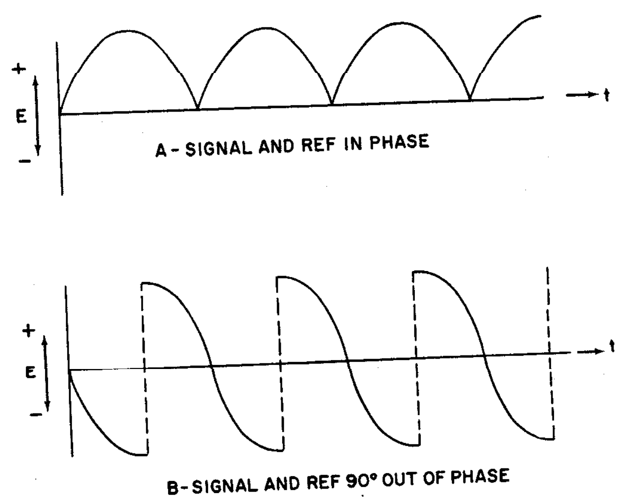


FIGURE 4-4

The DC ZERO screw driver adjustment fixes the average DC voltage level at one of the two mixer output points. With this adjustment properly made, and ZERO-OFFSET at zero, the panel meter reading (and recorder current, if a recorder is connected) will be zero when there is no signal applied. The DC voltage level at the other mixer output point is determined by the ZERO OFFSET (front panel control). The offset voltage inserted at this point works through the following DC amplifier circuits and offsets the zero on the panel meter (when measuring output) and the recorder circuit. A switch selects either positive or negative offset voltage.

The output voltage of the mixer, when the reference is exactly in phase with the signal, has the waveform of a series of half sine waves as shown in Figure 4-4A. When the reference is 90° out-of-phase, the output waveform changes to that shown in Figure 4-4B and the effective output, after passing through the time constant filter, is zero.

The single-ended reference voltage output from the phase potentiometer is converted to balanced voltages in a phase inverter which includes the transistors Q720 and Q721. The balanced voltage is further amplified by the transistors Q722 and Q723, and applied to the Schmitt trigger Q724 and Q725. The output of the trigger is a square wave of 2 volts peak-to-peak amplitude, which is applied to the mixer circuit at points α and β.

TIME CONSTANT CIRCUIT (Circuit Board MI 1397)

A three-stage high gain amplifier follows the mixer circuit. (This is the amplifier A in Figure 3-4). The first stage includes the pair of transistors Q705. A screwdriver adjustment of DC BALANCE is provided in the collector circuit. The second stage includes the two ansistors Q707. Q708 and Q709 are connected as emitter followers in the third stage. Two 47.5K resistors, R738 and R739, are connected in series between the two emitters. Any unbalance in output voltage at this point causes a voltage to appear at the midpoint of the two resisfors, and this is amplified by Q711 and Q706. The amplified voltage is applied as negative feedback to the emitters of Q705 to remove the common mode component of the output voltage.

The voltage amplification ratio is controlled by negative feedback through two resistors, R745 and R746. Since the feedback resistance is 4 megohms and the amplifier input resistance is 13K ohms, the closed loop gain is approximately 310 at frequencies from zero to the cut-off frequency determined by the time constant capacitors. The roll-off rate resulting from the RC feedback circuit is 6 dB/octave. Additional filtering, increasing the roll-off rate to 12 dB/octave, is provided by the 8.2 megohm resistor, R747, and the capacitor C2 associated with it.

Up to the point where the second RC circuit is connected, the circuit is completely balanced. Starting at that point, however, the circuit is essentially single-ended (though balanced circuits are used at some points to reduce drift caused by temperature changes). The output voltage across the second RC filter is impressed on one of the two transistors Q712. These transistors are followed by the two-stage balanced amplifier Q713-Q714 and Q717-Q718. Q718 drives the single-ended emitter follower Q719. A feedback connection from Q719 to the other transistor of the pair Q712 reduces the closed loop gain to unity. The transistors Q715 and Q716 are current sources, whose function is to maintain push-pull operation in the balanced portion of the circuit. Current for the recorder circuit, the monitor terminal, and the panel meter is supplied by the emitter circuit of Q719. Protection against damage due to inadvertent connection of a voltage source to any of these circuits is provided by the diodes D704 and D705. Each diode is reverse biased at 24 volts, and has no effect on signals of normal amplitude.

POWER SUPPLIES I AND II (Circuit Boards PO 1396)

The power transformer and two sets of rectifiers are shown in the wiring diagram. These parts are mounted on the main chassis. There are two regulators on each of the two identical circuit boards. One receives −31 volts from the rectifier and regulates it to −24 volts. The reference voltage is supplied by the zener diode D505. The output voltage is adjusted by the potentiometer R510.

The second regulator takes +31 volts from the rectifier and regulates it to +24 volts. The reference voltage is −24 volts from the first regulator. The +24 volt output is adjusted by the potentiometer R533.

The two regulators are similar, with only slight differences resulting from the difference in polarity, and are conventional in design.

Protection of the transistors from damage due to excessive current flow is afforded by the two fuses F501 and F502 in the 31 volt supply lines. These fuses may be reached for inspection or replacement by removing the top panel of the instrument case. The power transformer is protected by one fuse in its primary circuit. This fuse is in a fuse holder on the rear panel.

POWER SUPPLY ADJUSTMENT: (Board PO1396)

1. Insert one of the PO1396 boards into the 23 pin extender board and insert into the Power Supply II connector (closest to the transformer.)
2. Monitor TP 501 with the DC voltmeter.
3. Adjust the −24 ADJ potentiometer until the meter reads −24 volts.
4. Short the bases of Q505.
5. Adjust BAL-potentiometer until the meter reads −24 volts or until the adjustment becomes such that the meter varies critically between −32 volts and −3 volts.
6. Remove the short and ascertain that the voltage is −24 volts.
7. Monitor TP 502 with the DC voltmeter.
8. Adjust the +24 ADJ potentiometer until meter reads +24 volts.
9. Short the bases of Q510.
10. Adjust BAL + potentiometer until the meter reads +24 volts or the adjustment becomes such that the meter varies critically between +3 volts and +32 volts.
11. Remove the jumper and ascertain that the voltage remains at +24 volts.
12. After removing the extender board place Power Supply II in its connector.
13. Repeat steps I through 12 above for Power Supply I.

SIGNAL CHANNEL TUNED AMPLIFIER (Board SI1400).

1. Set the front panel controls as follows:
   FREQUENCY 4.0
   FREQ. RANGE .... x10^2
   SIG. Q 5
   METER/MONITOR switch .... SIG
2. Using the 20-pin extender board insert board #SI1400 into its connector.
3. Connect the signal generator, set for 400 Hz and minimum amplitude to pin 14 of board SI1400.
4. Connect the oscilliscope to the MONITOR connector.
5. Increase the magnitude of the signal generator until a 400 Hz signal is seen on the scope.
6. Slowly adjust the signal generator frequency control to peak the signal appearing on the oscilloscope.
7. Increase the signal generator amplitude until a signal of 5 volts ptp appears on the oscilloscope.
8. Readjust the Model HR-8 controls as follows:
   FREQUENCY 4.0
   FREQ. RANGE .... 10^4
9. Set the signal generator to 40 Hz. Do not change amplitude.
10. The signal appearing on the oscilloscope should be less than 5 mV ptp. If necessary R240 should be tailored until the signal is less than 5 mV ptp.
11. Adjust the Model HR-8 controls as follows:
    FREQUENCY 4
    FREQ. RANGE .... x10^2
12. Adjust the signal generator around 400 Hz until a peak is seen on the oscilloscope.
13. Adjust the NULL ADJ. potentiometer until the front panel meter varies less than ±2% when the SIG Q on the front panel is varied from 5 to 25.
14. Connect the scope to pin 18 of Board #SI1400.
15. Increase the ... until clipping is observed on the oscilloscope.
16. If clipping is significantly asymmetrical, select R284 such that the clipping levels are approximately the same.
17. Increase the amplitude of the signal generator until the OVERLOAD lamp lights. This should occur when the output at the MONITOR connector is between 4.0 and 4.5 volts ptp.
18. Remove the extender board and plug board SI1400 into its connector.

INTERMEDIATE AMPLIFIER (Board IN1395)

1. Using the 23 pin extender board plug board IN1395 into its connector.
2. Locate the two 10 ohm resistors, R105 and R106.
3. Check the DC voltage on these resistors to ground to ascertain that one reads +15 volts and the other −15 volts.
4. Remove the extender board and plug board IN1395 into its socket.

REFERENCE TUNED AMPLIFIER (Board IN1393)

1. Using the 23-pin extender board insert board #IN 1393 into its connector.
2. Set the front panel controls as follows:
   FREQUENCY 4.0
   FREQ. RANGE .... x10^2
   MODE switch .... SEL. EXT.
   REF. ATTEN. 1.0
   REF. VERNIER .... MAX CW
   METER/MONITOR switch .... REF.
3. Connect the oscilloscope to the MONITOR connector.
4. Connect the signal generator, adjusted to 400 Hz and minimum amplitude to the REF IN/OUT connector.
5. Increase the magnitude of the signal generator until a 400 Hz signal is seen on the oscilloscope.
6. Slowly adjust the signal generator frequency control to peak the signal appearing on the oscilloscope.
7. Increase the signal generator amplitude until a signal of 5 volts ptp appears on the oscilloscope.
8. Reset the front panel controls of the Model HR-8 as follows:
   FREQUENCY 4.0
   FREQ. RANGE .... x10^4
9. Set the signal generator to 40 Hz. Do not change amplitude.
10. The signal now appearing on the oscilloscope should be less than 5 mV ptp.
11. If necessary select a resistor (R322) for a signal less than 5 mV ptp.
12. Reset the front panel controls of the Model HR-8 as follows:
    FREQUENCY 4.0
    FREQ. RANGE .... x10^2
13. Return the signal generator to 400 Hz.
14. Slowly adjust the signal generator frequency control to provide a peak reading on the Model HR-8 panel meter.
15. Monitor TP 301 with the oscilloscope.
16. The signal appearing on the oscilloscope should be less than 10 mV ptp.
17. If necessary, alternately adjust the frequency control on signal generator and the NULL ADJ. POTENTIOMETER for a signal of less than 10 mV ptp on the oscilloscope.

18. Connect the oscilloscope to pin 4 of board #IN1393. A signal of approximately 5 volts ptp should be present at this point.
19. Check pins 2, 5 and 3 to ascertain that all voltages at these points are within ±3% of one another and pin 4.
20. Remove the reference tuned amplifier board from the extender and plug it into its connector.

AUXILIARY REFERENCE BOARD (#AU1394)

1. Plug in board #AU1394 into its connector.
2. Disconnect the signal generator from the REF IN/OUT connector.
3. Connect the oscilloscope to the REF IN/OUT connector.
4. Place the MODE switch in the INT position.
5. A signal of approximately 2.8 volts ptp should appear on the scope.
6. The front panel meter should read close to 1 volt (Note: FS = 2 volts RMS)
7. If necessary adjust the NULL potentiometer on board #1393 for a panel meter reading of 1 volt.
8. Remove the oscilloscope from the REF IN/OUT connector and connect it to the CALIBRATE OUT connector.
9. Put the CALIBRATE switch in the 100 mV position.
10. A 222 mV ptp square wave should be present on the scope.
11. Check the symmetry of this signal by triggering the scope on the leading edge of the signal.
12. Set the oscilloscope time base to 200 μs/cm
13. When the oscilloscope trigger is switched from + to — the duty cycle shall be 50% ±20 μs.
14. If necessary the duty cycle can be adjusted by selecting either R465 or R466 to bring the duty cycle within the above tolerance.
15. Remove the oscilloscope from the CALIBRATE connector.
16. Set the CALIBRATE switch to the 222 mV position.
17. Connect the DC voltmeter to the CALIBRATE connector.
18. Adjust the CAL ADJ. potentiometer on Board AU1394 until the DC voltage reads 222 mv ±0.1%.
19. Remove the DC voltmeter and set the front panel controls as follows:

REF MODE	AUTO
METER/MONITOR	REF
FREQUENCY	4.0
FREQ. RANGE	$\times 10^2$

20. Connect the signal generator set to 400 Hz and maximum output to the REF IN/OUT connector.
21. Connect a scope to TP 401 on the Auxiliary Reference Board #AU1394.
22. Adjust the frequency of the signal generator around 400 Hz to peak the reading on the Model HR-8 front panel meter.
23. A square type waveform of approximately 110 mV ptp should appear on the scope.
24. Adjust the SYMMETRY potentiometer (R420) until the square wave is symmetrical (duration of positive and negative half-cycles equal).
25. Lower the amplitude of the signal generator and note the input level at which the signal on the scope disappears.
26. This level of signal should be in the order of 0.2V ptp.

MIXER BOARD (#MI1397)

1. Using the 23 pin extender board plug the mixer board into its connector.
2. Connect the signal generator to the REF IN/OUT connector.
3. Set the front panel controls of the Model HR-8 as follows:

TIME CONSTANT	OFF
METER/MONITOR switch	OUT
ZERO OFFSET	0 (locked)
6/12 dB/OCT switch	6 dB/OCT
REF MODE	EXT

4. Adjust the amplitude of the signal generator to about 3 volts ptp at a frequency of 400 Hz.
5. Connect the oscilloscope to TP 701.
6. If necessary adjust the SYMMETRY potentiometer (R766) on board MI1397 for the best symmetry of the square wave appearing at TP 701.
7. Reduce the amplitude of the signal generator to approximately 0.1 volts.
8. Readjust the SYMMETRY potentiometer for a 50% duty cycle.
9. Remove the signal generator from the REF IN/OUT connector.
10. Set the front panel controls of the Model HR-8 as follows:

REF MODE:	INT
FREQUENCY:	4.0
FREQ RANGE:	$X10^2$

11. Remove the SIGNAL TUNED AMPLIFIER board from its connector.
12. Connect the oscilloscope to the MONITOR connector.
13. Short the bases of Q703 (coded with green dot.)
14. Adjust the AC BAL V potentiometer for a minimum square wave on the scope. Remove the short.
15. Adjust the AC BAL I potentiometer for a minimum square wave on the scope.
16. Short the bases of Q705 (coded with a yellow dot.)
17. Adjust the DC BAL potentiometer for zero on the front panel meter. Remove the short.
18. Adjust the DC ZERO potentiometer to ascertain that it provides a minimum of ±10% of full scale on the meter.
19. Adjust the DC ZERO potentiometer to zero on the panel meter.
20. Remove the board from the extender and plug it directly into its connector.
21. Place the time constant switch to 100 mS, 6 db/oct.
22. Plug in the Signal Tuned Amplifier Board.

INTERNAL OSCILLATOR FREQUENCY CHECK

1. Set the front panel controls as follows:

REF MODE:	INT
REF ATTEN:	1
REF VERNIER:	MAX CW

2. Connect a frequency counter to the REF IN/OUT connector.

3. Check the lowest and highest frequency on each setting of the frequency range switch. At each of these settings the indicated frequency should be accurate to within ±5%.

At this point the individual plug-in boards have been aligned and located in their proper connectors in the main frame of the Model HR-8. The remainder of the alignment consists of checking out and trimming the overall Model HR-8 system including the particular preamplifier as described on the following pages.

TYPE A PREAMPLIFIER

1. Plug in the Type A Preamplifier.
2. Set the Model HR-8 front panel controls as follows:

PREAMP MODE switch: ...... A
SENSITIVITY: .... 500 μV
FREQUENCY: 4
FREQ. RANGE: .... $x10^2$
SIG Q: 25
MODE switch: .... INT
REF ATTEN: .... OFF
REF VERNIER: .... MAX CCW
TIME CONSTANT: .... 100 mS. 6 db/oct
QUADRANT switch: ...... 0°
PHASE control: .... 0°
METER/MONITOR: .... SIG
ZERO OFFSET .... 0 and lock
CALIBRATE switch: .... 50 mV

3. Connect a cable from the CALIBRATE connector to the input A connector on the preamplifier.
4. Note the reading on the front panel meter.
5. Carefully adjust the FREQ TRIM for a maximum reading.
6. Adjust the GAIN ADJUST potentiometer on the front of the instrument for a full scale panel meter reading.
7. Adjust the front panel controls on the Model HR-8 as follows:

CALIBRATE switch: .... 500 μV
METER/MONITOR switch: .... OUT

8. The reading on the meter should be to the right and within ±2% of full scale. Adjust phase to maximize meter indication.
9. If necessary select a value of resistance for R796 (board MI1397) which will bring the meter within ±2% of full scale.

NOTE: Steps 2 thru 8 above must be done several times during the remainder of the procedure. The procedure referred to hereafter as "Model HR-8 Tune Up" shall consist of steps 2 thru 8.

10. Set the front panel controls as follows:

+/− switch: .... +
CALIBRATE switch: .... 5 mV

11. Unlock the ZERO OFFSET potentiometer on the front panel and adjust to read 10.
12. Adjust the PHASE control on the front panel. This adjustment must be done carefully since it is very sensitive.
13. When the front panel meter is peaked with the PHASE CONTROL it should read zero ±10% of meter scale.
14. Return the CALIBRATE switch to 500 μv and the ZERO OFFSET potentiometer to 0 and lock in position.
15. Adjust the PHASE control for a peak reading on the panel meter.
16. Feed the same signal into inputs A and B of the Type A Preamplifier.
17. Set the preamplifier mode switch to A-B. The meter reading should drop to 0.
18. Set the calibrate switch to 5 mV.
19. Adjust the preamplifier AC BAL potentiometer such that the meter reads 0.
20. Adjust the front panel controls as follows:

CALIBRATE: .... 50 mV
METER/MONITOR: .... SIG
SENSITIVITY: .... 500 μV

21. Adjust the FREQ. TRIM potentiometer for a peak reading on the front panel meter.
22. The following table shows the various SENSITIVITY switch and CALIBRATION switch positions. At each set of positions the panel meter should read ±2% of full scale. If necessary, the indicated resistor can be changed to provide the required ±2% of full scale reading. These adjustments if required should be made in the order shown in the table. Check to ascertain that the output is peaked with the FREQ. TRIM control. The GAIN ADJ potentiometer should be adjusted only on the 500 μV SENSITIVITY setting.

SENSITIVITY Position	CALIBRATE Position	ADJUSTMENT Resistor	LOCATION OF ADJ. RESISTOR
200 μV	20 mV	R605	Sensitivity Switch
100 μV	10 mV	R606	Sensitivity Switch
50 μV	5 mV	Determined by Pre Amp	
20 μV	2 mV	NO ADJUSTMENT	
10 μV	1 mV	NO ADJUSTMENT	
5 μV	500 μV	R131	Board IN1395
2 μV	200 μV	NO ADJUSTMENT	
1 μV	100 μV	NO ADJUSTMENT	
500 nV	50 μV	R142	Board IN1395
200 nV	20 μV	NO ADJUSTMENT	
100 nV	10 μV	NO ADJUSTMENT	

23. To check the calibration of the 500 μV to 500 mV ranges, adjust the front panel controls as follows:

    SENSITIVITY: .... 500 μV
    CALIBRATE: .... 50 mV
    METER/MONITOR: .... SIG

24. The front panel meter should again read full scale ±2%.

25. Change the front panel controls as follows:

    CALIBRATE: .... 500 μV
    METER/MONITOR: .... OUT

26. Adjust the PHASE control for a peak panel meter reading to the right. This adjustment should be made carefully since it is difficult to detect this peak.

27. If the peak does not occur within ±2% of full scale repeat "Model HR-8 Tune Up" referred to previously.

28. If the peak occurs within the specified ±2% of full scale but not exactly on full scale, adjust the GAIN ADJ. potentiometer for exactly full scale.

29. Step the CALIBRATE and SENSITIVITY switches through all positions from 1 mV to 100 mV.

30. The panel meter should be within ±2% of full scale for all the above sensitivities.

31. This calibration should also be performed using the B input of the preamplifier.

32. Refer to Page 5-8 for power supply ripple, regulation, and noise checks for Model HR-8 with Type A Preamplifier.

TYPE B AND B-1 PREAMPLIFIERS

1. Plug in the Type B or B-1 Preamplifier.

2. Set the Model HR-8 front panel controls as follows:

    SENSITIVITY: .... 500 μV
    FREQUENCY: 4
    FREQ. RANGE: ....(Type B x10²)
    ....(Type B-1 x10⁴)
    SIG. Q: 25
    MODE: .... INT
    TIME CONSTANT: 100mS
    QUADRANT: .... 0°
    PHASE Control: .... 0°
    METER/MONITOR: .... SIG
    ZERO OFFSET: .... 0 and lock
    CALIBRATE: 50mV

3. Connect the 100:1 attenuator cable supplied with the Type B or Type B-1 Preamplifiers from the CALIBRATE connector to the input connector on the Preamplifier.

NOTE: THE CABLES SUPPLIED WITH TYPE B AND B-1 PREAMPLIFIERS ARE NOT INTERCHANGEABLE SINCE THE SOURCE IMPEDANCES OF THE TWO CABLES ARE DIFFERENT. THE TYPE B CABLE HAS A SOURCE IMPEDANCE OF 10 OHMS, WHILE THE TYPE B-1 CABLE PROVIDES A 2 OHM SOURCE IMPEDANCE. MAKE CERTAIN THAT THE PROPER CABLE IS USED.

4. Carefully adjust the FREQ TRIM control for a maximum reading on the meter.

5. Adjust the GAIN ADJ. potentiometer on the front of the instrument for a full scale panel meter reading.

6. Adjust the front panel controls on the Model HR-8 as follows:

    CALIBRATE: .... 500 μV
    METER/MONITOR: .... OUT

7. Remove the input cable from the CALIBRATE connector only and adjust the ZERO OFFSET, if necessary, such that the meter reads zero. (Type B-1 only).

8. Replace the input cable. (Type B-1 only).

9. The reading on the meter should be to the right and within ±2% of full scale after adjusting the PHASE control for a peak.

    NOTE: STEPS 2 THROUGH 9 MUST BE DONE SEVERAL TIMES DURING THE REMAINDER OF THE PROCEDURE AND HEREAFTER SHALL BE REFERRED TO AS "MODEL HR-8 TUNE-UP".

10. If necessary, select a value of resistance for R796 (BOARD MI1397) which will bring the meter reading within ±2% of full scale.

11. Adjust GAIN ADJ. potentiometer such that the meter reads exactly full scale.

12. Set the front panel controls as follows:

    +/− .... +
    CALIBRATE: 5mV

13. Unlock the ZERO OFFSET potentiometer on the front panel and adjust to read 10.

14. Adjust the PHASE control on the front panel for a peak. This adjustment must be done carefully, since it is very sensitive.

15. When the front panel meter is peaked with the PHASE control, it should read zero ±10% of meter scale.

16. Return the CALIBRATE switch to 500 μV and the ZERO OFFSET potentiometer to zero and lock in position.

17. Set the front panel controls as follows:

METER/MONITOR: .... SIG
CALIBRATE: 50mV
SENSITIVITY: 500μV

8. Adjust the FREQ. TRIM control for a peak reading on the front panel meter, and, if necessary, adjust the GAIN ADJ. potentiometer so that the meter reads exactly full scale.

19. The following table shows the various SENSITIVITY and CALIBRATE switch position. At each set of positions the panel meter should read within ±2% of full scale. If necessary, the indicated resistor can be changed to provide the required reading. These adjustments, if required, should be made in the order shown in the table.

20. The check the calibration of the 500 μV to 500 mV ranges, adjust the front panel controls as follows:

SENSITIVITY: .... 500 μV
CALIBRATE: 50mV
METER/MONITOR: .... SIG

21. The front panel meter should again read full scale.

22. Change the front panel controls as follows:

CALIBRATE: 500μV
METER/MONITOR: .... OUT

NOTE: TYPE B-1 ONLY: REPEAT STEPS 7 & 8.

23. Adjust the PHASE control for a peak panel meter reading to the right. This adjustment should be made carefully, since it is difficult to detect this peak.

4. If the peak does not occur within ±2% of full scale, Repeat "MODEL HR-8 TUNE-UP" referred to previously.

25. If the peak occurs within the specified ±2% of full scale, but not exactly on full scale, adjust the GAIN ADJ. potentiometer for exactly full scale.

26. Step the CALIBRATE and SENSITIVITY switches through all positions from 1mV to 100mV. Also, check for proper meter indication on the 200mV and 500mV SENSITIVITY settings with the 100mV calibrator signal as the input.

27. The panel meter reading should be within ±2% of full scale for all the above sensitivities, if not, the preamplifier is defective.

28. Refer to Page 5-8 for power supply ripple, regulation, and noise checks for Model HR-8 with Type B or B-1 Preamplifier.

TYPE C PREAMPLIFIER

1. Plug in the Type C Preamplifier.

2. Set the Model HR-8 front panel controls as follows:

PREAMPLIFIER MODE Switch: ..... A
SENSITIVITY: 500μV
FREQUENCY: 4
FREQ RANGE: .... x10^2
SIG Q: 25
MODE Switch: .... INT
REF ATTEN: .... OFF
REF VERNIER: .... MAX CCW
TIME CONSTANT: 100mS
QUADRANT Switch: .... 0°
PHASE Control: .... 0°
METER/MONITOR: .... SIG
ZERO OFFSET: .... 0 and lock
CALIBRATE Switch: 5mV

3. Connect a cable from the CALIBRATE connector to the A input connector on the Preamplifier.

4. Carefully adjust the FREQ TRIM control for a maximum panel meter reading.

5. Adjust the GAIN ADJ. potentiometer on the front of the instrument for a meter reading of exactly full scale.

6. Adjust the front panel controls as follows:

CALIBRATE: 50μV
METER/MONITOR: .... OUT

7. The reading on the meter should be to the right and within ±2% of full scale after adjustment of the PHASE control for maximum up scale meter indication.

8. If necessary, select a value of resistance for R796 (BOARD MI1397) which will bring the meter within 2% of full scale.

NOTE: STEPS 2 THROUGH 7 MUST BE DONE SEVERAL TIMES DURING THE REMAINDER OF THE PROCEDURE AND HEREAFTER SHALL BE REFERRED TO AS "MODEL HR-8 TUNE-UP".

SENSITIVITY POSITION	CALIBRATE POSITION	ADJUSTMENT RESISTOR	ADJUSTMENT LOCATION
200μV	20mV	R-605	Sensitivity Switch
100μV	10mV	R-606	Sensitivity Switch
50μV	5mV	Determined by Preamp.	
20μV	2mV	No Adjustment	
10μV	1mV	No Adjustment	
5μV	500μV	R-131	BOARD IN1395
2μV	200μV	No Adjustment	
1μV	100μV	No Adjustment	
500nV	50μV	R-142	BOARD IN1395
200nV	20μV	No Adjustment	
100nV	10μV	No Adjustment	

9. Adjust GAIN ADJ. potentiometer for a meter indication of exactly full scale, and set the front panel controls as follows:

+/— Switch: .... +
CALIBRATE: 500μV

10. Unlock the ZERO OFFSET potentiometer on the front panel and adjust to read 10.

11. Adjust the PHASE control on the front panel. This adjustment must be done carefully, since it is very sensitive.

12. When the front panel meter is peaked with the PHASE control, it should be read zero ±10% of meter scale.

13. Return the CALIBRATE switch to 50μV and the ZERO OFFSET switch to 0 and lock in position.

14. Adjust the PHASE control to ascertain that the panel meter is peaked.

15. Feed the same signal into inputs A and B of the Preamplifier.

16. Set the Preamplifier mode switch to A-B. The meter reading should drop to zero.

17. Set the CALIBRATE switch to 500μV.

18. Adjust the AC BAL potentiometer such that the meter reads zero.

19. Adjust the front panel controls as follows:

CALIBRATE: 500μV
METER/MONITOR: .... SIG
SENSITIVITY: 50μV

20. Adjust the FREQ TRIM potentiometer for a peak reading on the front panel meter, and adjust the GAIN ADJ. potentiometer such that the meter reads exactly full scale.

SENSITIVITY POSITION	CALIBRATE POSITION	ADJUSTMENT RESISTOR	LOCATION OF ADJ. RESISTOR
500μV	5mV	Determined by Preamp.	
200μV	2mV	R-605	Sensitivity Switch
100μV	1mV	R-606	Sensitivity Switch
50μV	500μV	Gain Adj. Pot.	
20μV	200μV	No Adjustment	
10μV	100μV	No Adjustment	
5μV	50μV	R-131	BOARD IN1395
2μV	20μV	No Adjustment	
1μV	10μV	No Adjustment	
500nV	5μV	R-142	BOARD IN1395
200nV	2μV	No Adjustment	
100nV	1μV	No Adjustment	

21. The above table shows the various SENSITIVITY switch and CALIBRATE switch positions. At each set of positions the panel meter should read within ±2% of full scale. If necessary, the indicated resistor can be changed to provide the required reading.

These adjustments, if required, should be made in the order shown in the table. Check to ascertain that the output is peaked with the FREQ. TRIM control. The GAIN ADJ. potentiometer should be adjusted only on the 50μV SENSITIVITY setting.

22. To check the calibration of the 500μV to 500mV ranges, adjust the front panel controls as follows:

SENSITIVITY: 500μV
CALIBRATE: 5mV
METER/MONITOR: .... SIG

23. The front panel meter should again read full scale within ±2%.

24. Change the front panel settings as follows:

CALIBRATE: 50μV
METER/MONITOR: .... OUT

25. Adjust the PHASE control for a peak reading to the right. This adjustment should be made carefully, since it is difficult to detect this peak.

26. If the peak does not occur with ±2% of full scale, repeat "MODEL HR-8 TUNE-UP" referred to earlier.

27. If the peak occurs within the specified ±2% of full scale, but not exactly on full scale, adjust the GAIN ADJ. potentiometer for exactly full scale.

28. Simultaneously sequence the SENSITIVITY and CALIBRATE switches through all positions from 1mV to 500mV and 100μV to 50mV respectively.

29. The meter should be within ±2% of full scale for all the above sensitivities.

NOTE: IF THE METER READING IS NOT WITHIN THIS TOLERANCE, THE PREAMPLIFIER IS DEFECTIVE.

30. The calibration should also be performed using the B input of the Preamplifier.

31. Refer to Page 5-8 for power supply ripple, regulation, and noise checks for Model HR-8 with Type C Preamplifier.

POWER SUPPLY RIPPLE AND LINE REGULATION TEST

1. Plug the Model HR-8 into the Variac.
2. Monitor the four test points on each Power Supply board and ascertain that the DC voltage does not vary by more than 100 millivolts when the line voltage is changed from 105 volts to 125 volts.
3. With the oscilloscope, check the four test points to ascertain that the ripple is less than 2 mV ptp.

NOISE CHECK

1. Set the front panel controls as follows:

	Preamplifier			
	A	B*	B-1*	C
REF MODE	500 μV	500 μV	500 μV	500 μV
SENSITIVITY	INT	INT	INT	INT
SIG Q	10	10	10	10
TIME CONSTANT	100 mSec	100 mSec	100 mSec	100 mSec
6db/12db OCTAVE	6db/octave	6db/octave	6db/octave	6db/octave
METER/MONITOR	OUT	OUT	OUT	OUT
FREQUENCY	4	4	4	4
FREQ RANGE	x10^2	x10^2	x10^4	x10^2
CALIBRATE	500 μV	500 μV	500 μV	50 μV

*Use 100:1 Attenuator Cable

2. Adjust FREQ TRIM and PHASE for peak meter reading.
3. Adjust GAIN ADJ potentiometer, if necessary, for full scale reading.
4. Remove the input signal and short inputs to ground.
5. Adjust front panel controls as follows:

	Preamplifier			
	A	B	B-1	C
SENSITIVITY	100 nV	100 nV	100 nV	100 nV
PREAMP MODE	A	-	-	A
TIME CONSTANT	1 Sec.	1 Sec.	1 Sec.	1 Sec.

6. Peak-to-peak meter fluctuations about zero over a 10-second period should be as follows:

Preamplifier			
TYPE A	TYPE B	TYPE B-1	TYPE C
(F.S.=100 nV)	(F.S.=1 nV)	(F.S.=1 nV)	(F.S.=10 nV)
15 nV	0.5 nV	0.15 nV	4 nV

7. For Type A & C Preamplifiers set the PREAMPLIFIER MODE SWITCH to —B and repeat the measurement described in Step. 6.
8. Set the front panel controls as follows:

	Preamplifier			
	A	B	B-1	C
SENSITIVITY	1 μV	1 μV	100 nV	1 μV
PREAMP MODE	A	-	-	A

9. Open the inputs to the preamplifier.
10. Peak-to-peak fluctuations over a 10-second period should be as follows:

Preamplifier			
TYPE A	TYPE B	TYPE B-1	TYPE C
(F.S.=1 μV	(F.S.=10 nV)	(F.S.=1 nV)	(F.S.=100 nV)
800 nV	4 nV	0.1 nV	40 nV

11. For Type A and C Preamplifiers set the PREAMPLIFIER MODE SWITCH to —B and repeat the measurement described in Step 6.

SECTION VI

WARRANTY

Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty are limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned prepaid to our factory for that purpose within ONE YEAR of delivery to the original purchaser. Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Princeton Applied Research 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.

Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This Warranty is in lieu of, and excludes all other warranties or representations, expressed, implied or statutory, and all other obligations or liabilities of Princeton Applied Research Corporation including special or consequential damages, and no other source is authorized to assume for Princeton Applied Research Corporation any other liability.

HR-8 INSTRUCTION MANUAL SUPPLEMENT

I. GENERAL:

With the exception of those cases specified below under II-1 (a), II-2 (a), and II-3 (a), transistor type 2N3711 is to be considered interchangeable with transistor type 2N3391A, although the latter type is indicated on the schematics.

II. SPECIFIC:

1. Signal Tuned Amplifier Board Schematic (1390-C-SD)

   (a) Transistors Q202, and Q203, indicated as being transistor type 2N3391A, are type 2N3904.

   (b) Transistors Q201, Q204, Q206, Q207, Q210, Q211, Q213, Q215, and Q219, indicated as being transistor type 2N3702, are instead type 2N4062.

   (c) R229, indicated as being 470 ohms, is instead 100 ohms.

   (d) An RC network, consisting of a 100 ohm resistor in series with a 220 pf capacitor, has been connected from the collector of Q212 to ground.

   (e) An RC network, consisting of a 100 ohm resistor in series with a 220 pf capacitor, has been connected from the collector of Q219 to ground.

2. Auxiliary Reference Board Schematic (1385-C-SD)

   (a) Transistors Q402, Q403, Q414, and Q416, indicated as being transistor type 2N3391A, are instead type 2N3904.

   (b) Capacitor C413, 0.1 microfarads, has been deleted.

   (c) Capacitor C414, 200 microfarads, has been deleted.

3. Mixer Board Schematic (1388-D-SD)

   (a) Transistors Q719, Q724, and Q725, indicated as being transistor type 2N3391A, are instead type 2N3904.

4. Reference Tuned Amplifier Board Schematic (1384-C-SD)

   (a) Transistors Q302, Q303, Q306, Q308, Q310, and Q313, indicated as being transistor type 2N3702, are instead type 2N4062.

   (b) R370, 330 ohms, has been deleted.

   (c) C311, 22 pf, has been deleted.

   (d) An RC network, consisting of a 100 ohm resistor in series with a 220 pf capacitor, has been connected from the collector of Q307 to ground.

(e) An RC network, consisting of a 100 ohm resistor in series with a 220 pf capacitor, has been connected from the collector of Q313 to ground.

5. Chassis Wiring Schematic (1391-D-SD)

(a) C612, indicated as being 22 pf, is instead 12 pf.

(b) C614, indicated as being 22 pf, is instead 12 pf.

(c) A 470 ohm resistor has been inserted in series with the wiper of the phase pot.

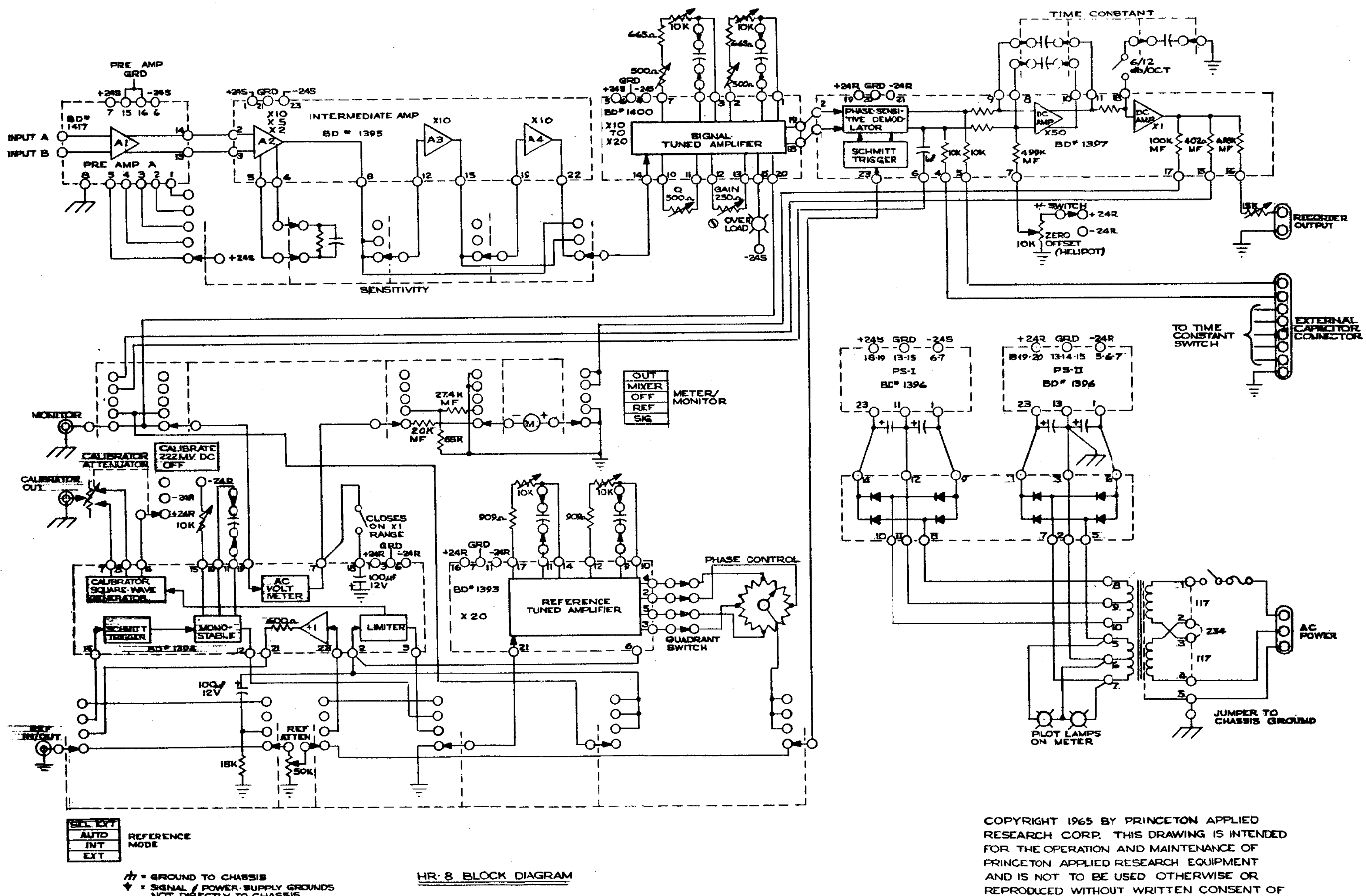
6. Power Supply Board Schematic (1387-C-SD)

(a) Fuses F501 and F502, indicated as being 3AG 4/10 A, slo-blo fuses, are instead 3AG 3/8 A, fast-blo fuses.

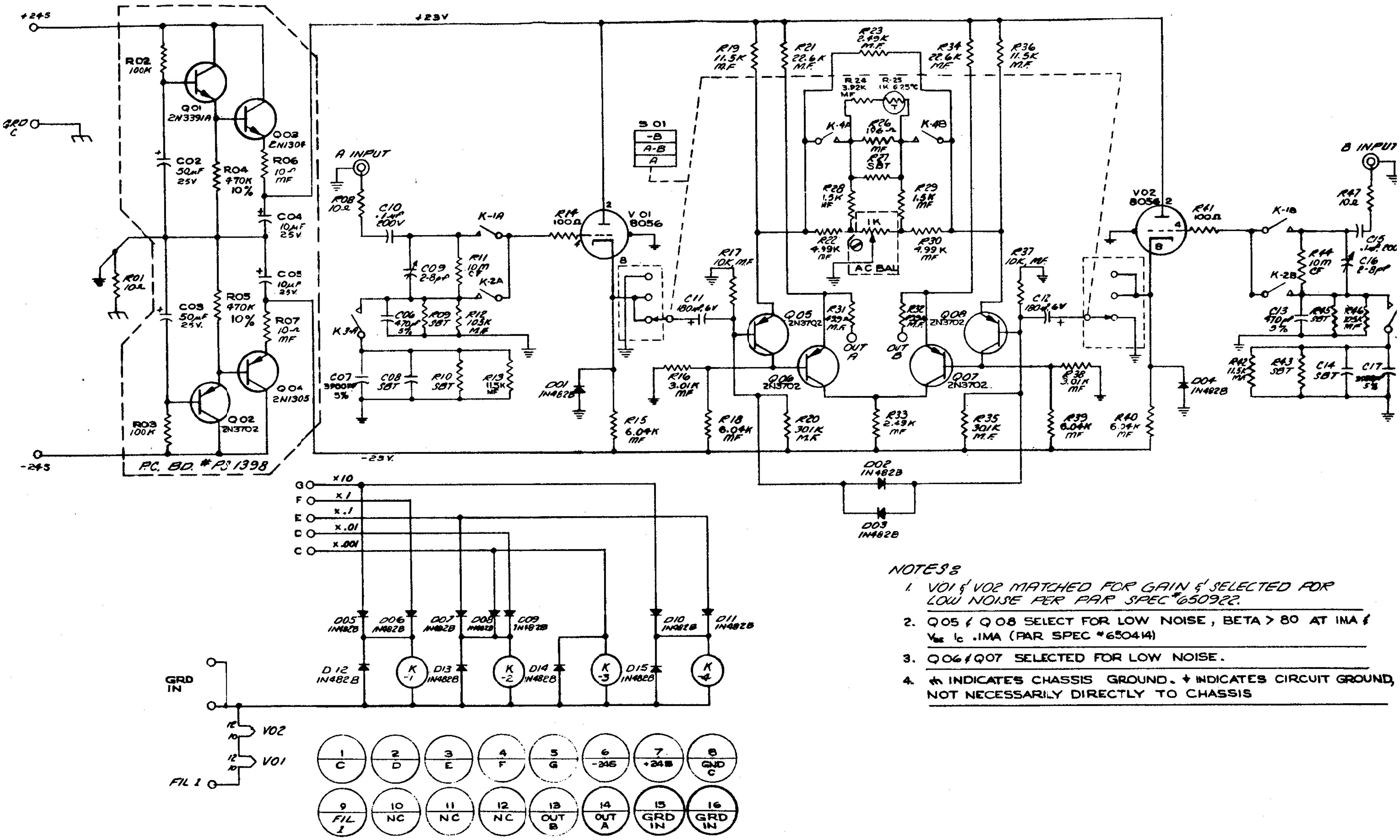
7. Page 2-1, right column, lines two and three, should read "Two fast-blo 3AG fuses rated at 3/8 A ---"

8. Type A Preamplifier Schematic (1389-C-SD)

(a) Transistor Q02, indicated as being transistor type 2N3702, is instead type 2N4062.



HR-8 BLOCK DIAGRAM

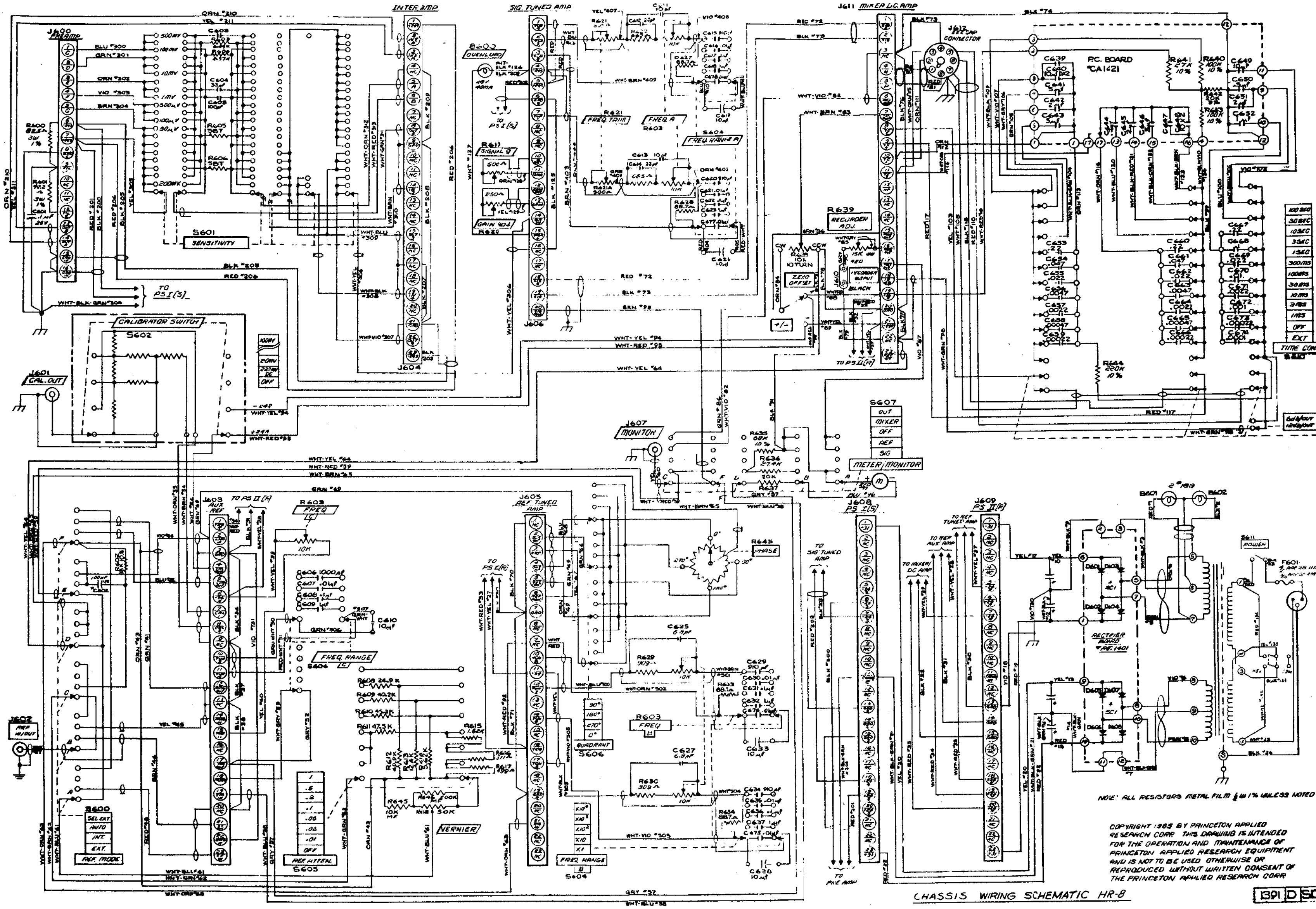


NOTES:

1. V01 & V02 MATCHED FOR GAIN & SELECTED FOR LOW NOISE PER PAR SPEC #650922.
2. Q05 & Q08 SELECT FOR LOW NOISE, BETA > 80 AT 1MA & V_{CE} I_c .1MA (PAR SPEC #650414)
3. Q06 & Q07 SELECTED FOR LOW NOISE.
4. ⏚ INDICATES CHASSIS GROUND. ⏚ INDICATES CIRCUIT GROUND, NOT NECESSARILY DIRECTLY TO CHASSIS

CIRCUIT BOARDS #PS 1398 & #PK 1399 — TYPE A PREAMPLIFIER — MODEL HR-8

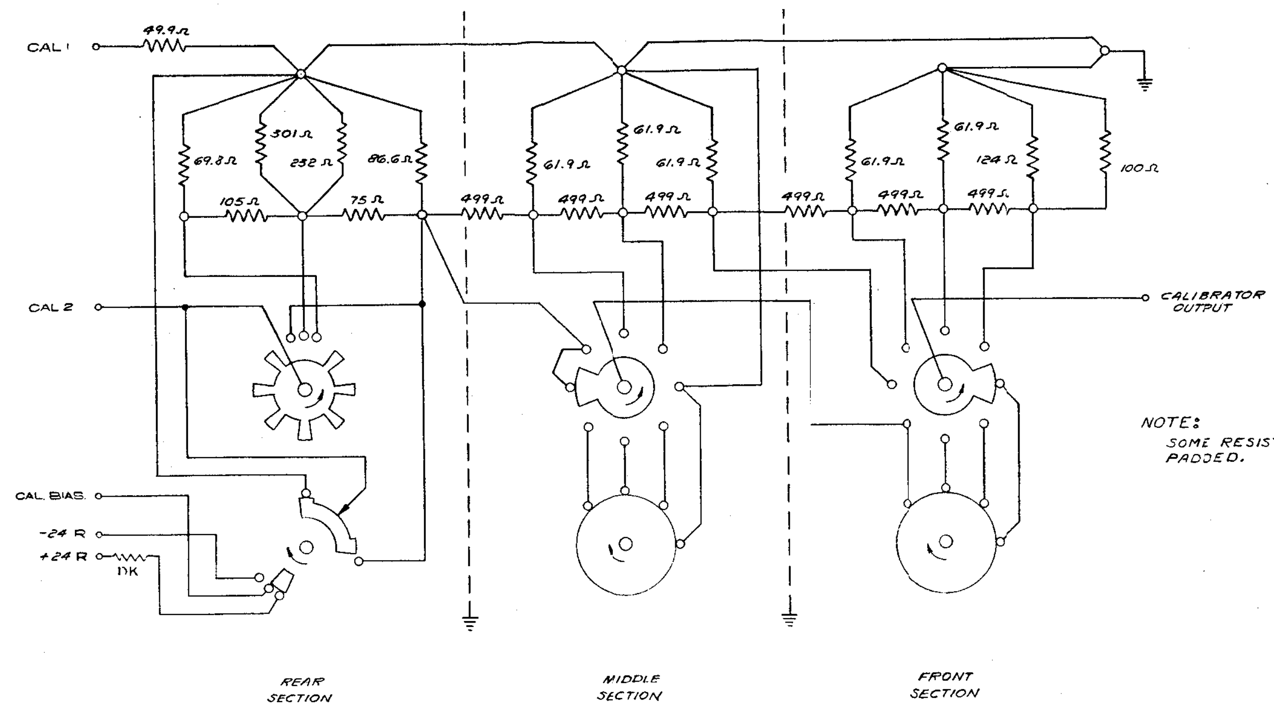
1389 | C | SD



NOTE: ALL RESISTORS METAL FILM ¼W 1% UNLESS NOTED

CHASSIS WIRING SCHEMATIC HR-8

1391 D SD

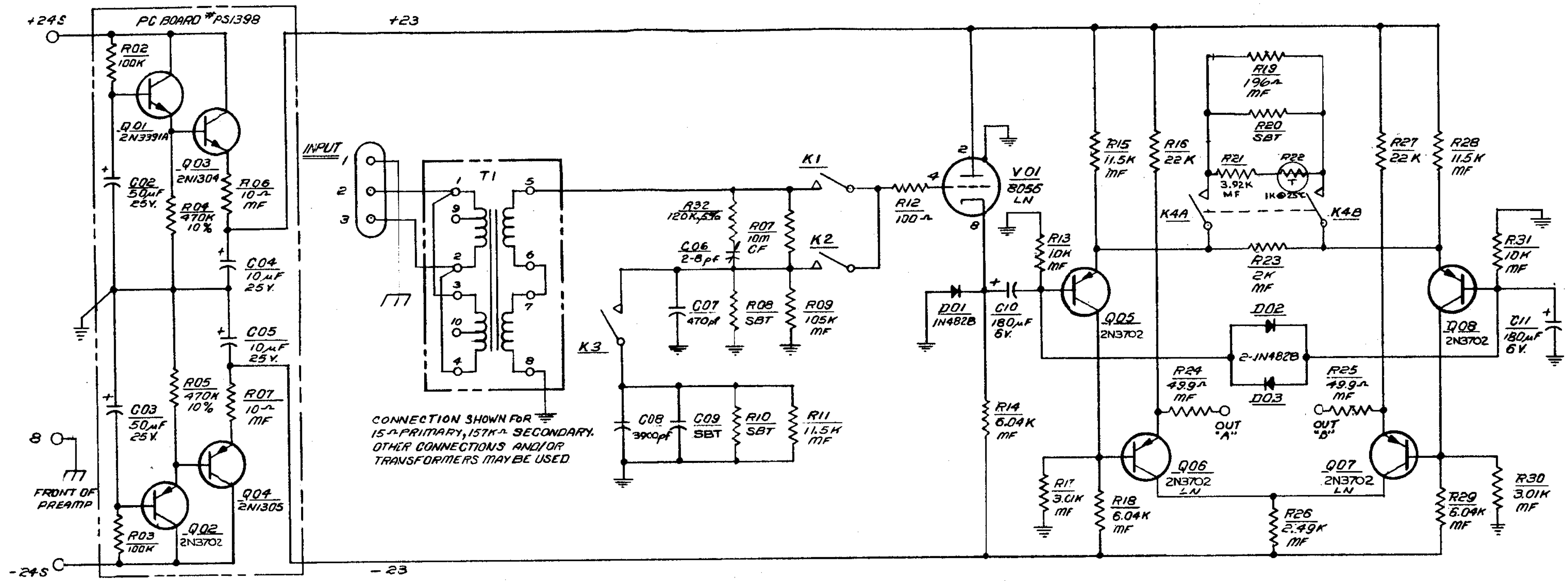


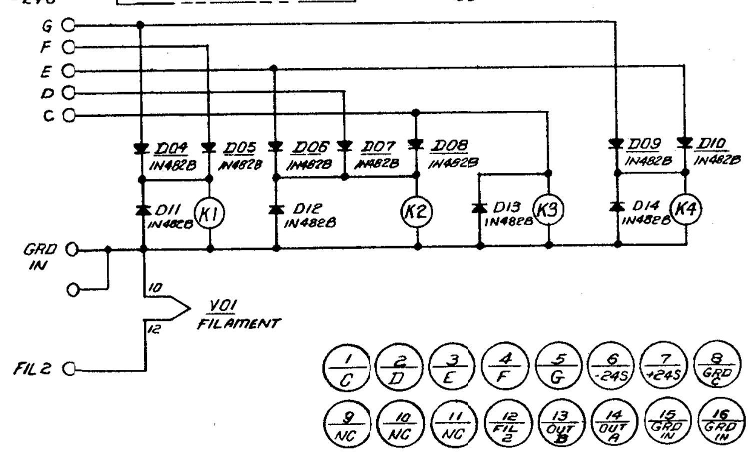
NOTE: SOME RESISTORS MAY BE PADDED.

CALIBRATOR ATTENUATOR SWITCH

MODEL—HR-8

1383	C	SD	B





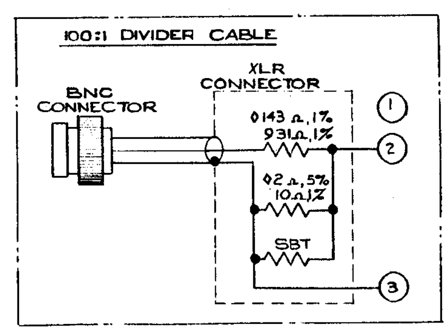
PIN CONNECTIONS

CIRCUIT BOARD #PS1398 & PR1574 TYPE B & B1 PREAMPLIFIER MODEL HR8

NOTES:

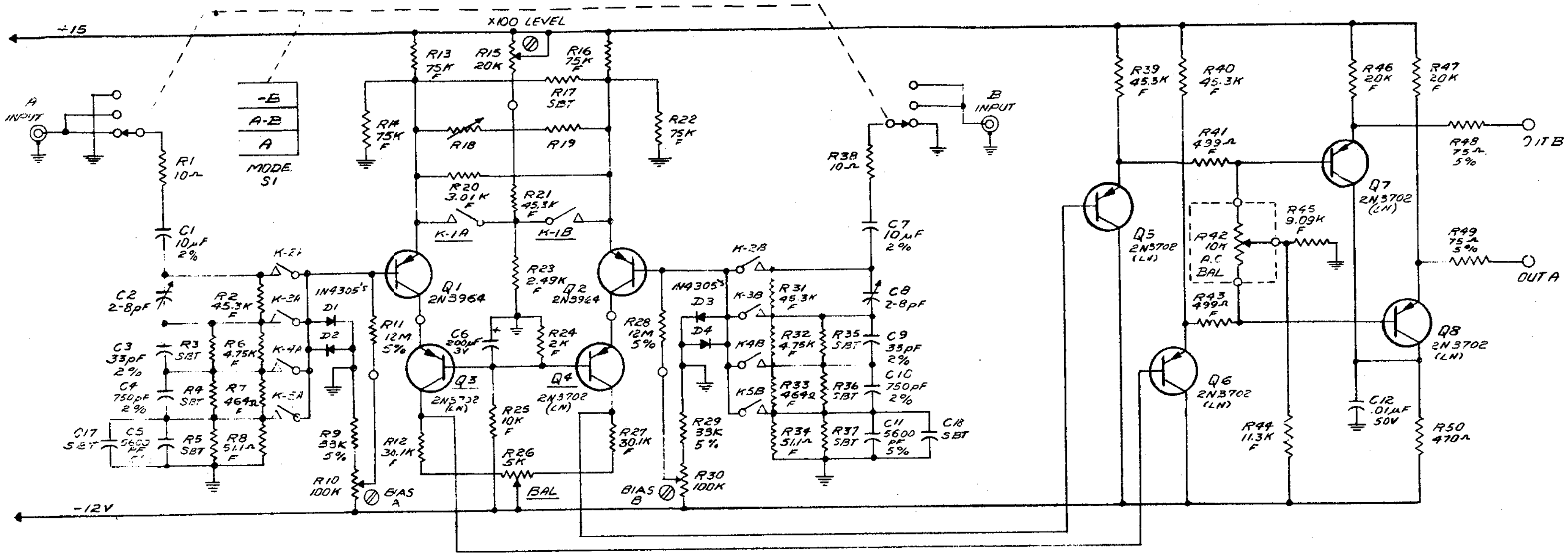
1. Q05 AND Q08 MATCHED FOR LOW NOISE, BETA > 80 @ Ic 1MA & Vbe Ic = .1MA (SPEC 650414).
2. ⏊ INDICATES CHASSIS GROUND. ⏚ INDICATES CIRCUIT GROUND, NOT NECESSARILY DIRECTLY TO CHASSIS.
3. V01 SELECTED FOR LOW NOISE PER PAR SPEC. #650923.
4. ◊ COMPONENT VALUES TO BE USED IN MODEL TB1-P ONLY.

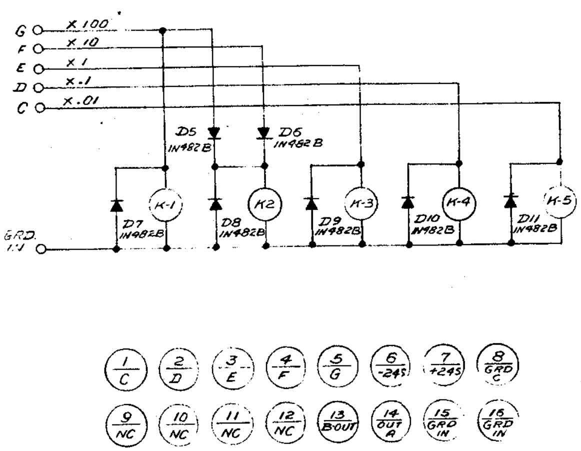
100:1 DIVIDER CABLE



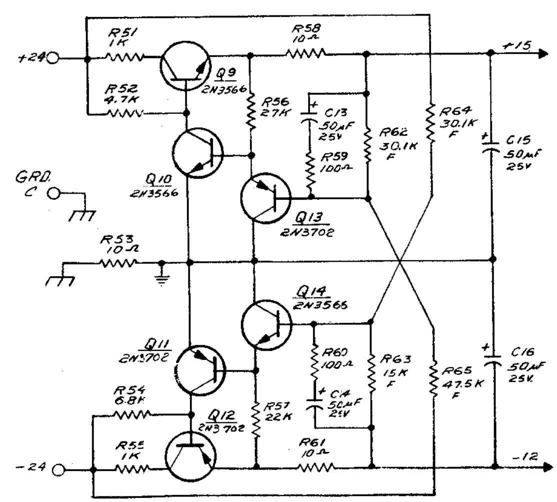
T1	
MODEL	TRANSFORMER
B	TRIAD G4
B1	PAR #650525A

1577 C SD R





PIN CONNECTIONS



NOTES:

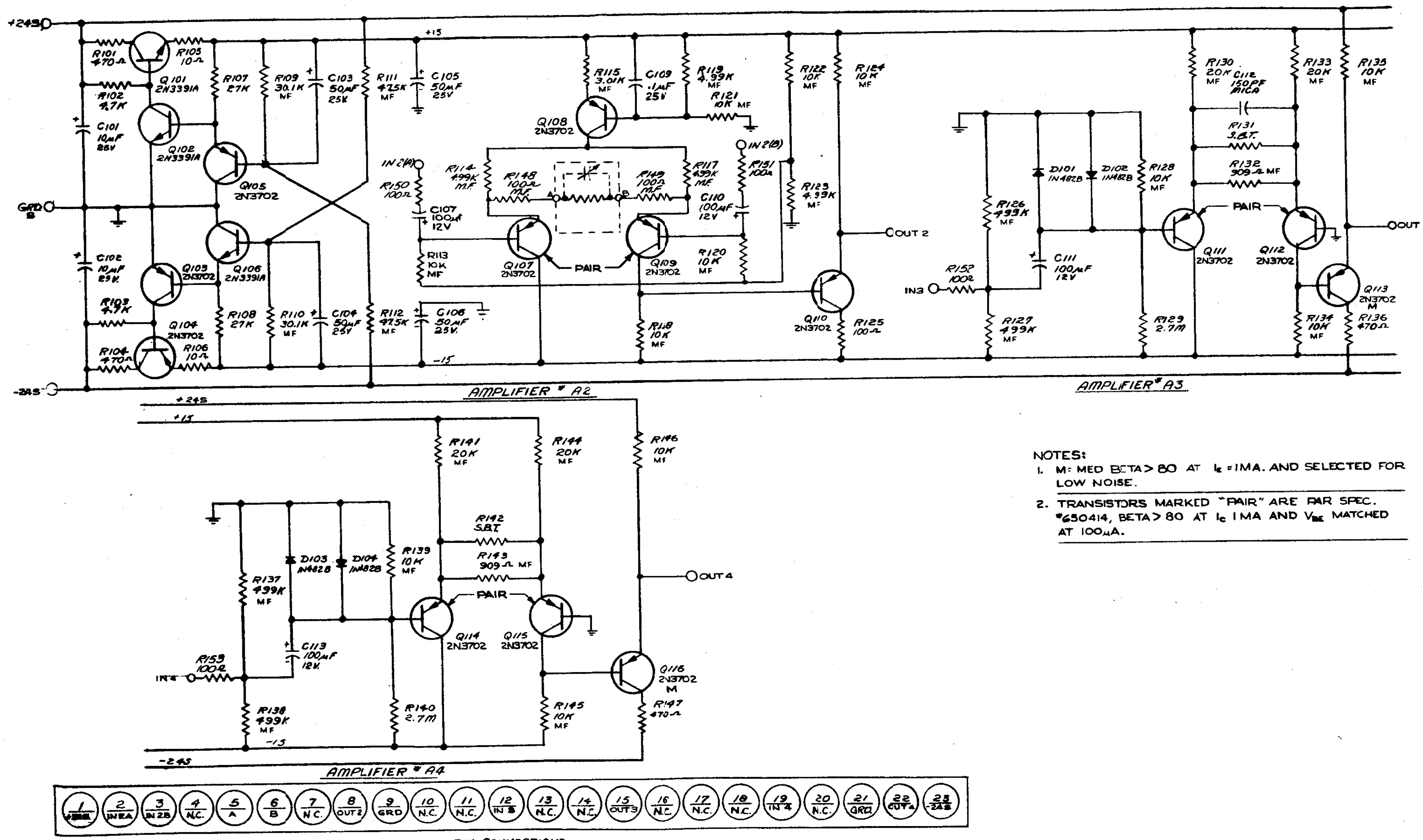
(1) Q1 & Q2 MATCHED FOR Beta, V_{BE} < 2mV & LOW NOISE, [PAR SPEC #660225]

(2) Q3 & Q4 MATCHED FOR Beta >80 @ 100μA LOW NOISE, [PAR SPEC #660204]

(3) Q5 THRU Q8 CHECKED FOR BETA >80 @ 1MA AND LOW NOISE.

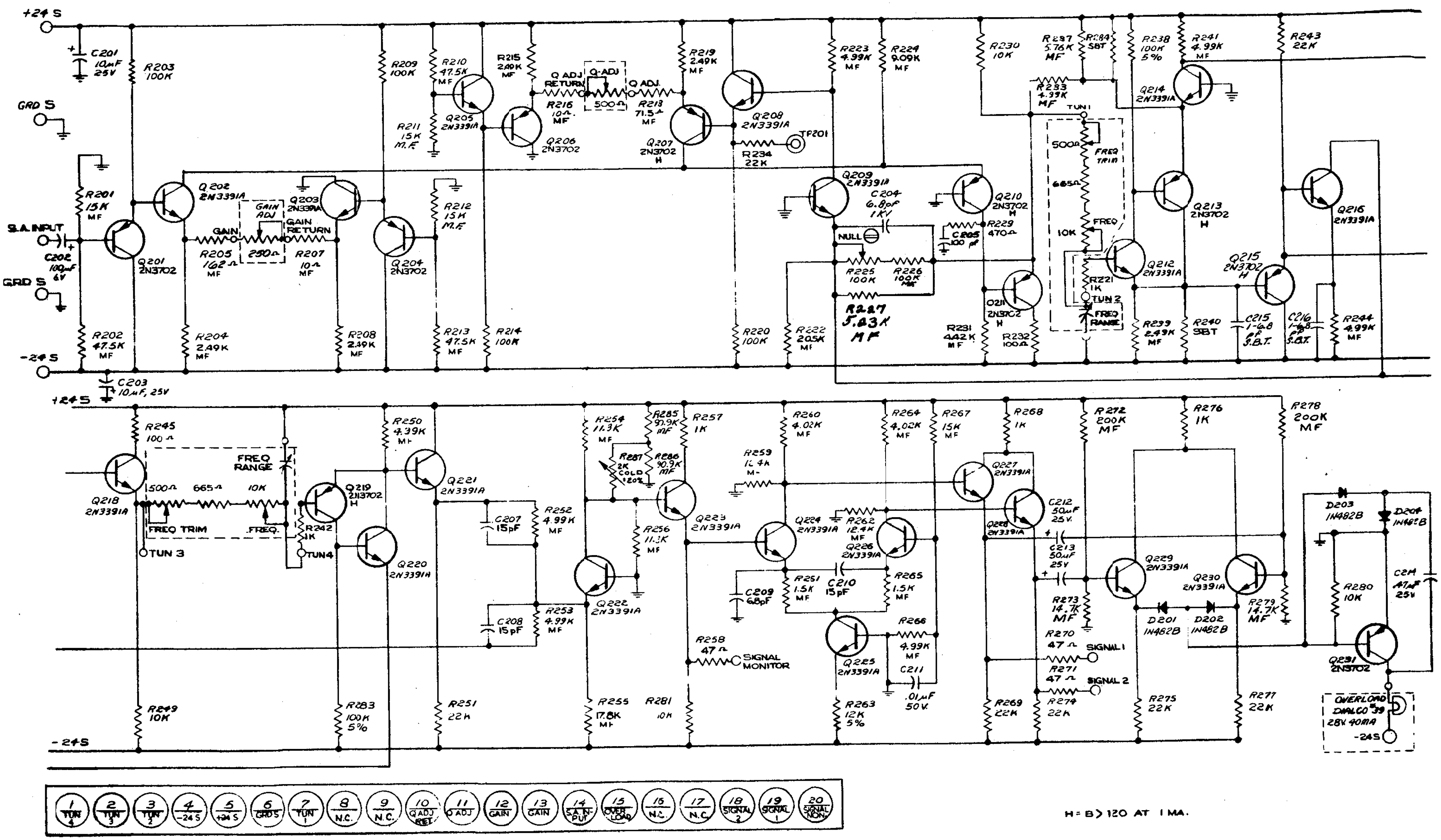
CIRCUIT BOARDS #PR 1965 #PS 1966 — TYPE C PREAMPLIFIER — MODEL MR-8

| 1975 | C | 50 | B |



NOTES:
1. M: MED BETA > 80 AT I_c = 1MA. AND SELECTED FOR LOW NOISE.
2. TRANSISTORS MARKED "PAIR" ARE PAR SPEC. #650414, BETA > 80 AT I_c 1 MA AND V_{BE} MATCHED AT 100 μA.

CIRCUIT BOARD # IN 1395 INTERMEDIATE AMPLIFIERS MODEL HR-8

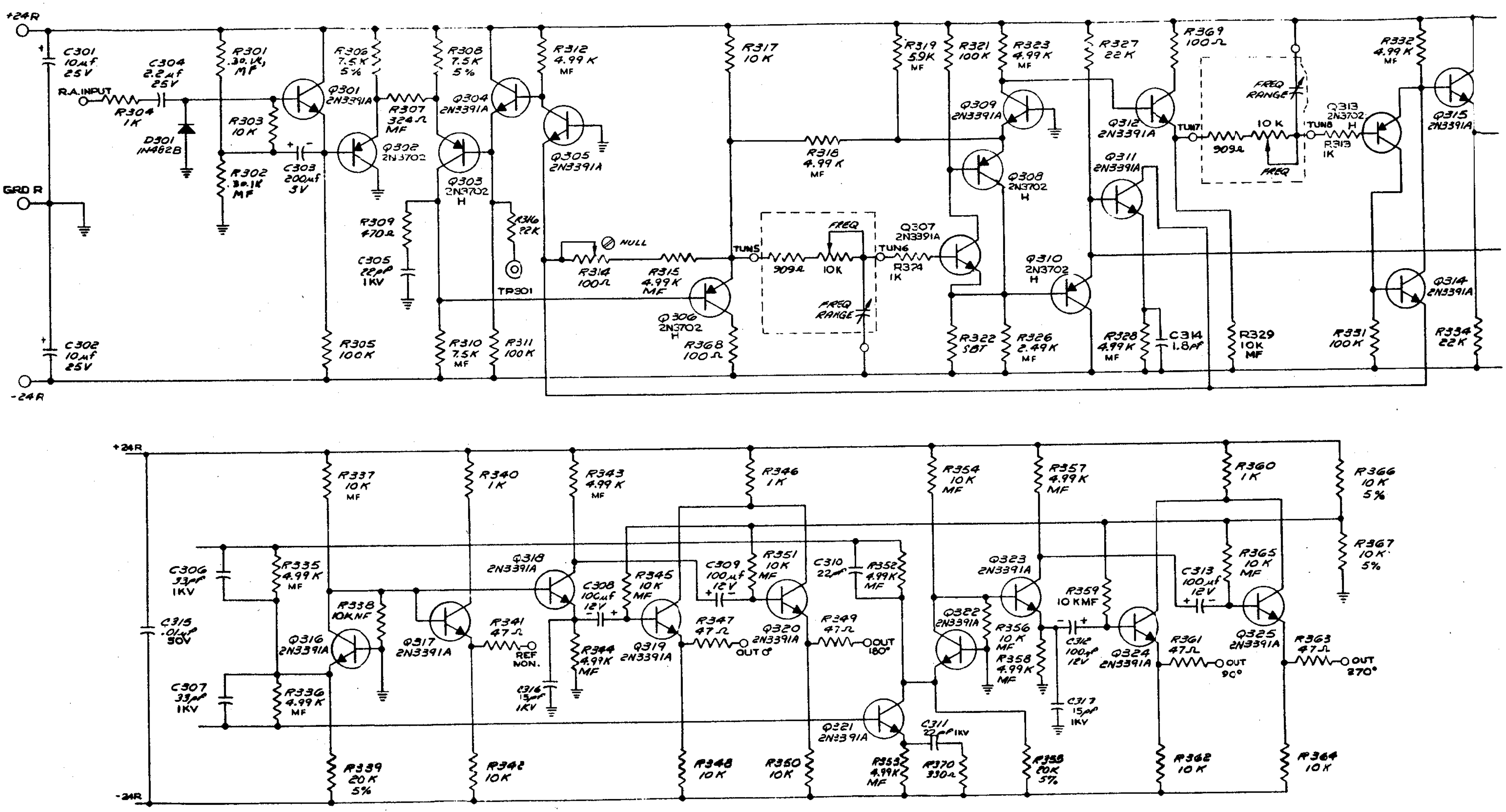


PIN CONNECTIONS

H = B > 120 AT 1 MA.

CIRCUIT BOARD # SI 1400 SIGNAL TUNED AMPLIFIER MODEL HR-8

1990 | C | SD | 1 N



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
N.C.	OUT 90°	OUT 270°	OUT 0°	OUT 180°	REF MON.	GRD R	N.C.	N.C.	TUN 4	-24R	TUN 7	N.C.	TUN 6	N.C.	+24R	TUN 5	N.C.	GRD R	N.C.	RA IN-PUT	N.C.	N.C.

CONNECTOR PIN CONNECTIOINS

NOTES:

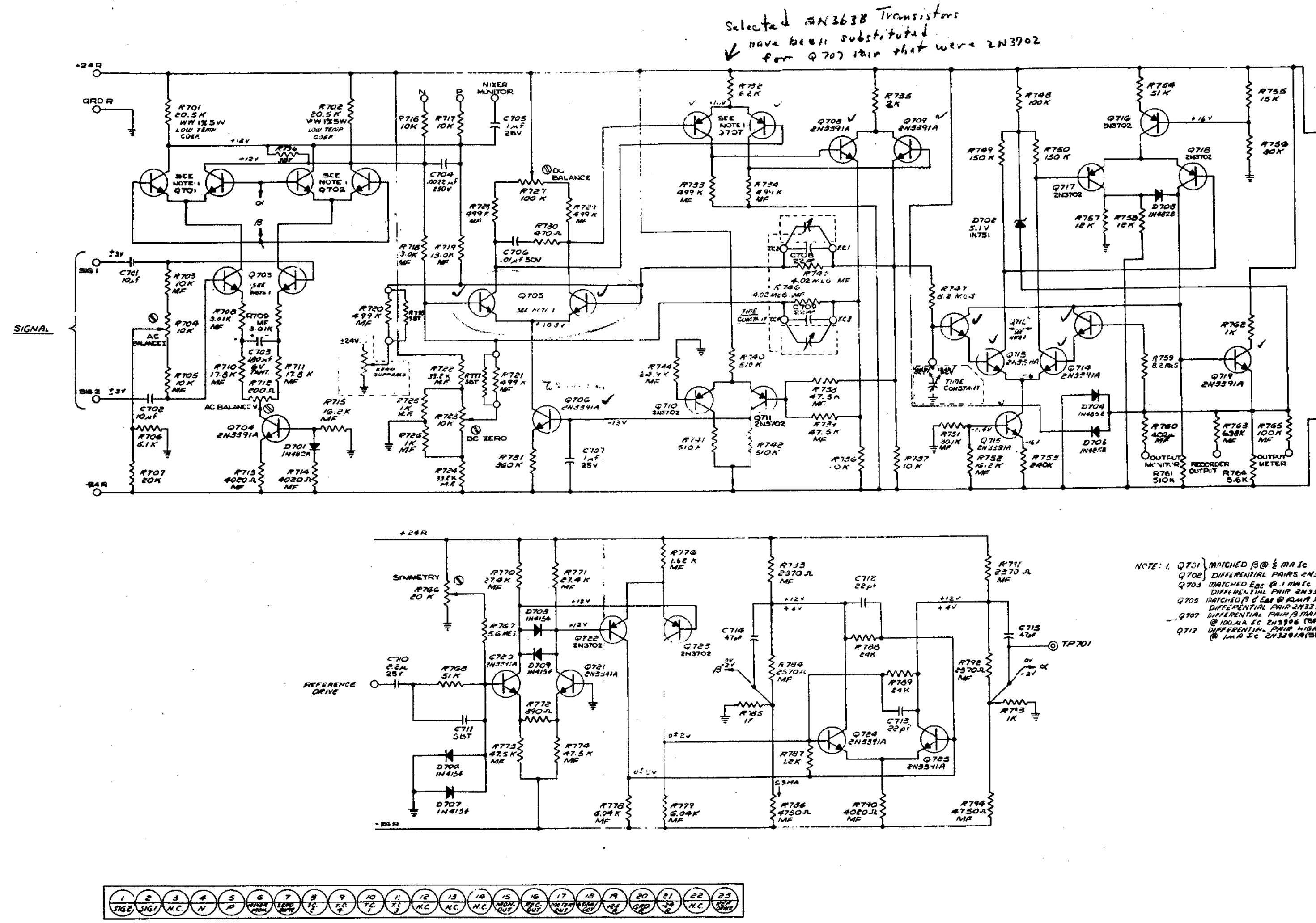
1. H: SELECTED FOR BETA>120 AT 1MA

CIRCUIT BOARD No. RE 1393

REFERENCE TUNED AMPLIFIER

MODEL – HR-8

1384 | C | SD | F



CONNECTOR PIN CONNECTIONS

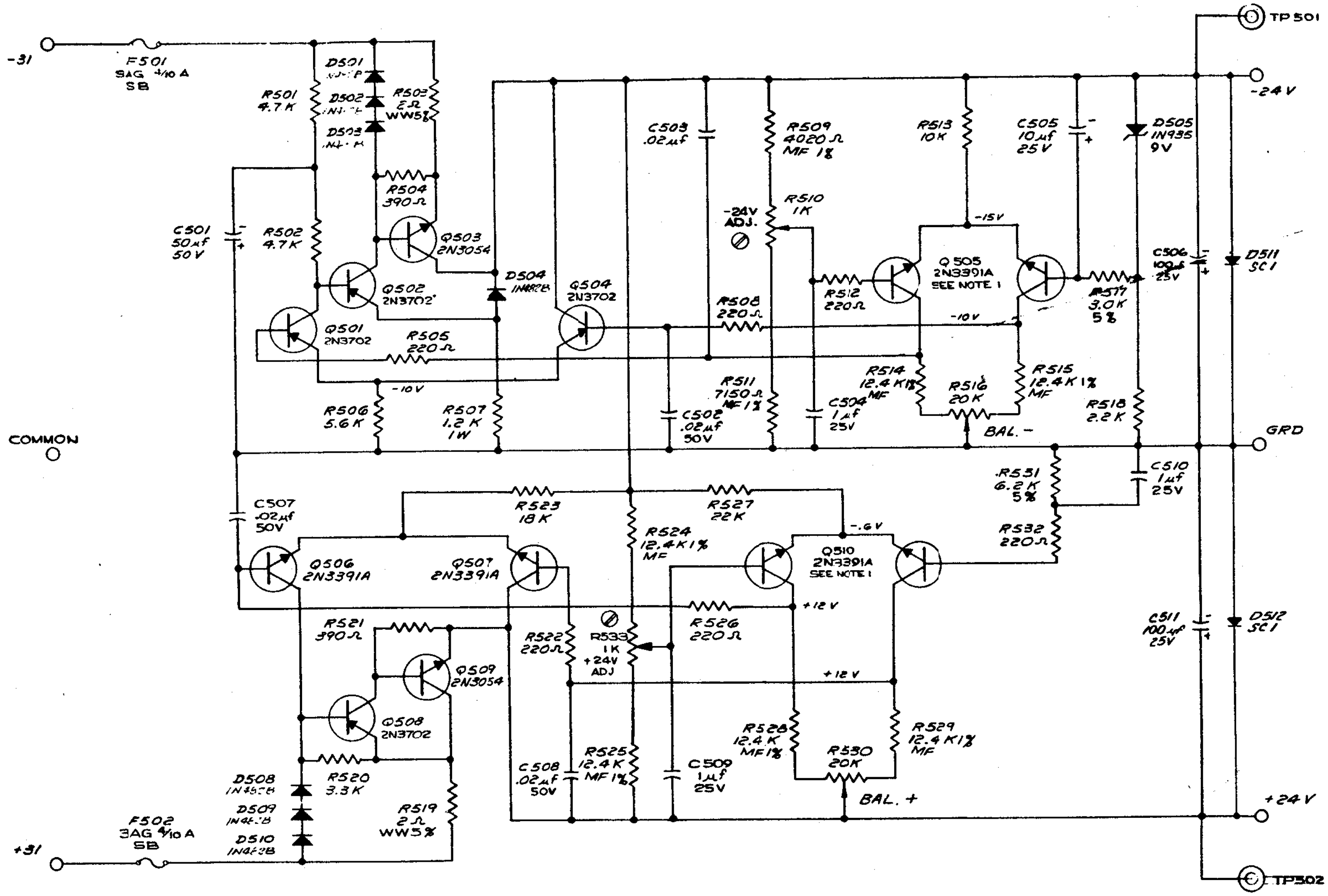
CIRCUIT BOARD No. MI 1397

MIXER

MODEL – HR-8

NOTE: 1. Q701, Q702 MATCHED β @ ½ mA Ic DIFFERENTIAL PAIRS 2N3391A (SPEC 650411 - WHITE)
Q703 MATCHED E_{BE} @ .1 mA Ic DIFFERENTIAL PAIR 2N3391A (SPEC 650412 - GREEN)
Q705 MATCHED β & E_{BE} @ 10μA Ic DIFFERENTIAL PAIR 2N3391A (SPEC 650409 - YELLOW)
Q707 DIFFERENTIAL PAIR β MATCH @ 100μA Ic 2N3906 (SPEC 650413 - RED)
Q712 DIFFERENTIAL PAIR HIGH β @ 1mA Ic 2N3391A (SPEC 650410 - BLUE)

1358 | D | 80 | I



NOTE

1. Q 505 & Q510 ARE DIFFERENTIAL PAIR E_{BE} MATCHED @ 100µa (SPEC. # 650412 - GREEN)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
-31	N.C.	N.C.	N.C.	-24	-24	-24	N.C.	N.C.	N.C.	COMMON IN	N.C.	GRD	GRD	GRD	N.C.	N.C.	+24	+24	+24	N.C.	N.C.	+31

CONNECTOR PIN CONNECTIONS

CIRCUIT BOARD No. P01396

POWER SUPPLIES I & II

MODEL – HR-8

1387 | C | SD | D