Model 5202

Lock-in Amplifier

Instruction Manual

Notice:
This manual is made available as a convenience to users of the EG&G Model 5202. This product has been obsolete since 1987 and as such we can offer no service or further support for it.

SIGNAL RECOVERY
...part of AMETEK® Advanced Measurement Technology

Model 5202

Lock-In Amplifier

Instruction Manual

215449-A-MNL-C

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SAFETY CONSIDERATIONS

A. INTRODUCTION

The apparatus to which this instruction manual applies has been supplied in a safe condition. This manual contains some information and warnings that have to be followed by the user to ensure safe operation and to retain the apparatus in a safe condition. The described apparatus has been designed for indoor use.

B. INSPECTION

Newly received apparatus should be inspected for shipping damage. If any is noted, immediately notify EG&G PARC and file a claim with the carrier. The shipping container should be saved for possible inspection by the carrier.

WARNING!

THE PROTECTIVE GROUNDING COULD BE RENDERED INEFFECTIVE IN DAMAGED APPARATUS. DAMAGED APPARATUS SHOULD NOT BE OPERATED UNTIL ITS SAFETY HAS BEEN VERIFIED BY QUALIFIED SERVICE PERSONNEL. DAMAGED APPARATUS SHOULD BE TAGGED TO INDICATE TO A POTENTIAL USER THAT IT MAY BE UNSAFE AND THAT IT SHOULD NOT BE OPERATED.

C. SAFETY MECHANISM

As defined in IEC Publication 348, *Safety Requirements for Electronic Measuring Apparatus*, the Model 5202 is Class I apparatus, that is, apparatus that depends on connection to a protective conductor to earth ground for equipment and operator safety. Before any other connection is made to the apparatus, the protective earth terminal shall be connected to a protective conductor. The protective connection is made via the earth ground prong of the Model 5202's power cord plug. This plug shall only be inserted into a socket outlet provided with the required earth ground contact. The protective action must not be negated by the use of an extension cord without a protective conductor, by use of an "adapter" that doesn't maintain earth ground continuity, or by any other means.

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

WARNING!

IF IT NECESSARY TO REPLACE THE POWER CORD OR THE POWER CORD PLUG, THE REPLACEMENT CORD OR PLUG MUST HAVE THE SAME POLARITY AS THE ORIGINAL. OTHERWISE A SAFETY HAZARD FROM ELECTRICAL SHOCK, WHICH COULD RESULT IN PERSONNEL INJURY OR DEATH, MIGHT RESULT.

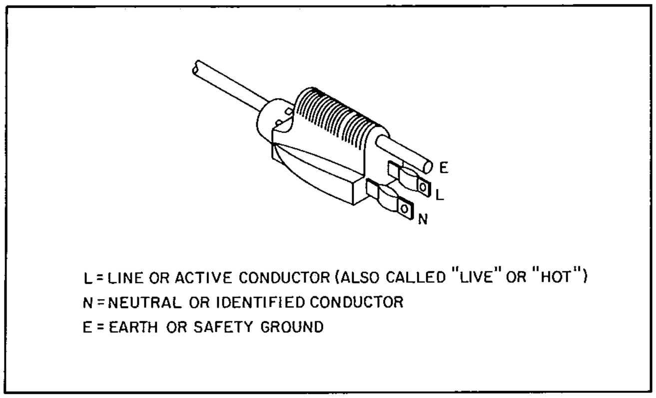


Figure 1. POWER CORD PLUG WITH POLARITY INDICATION

D. POWER VOLTAGE SELECTION AND LINE FUSES

Before plugging in the power cord, make sure that the equipment is set to the voltage of the ac power supply.

CAUTION!

THE APPARATUS DESCRIBED IN THIS MANUAL MAY BE DAMAGED IF IT IS SET FOR OPERATION FROM 110 V ac AND TURNED ON WITH 220 V ac APPLIED TO THE POWER INPUT CONNECTOR.

A detailed discussion of how to check and, if necessary, change the power-voltage setting follows.

The Model 5202 can operate from any of four different power-voltage ranges, 90-110 V, 110-130 V, 180-220 V, and 220-260 V, 50-60 Hz. Change from one voltage range to another is made by repositioning a plug-in circuit card internal to the rear panel Line Cord/Fuse Assembly. Instruments are ordinarily shipped ready for operation from 110-130 V ac, unless destined for an area known to use a line voltage in the 220-260 V range. If this is the case, they are shipped configured for operation from the higher range.

If necessary, the change from one range to another can be accomplished in the field. CHANGING THE VOLTAGE RANGE OR CHANGING THE LINE FUSE SHOULD ONLY BE DONE BY A QUALIFIED SERVICE TECHICIAN, AND THEN ONLY WITH THE INSTRUMENT DISCONNECTED FROM ALL SOURCES OF POWER. Observing the instrument from the rear, note the clear-plastic "door" immediately adjacent to the power cord connector (Figure 2). When the power cord is disconnected from the rear-panel connector, the plastic door is free to slide to the left, giving access to the fuse and to the voltage selector circuit card. The selector card is located at the lower edge of the fuse compartment. A number printed on the upper surface of the selector card is visible without removing the card. The number is somewhat obstructed by the fuse but can be read if the viewing angle is just right. This number indicates the selected nominal line voltage. There are four numbers on the card, but only one is visible. In other words, the card can be inserted in any of four different positions, and a different number can be read in each. Table I-1 indicates the actual line voltage range for each number. If the number showing is incorrect for the prevailing line voltage, the card will have to be repositioned, as follows.

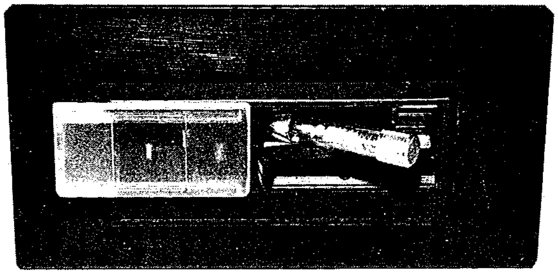


Figure 2. LINE CORD/FUSE ASSEMBLY

The first step is to remove the fuse. When the lever labeled FUSE PULL is rotated out and towards the left, the fuse will lift so that it can be easily removed. At the front center of the circuit card is a small hole that serves as a convenient pry point. A small screwdriver or other tool can be used as an aid in removing the board. With the board removed, four numbers become visible: 100, 120, 220, and 240. Orient the board so that the desired number (Table 1) will be visible when the board is inserted. Then isnert the board into its connector. The selected number should be the only one that shows. Be sure the board is securely seated in its connector.

SELECTOR CARD NUMBER EXPOSED	OPERATING VOLTAGE RANGE
100	90-110 V
120	110-130 V
220	180-220 V
240	220-260 V

Table 1. VOLTAGE-SELECTION CARD POSITION AS A FUNCTION OF LINE VOLTAGE

Next check the fuse rating. For operation from a nominal line voltage of 120 V, use a slow-blow fuse rated at 0.5 A (voltage rating 125 V or higher). For operation from a nominal line voltage of 220 V, use a slow-blow fuse rated at 0.25 A (voltage rating of 250 V or higher). When the proper fuse has been installed, slide the plastic door back over the fuse compartment so that the power cord can be reconnected.

Make sure that only fuses with the required current rating and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

WARNING!

TO AVOID THE POSSIBILITY OF A SAFETY HAZARD FROM ELECTRICAL SHOCK, WHICH COULD RESULT IN PERSONNNEL INJURY OR DEATH, DISCONNECT THE POWER CORD BEFORE REMOVING OR INSTALLING A FUSE.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

E. MAINTENANCE

WARNING!

POTENTIALLY LETHAL VOLTAGES ARE PRESENT INSIDE THIS APPARATUS. SERVICE SHOULD BE PERFORMED BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS YOU ARE QUALIFIED TO DO SO.

Any adjustment, maintenance, or repair of the opened apparatus under voltage, INCLUDING INSTALLATION OF THE VECTOR PHASE and RATIO OPTIONS (Paragraphs 4.8B and 4.9B respectively) shall be avoided as far as possible and, if unavoidable, shall be carried out only by a skilled person who is aware of the hazard involved. When the apparatus is connected to a power source, terminals may be live, and the opening of covers or removal of parts is likely to expose live parts. The apparatus shall be disconnected from all voltage sources before it is opened for any adjustment, maintenance, or repair. Once opened, power can be reconnected as necessary for the required maintenance. Note that capacitors inside the apparatus may still be charged, even if the apparatus has been disconnected from all voltage sources. Service personnel are thus advised to wait several minutes after unplugging the instrument before assuming that all capacitors are discharged. If any fuses are replaced, be sure to replace them with fuses of the same current and voltage rating and of the same type. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

F. VENTILATION

The Model 5202 does not incorporate forced air ventilation. With a power consumption of less than 50 watts, this instrument can be operated on most laboratory benches. Alternatively, it can be rack mounted, if desired. The only requirement is that the ambient temperature be restricted to the range of 15° C to 45° C.

G. DEFECTS AND ABNORMAL STRESSES

Whenever it is likely that the protection provided by the connection to earth ground has been impaired, the apparatus shall be made inoperative and secured against any unintended operation. The protection is likely to be impaired if, for example, the apparatus:

(1) Shows visible damage,

(2) Fails to perform the intended measurement,

(3) Has been subjected to prolonged storage under unfavorable conditions,

(4) Has been subjected to severe transport stresses.

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

SECTION I
CONDENSED OPERATING INSTRUCTIONS

The following instructions are provided as an assistance in placing the Model 5202 Lock-In Amplifier into operation as quickly as possible. Generally speaking, these instructions allow good results to be obtained in most applications. However, because of their brevity, many considerations that might have bearing on a particular measurement have been omitted. For this reason, it is advisable to read Section IV, the complete Operating Instructions, to be assured of optimum performance. Note that these condensed operating instructions do not apply to the options. For instructions regarding their use, refer to the appropriate portion of Section IV.

STEP ONE

PRELIMINARY STEPS AND CONTROLS: Check that the rear-panel Line Voltage Selector circuit card (see Subsection 3.3) is in the proper position. Then plug in the line cord. At the front panel, set the controls as follows.

Sensitivity: 250 mV
Phase pushbuttons: 0° depressed
Phase dial: Five full turns from the fully counterclockwise position
Frequency Range: Selected range must bracket reference signal frequency
Reference pushbuttons: If reference signal is sine wave, press center REFERENCE pushbutton. If a positive pulse, press left REFERENCE pushbutton. If a negative pulse, press right REFERENCE pushbutton.
Reference Slope: Selected edge will define trigger point (0°) on reference signal (usually select positive slope)
In Phase Meter pushbuttons: IN PHASE depressed
Quadrature Meter pushbuttons: QUADRATURE depressed
Time Constant pushbuttons: 0.1 s depressed in both channels
X10 pushbuttons: released in both channels
Offset pushbuttons: both released in both channels
Offset dials: setting immaterial in both channels
Filter pushbuttons: released in both channels
Power: ON (Power switch lighted)

STEP TWO

CONNECTIONS: Connect the reference signal (300 mV pk-pk minimum) to the REF. IN connector. The Reference UNLOCK light should immediately extinguish. Then connect the input signal to the "A" input. If possible, connect a heavy gauge ground strap from signal-source ground to the Model 5202 GND post (located next to the Signal Input connector).

STEP THREE

PHASE AND SENSITIVITY: Rotate the Sensitivity switch counterclockwise until one (or both) of the panel meters deflects. If the instrument overloads before significant meter deflection occurs, depress the OUTPUT EXPAND X10 pushbuttons to increase the input noise tolerance (relative to a full scale input signal) by a factor of ten as the output gain is increased. With the output expansion selected, the sensitivity for a given position of the Sensitivity switch is a factor of ten greater than is indicated by the switch symbolization. If output noise fluctuations are causing the overload, increase the Time Constant. Note that the FILT pushbuttons provide output smoothing but do not prevent overload.

Find the phase setting (adjust phase dial while selecting different Quadrant pushbuttons) that yields a positive indication on the IN PHASE meter. Then adjust the phase dial for rough maximum on the IN PHASE meter. The QUADRATURE meter indication will indicate "0". Since the null is much sharper than the In Phase peak, the PHASE dial should be fine-adjusted for an exact null at the QUADRATURE meter, which will correspond identically to the desired maximum at the IN PHASE meter. When these adjustment criteria have been satisfied, the IN PHASE meter will indicate the amplitude of the input signal. Analog dc outputs are provided at the I OUT and Q OUT connectors (±1 V f.s.) at both the front and rear panels.

STEP FOUR

FINAL CONSIDERATIONS: It may be necessary to correct the final readings for other than sinusoidal inputs. The Model 5202 is rms calibrated but average responding. A discussion of this topic can be found in Subsection 4.6.

The reading resolution of small amplitude changes in the input signal can be increased by using the OFFSET controls to suppress the output, thereby allowing the system gain to be increased without output overload. The signal amplitude can be read directly from the OFFSET controls, provided they have been set to obtain a null on the corresponding meter. The "+" OFFSET pushbutton should be depressed to suppress a positive indication. The "–" OFFSET pushbutton should be depressed to suppress a negative indication.

SECTION II
CHARACTERISTICS

2.1 INTRODUCTION

The Model 5202 Lock-In Amplifier is the first commercially available lock-in amplifier to operate in the high frequency range. P.A.R.C. has applied its years of experience in the design and manufacture of sophisticated low level signal processing circuitry to provide this unique instrument. The Model 5202 combines an operating frequency range of 100 kHz, dynamic reserve of over 2000, sensitivity up to 100 μV, and low input noise to provide the researcher with the exceptional instrument performance that until now was available only in lower frequency ranges.

The Model 5202 will extend the capabilities of lock-in technology to such varied applications as nuclear magnetic resonance, electron spin resonance, electron paramagnetic resonance, semiconductor research, fluorescence decay, RF and laser noise measurements, RF communications research, cyclotron chemistry, plasma research, and nuclear quadrapole resonance.

2.2 SPECIFICATIONS

SIGNAL CHANNEL

FREQUENCY RESPONSE: 100 kHz to 50 MHz

GAIN BANDWIDTH LINEARITY: Flat, from 100 kHz to 10 MHz, to within ±0.5 dB

SENSITIVITY: 8 full-scale ranges from 100 μV to 250 mV in 1-2.5-10 sequence. Two output expansion ranges of X1 and X10 increase the overall sensitivity to 10 μV full scale.

INPUT: Single-ended, with auxiliary ground lug

INPUT IMPEDANCE: 50 Ω, VSWR <1.2

MAXIMUM ALLOWABLE INPUT SIGNAL: 5 V rms or 10,000X full scale (whichever is less)

MAXIMUM INPUT BEFORE OVERLOAD: 200X full scale; expandable to 2000X full scale

INTERNAL NOISE: Less than 10 nV/Hz$^{1/2}$; 100 kHz to 50 MHz

COHERENT PICKUP: Less than 5% of full scale worst case (50 MHz on the most sensitive range)

GAIN STABILITY: Better than 0.2%/ °C

REFERENCE CHANNEL

FREQUENCY RANGE: 100 kHz - 50 MHz in 9 overlapping ranges, selectable with front-panel switch.

INPUT REQUIRED: The reference channel locks to virtually any external voltage having amplitude excursions of at least 300 mV pk-pk. Front-panel reference and slope pushbutton controls enable phase lock to optimum point of the reference waveform. The front-panel REFERENCE UNLOCK lamp indicates the absence of a proper reference input.

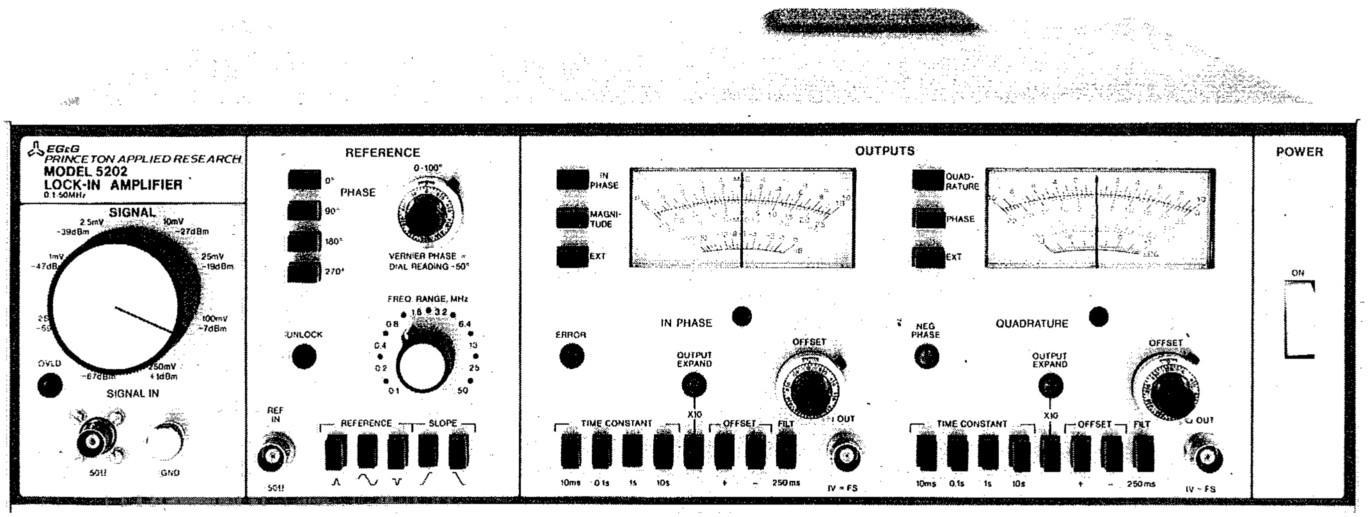
REFERENCE INPUT IMPEDANCE: 50 Ω (nominal)

MAXIMUM INPUT LEVEL: 5 V peak

PHASE ADJUSTMENT: A calibrated ten-turn potentiometer provides 0 - 100° phase shift. The accuracy of the phase shift is ±5° with a resolution of ±0.1°. A four-position Quadrant switch provides 90° phase shift increments accurate to 5°. **NOTE:** Overall phase accuracy of instrument is ±15°.

PHASE NOISE: Less than 0.035° pk-pk (100 kHz to 50 MHz; 10 ms time constant)

REFERENCE ACQUISITION TIME: 0.1 s max.



PHASE-SENSITIVE DETECTORS

DESCRIPTION: The Model 5202 features two fully-independent Phase-Sensitive Detectors (PSD's) driven by orthogonal reference signals. Each PSD is provided with its own ZERO OFFSET, OUTPUT EXPAND, and TIME CONSTANT controls, allowing each to be independently optimized for the signal undergoing analysis. Wide variations between in-phase and quadrature signals can therefore be readily measured.

DYNAMIC RESERVE: Defined as the ratio, at the input of the Model 5202, of the maximum peak signal (non-coherent and outside the passband) that can be applied without overload, to the peak coherent signal required for full-scale output. The OUTPUT EXPAND switch permits output stability to be traded for overload capability, as indicated in Table II-1.

OUTPUT EXPAND SETTING	OUTPUT STABILITY (%/°C of Output f.s.)	DYNAMIC RESERVE
X1	0.05	200X FS
X10	0.50	2000X FS

NOTE: FS = full-scale sensitivity setting divided by the output expand setting.

Table II-1. DYNAMIC RESERVE AND OUTPUT STABILITY AS A FUNCTION OF OUTPUT EXPANSION

FILTER TIME CONSTANTS: The two outputs are provided with switch-selectable choices of four time constants, 10 ms, 100 ms, 1 s, and 10 s, plus a MIN. position in which the time constant is less than 1 ms. An additional dc prefilter switch inserts a 250 ms filter after the main Time Constant filter.

DC ZERO OFFSET: Calibrated 10-turn potentiometer is provided for each channel permitting up to ±10 times full scale to be suppressed. Suppression polarity selected by front-panel pushbuttons.

OUTPUTS

METER READOUT: Two meters are provided, one for each channel. They are calibrated to provide full-scale deflection with a properly phased full-scale signal at the input. The left meter can be switched to monitor the in-phase signal, or, if the Vector Phase option has been installed, the vector magnitude. The right meter monitors either the amplitude of the quadrature signal or the phase of the input signal with respect to the applied reference (Vector phase option installed). Either meter can monitor the amplitude of a dc signal (externally derived or output of Ratio option, if installed) applied to a rear-panel connector. External Meter mode sensitivity is 1 V f.s. (100 μA movement through 10 kΩ).

RECORDER OUTPUT: Front and rear-panel I and Q OUT connectors are provided to interface to standard recorders. Output is 1 V f.s. through 600 Ω*.

RATIO OUTPUTS: Rear-panel BNC connector outputs are also provided for the Vector Phase and Ratio Options as described under OPTIONS.

ACCESSORY INTERFACE: A rear-panel card-edge connector allows peripheral instrumentation to be powered from the Model 5202. +15 V, −15 V, and ground are provided.

GENERAL

INDICATIONS: Six front-panel indicator lights define the operating states of the lock-in amplifier.

(1) OVERLOAD: Indicates that an overload condition exists in one or more of the critical amplifier circuits.

(2) UNLOCK: Indicates lack of an adequate external reference signal as defined in the reference specifications, or that the frequency range setting is incorrect.

(3) OUTPUT EXPAND: Indicates that the input sensitivity is increased by a factor of ten. One indicator is provided for each output channel.

(4) NEGATIVE PHASE: In units equipped with Vector option, indicates that Input Signal lags Reference Signal (Phase controls to 0°) by angle in range of 0° to −180°.

(5) ERROR: Indicator lights if vector magnitude and/or phase buttons are depressed and any of the following conditions exist.

  (a) In-phase and quadrature time constants are not equal.

  (b) In-phase and quadrature output expansions are not equal.

  (c) All Time Constant pushbuttons released (gives time constant of nominally 1 ms).

  (d) Output Offset in use.

  (e) Vector option board not installed.

AMBIENT TEMPERATURE RANGE: The instrument can be operated at temperatures ranging from 15°C to 45°C.

AUXILIARY POWER OUTPUT: A rear-panel connector provides ±15 V (100 mA) and ground.

POWER REQUIREMENTS: 100 to 130 or 210 to 260 V ac, 50 to 60 Hz; 50 watts.

SIZE: 17-1/2" W x 5-1/2" H x 19-1/2" D (44.5 cm W x 13.9 cm H x 49.5 cm D).

WEIGHT: 35 lbs (15.89 kg).

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*Approximately 8 kΩ in early units.

OPTIONS

MODEL 5202/95 VECTOR PHASE OPTION: Direct meter readout of the computed magnitude and phase angle of the input signal with respect to the reference input. Full continuous 360° phase measurement is accomplished by means of a front-panel meter and a negative phase indicator lamp. Rear-panel MAGNITUDE and PHASE output BNC connectors are provided, allowing convenient monitoring or recording. Vector Phase specifications follow.

(1) PHASE ANGLE OUTPUT VOLTAGE: 1.8 V ahead of 600 Ω for 180°; Linearity ±0.2°; accuracy ±0.2°; Transfer function of 10 mV/°.

(2) MAGNITUDE OUTPUT VOLTAGE: 1 V f.s. ahead of 600 Ω; Linearity ±0.1%; Accuracy ±1%.

MODEL 5202/96 RATIO OPTION: Option operates on dc levels (A & B) applied to rear-panel connectors and computes A/B, log A, or log A/B, as selected with a rear-panel toggle switch. Applied inputs can be I and Q outputs. Computed function is provided at rear-panel Ratio OUT connector. Ratio can also be indicated on front panel meter by making use of the EXTERNAL METER Input capability. Ratio specifications follow.

(1) Input Voltage Range: 10 mV - 1 V

(2) Input Offset (maximum): ±250 μV

(3) Input Offset Temperature Coefficients: ±15 μV/°C

(4) Output Voltage: LINEAR, +1 f.s. (unity); LOG, 0.5 V/decade with +0.5 V of offset.

(5) Log Range: 3 decades

(6) Ratio Accuracy: A function of the denominator voltage as follows. For A/B, ±0.4% from B = 0.1 V to B = 1 V; ±4% from B = 0.01 V to B = 0.1 V. For Log A, computed function is within 2 mV of correct value. For Log A/B, computed function is within 2 mV from B = 0.1 V to B = 1 V; computed function is within 10 mV from B = 0.01 V to B = 0.1 V.

ACCESSORIES

MODEL 115 HIGH FREQUENCY PREAMPLIFIER: Refer to P.A.R.C. literature T220D and TN115 for complete specifications on the Model 115 preamplifier.

2.3 HOW IT WORKS

As shown in Figure II-1, the input signal, after being routed through the Sensitivity switch, is applied to two RF Mixers

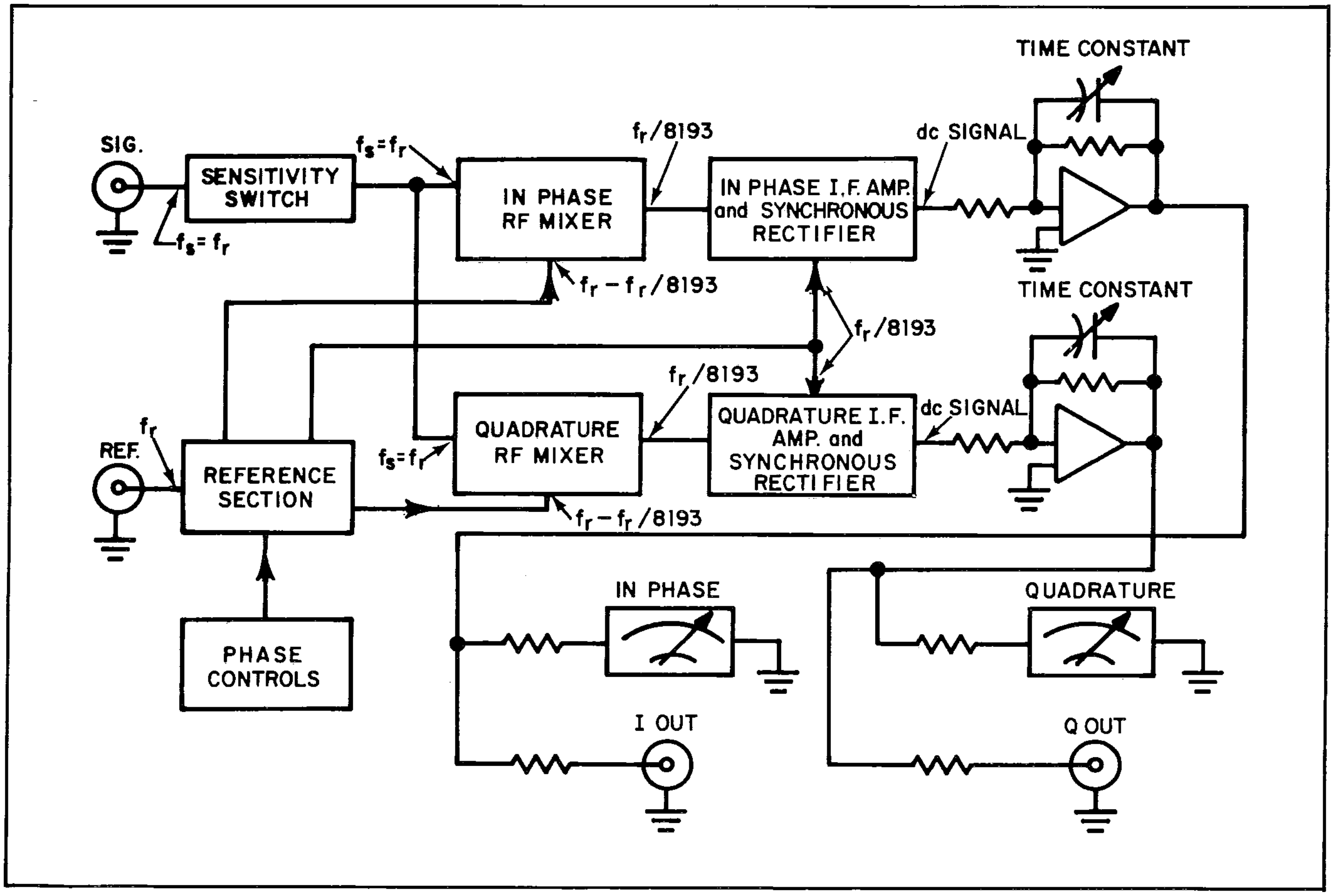

Figure II-1. SIMPLIFIED BLOCK DIAGRAM OF MODEL 5202 where mixing with an RF Drive developed in the Reference Channel occurs. A reference signal at frequency f_r is applied to the Reference Section circuitry, which generates the RF Drive and I.F. Drive signals, which are locked to the input reference signal. The Phase shift functions controlled by the front-panel Phase pushbuttons and dial are also accomplished here. When the phase controls are adjusted for maximum In Phase output, the Phase controls indicate the number of degrees of lead introduced into the reference channel to bring the In Phase RF Drive into phase with the input signal to the In Phase RF Mixer. The two RF Mixers differ only in that the RF Drive to the Quadrature RF Mixer leads the RF Drive to the In Phase Mixer by 90°, thereby allowing demodulation of both the in phase and quadrature components of the input signal.

Note that the mixed signals are not at the same frequency. The signal is at f_r and the RF Drive is at fr – $f_r/8193$. A signal at the difference frequency, $f_r/8193$ Hz, appears at the output of each mixer. This signal's magnitude is proportional to the magnitude of the respective in phase or quadrature component of the input signal to the RF Mixers. This I.F. signal is further amplified and then synchronously demodulated with respect to the $f_r/8193$ I.F. Drive signal from the Reference Section circuitry. Since both the I.F. Drive signal and the I.F. information signal are at the same frequency, the difference frequency is "0" or dc. The dc output level in each channel is amplified by the same dc amplifier as provides the main time constant filtering. The output of each of these amplifiers in turn, in addition to driving the panel meters, is provided at the I OUT and Q OUT connectors. Thus the Model 5202 provides a dc output voltage in each channel proportional to the amplitude of the corresponding input component.

SECTION III
INITIAL CHECKS

3.1 INTRODUCTION

The following procedure is provided to facilitate initial performance checking of the Model 5202 Lock-In Amplifier. In general, the procedure should be performed after inspecting the instrument for any obvious shipping damage (any noted to be reported to the carrier and to Princeton Applied Research Corporation), but before using the instrument. The basic intention of these checks is simply to determine that the instrument has arrived in good working order, and not to demonstrate that it "meets specs". Each instrument receives a painstaking checkout before leaving the factory, and one may safely assume that, if no shipping damage has occurred, it will in fact perform within the limits of the stated specifications. Before proceeding, check the inside back cover to see if there is an addendum that might influence the Initial Checks. If any problems are encountered in carrying out these checks, contact the factory or the proper factory representative for aid.

3.2 EQUIPMENT NEEDED

(1) High Frequency Signal Generator to provide 1 MHz sine wave at 0.5 V rms*. This signal will be applied to the REFERENCE INPUT of the Model 5202 in the following checks. It is also necessary to have a high frequency attenuator so that this same signal can be used as the source of input signal of the proper amplitude. The operator can check as many sensitivity ranges as is desired provided there is means of applying input signals of the amplitude indicated by the Model 5202 Sensitivity switch. It is necessary that this signal be synchronous with that applied to the Reference Input, a condition automatically satisfied if they are both taken from the same oscillator output. Some signal generators have an internal attenuator and two outputs, one fixed (suited to driving the Reference Input) and the other variable (suited to driving the Signal Input). Otherwise, a power splitter such as a MINI-CIRCUITS Model ZSC-2-1 or ZSC-2-2 is required (alternatively a triangle of three 51 Ω composition resistors). Also required would be two 20 dB fixed attenuators or one step attenuator (used in Steps 15 and 16).

(2) Such cables as may be necessary to interconnect the Model 5202 with the above equipment. Since both the Signal Input and the Reference Input have a 50 Ω input impedance, cable having a characteristic impedance of 50 Ω should be used.

3.3 LINE VOLTAGE SELECTION

The Model 5202 can be operated from line voltages in the range of 100-130 V ac or 200-260 V ac. Changeover from one range to the other is accomplished by appropriately positioning a plug-in circuit card internal to the rear-panel Line Cord/Fuse Assembly. Instruments are ordinarily shipped for operation from 100-130 V ac, unless they are being shipped to an area known to use a line voltage in the 200-260 V ac range. Where this is the case, they are set to the high voltage range configuration before being shipped.

It should be noted that each of these ranges is further divided in two, the 100-130 V range is divided into a 100-110 V range and a 110-130 V range, and the 200-260 V range is divided into a 200-220 V range and a 220-260 V range. The choice of range is made by appropriately adjusting the line-voltage selector board as determined by the actual line voltage to be applied.

Changeover from one range to another can be made in a moment by the user. Observing the instrument from the rear, note the clear plastic "DOOR" immediately adjacent to the line cord connector. When the line cord is disconnected from the connector, this plastic door is free to slide to the left, giving access to the fuse and to the line-voltage selector circuit board. The selector board is located at the lower edge of the fuse compartment. A number printed on the upper surface of the selector board is visible without removing the board. Even though this number is somewhat obstructed by the fuse, it can be read if the viewing angle is proper. There are four such numbers on the board, each specifying a different line voltage. Only one of these numbers is visible when the board is in place, as determined by the board orientation. The correct selector board number as a function of the applied line voltage is indicated in Table III-1 below.

RANGE IN WHICH ACTUAL LINE VOLTAGE FALLS	SELECTOR BOARD NUMBER
100-110 V	100
110-130 V	120
200-220 V	220
220-260 V	240

Table III-1. SELECTOR BOARD NUMBER (ORIENTATION) AS A FUNCTION OF APPLIED LINE VOLTAGE

If inspection shows the selector board number to be incorrect for the line voltage to be applied, the board will have to be reoriented.

The first step is to remove the fuse. When the lever labeled FUSE PULL is pulled out and towards the left, the fuse will lift so that it can be easily removed. Next remove the selector circuit board. At the front center of the selector circuit board is a small hole that serves as a convenient pry point. A small screwdriver or other tool can be used as an aid in removing the board. With the board removed, four numbers become visible: 100, 120, 220, and 240. Orient the board so that the desired number is right-side up and to

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*Although these checks are made at 1 MHz, higher frequency checks can also be made within the limits set by the signal generator and Model 5202 frequency response.

the left. Then reinsert the board. The selected number should be the only one visible when the board is fully inserted. Be sure the board is pushed all the way in. Then check the fuse rating. For operation from a voltage in the 100-130 V range, a 0.5 A slow-blow fuse should be used. For operation from a voltage in the 200-260 V range, use a 0.25 A slow-blow fuse. Once the proper fuse has been installed, slide the plastic door back over the fuse compartment so that the line cord can be reconnected.

3.4 PROCEDURE

(1) Plug in the line cord (front-panel POWER switch should be in OFF position).

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

Sensitivity switch: 250 mV
Reference Quadrant pushbuttons: 0° depressed
Reference dial: Five turns from fully counterclockwise position
Frequency Range switch: 0.8 - 1.6 range
Reference Mode pushbuttons: Sine wave (center) pushbutton depressed
Reference Slope pushbuttons: Positive (left) pushbutton depressed
Meter pushbuttons: IN PHASE and QUADRATURE depressed
Time Constant: 10 ms (both channels) depressed
Output Expand: pushbutton released (both channels)
Offset pushbuttons: all released
Filter pushbuttons: released (both channels)
Offset dials: fully counterclockwise (both channels)
Power: ON

NOTE: Instrument behavior is not predictable until reference signal is applied (following step).

(3) Set up the signal generator to provide a 1 MHz sine wave output. Two different signals must be provided to the Model 5202. One 250 mV rms sine wave must be applied to the REFERENCE INPUT connector and another 250 mV rms sine wave must be applied to the SIGNAL INPUT connector. The two signals must be coherent. Some generators provide two outputs, one of fixed amplitude and the other variable, simplifying the connection problem. Others have a single output, requiring use of an external attenuator/splitter. Note that the input impedance of both the Signal and Reference Inputs is 50 Ω. Loading effects must be considered in the hookup. If the generator has two outputs, they must supply the required levels when driving 50 Ω. Similarly, the attenuator/splitter used with a single output generator must supply the required levels when its output ports are loaded with 50 Ω. The frequency should be 1 MHz.

(4) Observe the Model 5202 front panel. The POWER switch should be illuminated. Of the indicator lamps, NEG PHASE may or may not be lighted*. The net phase shift established in step 2 is 0°, that is, right on the line between a positive and negative phase indication. Residual absolute phase errors could give either phase polarity, or even a flickering NEG PHASE indication*.

(5) Note the meter indications. The IN PHASE meter should indicate full scale to the right and the QUADRATURE meter should indicate "0". Some adjustment of the PHASE dial will probably be required to obtain exactly "0" at the QUADRATURE meter. The magnitude of the adjustment will depend on the absolute phase accuracy of the Model 5202. In addition, the adjustment will have to compensate for any phase difference between the Input signal and the Reference signal at their respective front-panel connectors. Phase differences can arise in the signal generator, in the attenuator/splitter, and in the signal and reference cables if they are not the same length. In any case, the important thing is to adjust the Phase dial to where the desired "0" indication is obtained on the Quadrature meter. The In Phase meter indication will be maximum at that time. If the In Phase reading is not exactly full scale, adjust the level of the applied signal to where the desired full-scale indication is obtained. Recall that the signal level at the Reference Input should remain constant throughout these checks. However, the specified 250 mV rms reference signal level is nominal only and can be varied with no effect on the instrument's performance. However, if the reference level is reduced, additional phase error will be introduced, making it necessary to readjust the Phase dial for "0" on the Quadrature Meter.

(6) Press the 90° Reference Phase pushbutton. The In Phase meter will indicate "0" and the Quadrature meter will indicate negative full scale.

(7) Press the 180° Reference Phase pushbutton. The Quadrature meter will indicate "0" and the In Phase meter will indicate negative full scale.

(8) Press the 270° Reference Phase pushbutton. The In Phase meter will indicate "0" and the Quadrature meter will indicate positive full scale.

(9) Press the 0° Reference Phase pushbutton, restoring the initial phase relationship. The In Phase meter will indicate positive full scale and the Quadrature meter will indicate "0".

(10) Press and latch both the In Phase and Quadrature OUTPUT EXPAND X10 pushbuttons, giving an effective sensitivity with respect to the input of 25 mV rms. The two OUTPUT EXPAND indicator lamps should be lighted and the In Phase meter indication will go off scale.

(11) Press the In Phase "+" OFFSET pushbutton. Then begin rotating the In Phase OFFSET dial clockwise. At nine full turns from the fully counterclockwise position, the introduced offset will equal the *excess* output and the In Phase meter should indicate full

*NEG PHASE light only functions on units equipped with VECTOR Option.

scale. At ten full turns from the fully counterclockwise position, all of the output will be offset, giving an indication of "0" on the In Phase meter.

(12) Return the In Phase OFFSET dial to the fully counterclockwise position and release the "+" OFFSET pushbutton.

(13) Press and latch the Quadrature "–" OFFSET pushbutton. Then rotate the Quadrature OFFSET dial clockwise. The Quadrature panel meter should indicate positive full scale after one full turn (dial setting 1.00). Next release the Quadrature "–" OFFSET pushbutton and press the "+" OFFSET pushbutton. The Quadrature panel meter should indicate negative full scale. If the Quadrature Offset dial is then rotated counterclockwise back to zero, the Quadrature panel meter indication will return to zero as well.

(14) Release the Quadrature "+" OFFSET pushbutton. Also, release the OUTPUT EXPAND X10 pushbutton in both channels. Before proceeding, check to be sure that all four (includes both channels) of the OFFSET polarity pushbuttons are in the released position. The In Phase panel meter should indicate positive full scale and the Quadrature panel meter should indicate "0".

(15) Decrease the amplitude of the input signal to 25 mV rms (Reference input to remain nominally 250 mV rms). The In Phase meter indication should decrease to positive 10% of full scale. Then press the In Phase OUTPUT EXPAND X10 pushbutton. The In Phase meter indication should increase to positive full scale.

(16) Further decrease the amplitude of the input signal to 2.5 mV rms (amplitude of reference signal to remain nominally 250 mV rms. The In Phase meter indication should decrease to positive 10% of full scale.

(17) Set the Model 5202 Signal Level Selector to 25 mV. The In Phase meter indication should increase to full scale. If the In Phase OUTPUT EXPAND X10 pushbutton is then released, the indication will decrease to 10% of full scale. Leave the Output Expand pushbutton in the released position.

(18) Set the Signal Level Selector to 2.5 mV. The full-scale indication of the In Phase meter will be restored.

(19) Gradually change the input frequency over a wide range, remaining within the specified frequency limits of the Model 5202. If the frequency is changed slowly, the UNLOCK light will remain out. However, some phase error may be introduced while the frequency change is in progress. This would appear as a deviation in the panel meter readings, with the deviation being proportional to the rate of frequency change. If the frequency change rate is very high, the UNLOCK light may light momentarily as frequency lock is lost and then re-established.

In addition, phase errors may originate in the signal generator or in the attenuator/splitter (if used). However, once the Phase dial is adjusted for "0" indication on the Quadrature meter, nominally full-scale In Phase indication should be obtained at any frequency in the operating range. Bear in mind that amplitude shifts in the signal generator output can occur with frequency and that the Model 5202 amplitude response, as indicated in the specification, is not absolutely flat.

This completes the initial checks for the basic unit. Additional checks may be performed as detailed in the following paragraphs if the instrument is equipped with either the Vector Phase option or the Ratio Option. The options checks should only be carried out after the basic checks, and then only in the indicated sequence.

3.5 RATIO OPTION (5202/96)

(1) The Ratio Option is checked by establishing arbitrarily selected output levels with the OFFSET controls, applying these levels to the Ratio Option inputs, and then measuring the resulting ratio output. No equipment is required other than three BNC cables. The required initial control settings are:

Sensitivity switch: 250 mV
Reference Quadrant pushbuttons: 0° depressed
Reference Phase dial: Five full turns from fully counterclockwise position
Reference Slope pushbuttons: Positive (left) pushbutton depressed
Meter pushbuttons
    In Phase pushbuttons: IN PHASE depressed
    Quadrature pushbuttons: QUADRATURE depressed
Time Constant: 10 ms (both channels)
Output Expand: pushbutton released (both channels)
Offset pushbuttons: "–" depressed (both channels)
Filter pushbuttons: released (both channels)
Offset dial: fully counterclockwise (both channels)
Power: ON

(2) If the signal generator output is still connected to the Model 5202 Signal Input, break the connection at this time. The 0.5 V rms 1 MHz reference signal should still be applied. Both panel meters should indicate "0".

(3) Rotate the In Phase OFFSET dial clockwise until the In Phase panel meter indicates +34% of full scale. Then adjust the Quadrature OFFSET dial clockwise to where the Quadrature panel meter indicates +94% of full scale.

(4) At the rear panel of the Model 5202, connect one cable from the I OUT connector to the "A" RATIO INPUT, and another cable from the Q OUT connector to the "B" RATIO INPUT. Then connect a third cable from the RATIO OUT connector to the EXTERNAL METER IN connector.

(5) At the front panel, press the Quadrature EXT. pushbutton, thereby allowing the voltage applied to

the rear-panel METER INPUT to be read on the Quadrature panel meter.

(6) Set the rear-panel Ratio Function switch to A/B. The ratio of A/B will be 0.34/0.94 = 0.36, and the Quadrature panel meter should indicate 36% of full scale.

(7) Set the rear-panel Ratio Function switch to LOG A. The ratio transfer function is 0.5 V/decade. In addition, there is +0.5 V of offset at the RATIO OUTPUT. The log is read from the lower-most scale of the Quadrature meter, with "0" corresponding to A = 1 V. With the established conditions (A = 0.34 V) LOG A = –0.47, which should be the indication on the Quadrature meter log scale (lowest scale). The actual voltage at the Ratio Out connector will be +0.27 V (Ratio Out = 0.5 Log A + 0.5 V).

(8) Set the rear-panel Ratio Function switch to LOG A/B. As stated in step 6, A/B = 0.36. The log of 0.36 is –0.44, which should be the indication on the log scale (lowest scale on the Quadrature meter). The corresponding Ratio Out voltage will be +0.28 V (Ratio Out = 0.5 Log A/B +0.5 V).

(9) Reverse the two ratio option inputs. A/B will now be 2.76 and the log 2.76 = 0.44. Thus the Quadrature meter indication (log scale) should increase to 0.44, while the Ratio Out voltage increases to 0.72 V.

This completes the ratio checks. If desired, the operator can verify that the ratio and log ratio functions are computed on the absolute value. This is done by making either the In Phase or Quadrature (or both) OFFSET negative (release OFFSET "–" pushbutton and press "+" OFFSET pushbutton). The ratio output should not change. When finished, remove the cables, leave all of the OFFSET polarity pushbuttons in the released position, and press the QUADRATURE Meter pushbuttons as well to restore normal lock-in meter function.

3.6 VECTOR PHASE OPTION (5202/95)

(1) Set up as described in the first three steps of Subsection 3.4.

(2) Adjust the Reference Phase dial for "0" indication on the Quadrature meter. If necessary, adjust the amplitude of the signal generator output as required to get exactly full-scale deflection at the In Phase panel meter.

(3) Depress the MAGNITUDE and PHASE Meter pushbuttons. With these pushbuttons depressed, the vector magnitude will be displayed on the In Phase meter and the vector phase on the Quadrature meter.

(4) Note the meter indications. The In Phase meter should indicate positive full scale and the Quadrature meter should indicate 0°. At this crossover phase, the NEG PHASE light could be on, off, or flickering. **NOTE:** Use the top In Phase magnitude scale, which has "0" at the left end of the scale instead of at the center. A left-zero scale can be provided for magnitude measurements because all magnitudes are positive.

(5) Note and record the Phase dial setting (ten-turn range corresponding to 0-100°). The setting should be in the range of 35° to 65°. For the purpose of these checks, think simply in terms of the 0°-100° adjustment range. Do not make "allowances" for the "subtract 50°" instructions beneath the Phase dial.

When the Phase dial phase has been recorded, begin rotating the Phase dial counterclockwise. The magnitude indication will remain unchanged, but the Phase indication (Quadrature meter) will increase, tracking the changing dial setting. The NEG PHASE light will be out. When the dial is fully counterclockwise, the meter will indicate (within 5°) the Phase dial setting recorded at the start of this step. Leave the Phase dial in the fully counterclockwise position.

(6) Press the 90° Phase pushbutton. The NEG PHASE lamp should light and the Phase meter should indicate the difference between 90° and the angle recorded in the previous step. The ±5° tolerance of the Quadrant Selector could introduce as much as 5° of phase meter indication error. The magnitude indication will remain unchanged.

(7) Press the 180° Phase pushbutton. The Phase Meter should indicate the difference between 180° and the angle recorded in step 5. Again, the Phase Quadrant tolerance could introduce as much as 5° error. The magnitude indication will remain unchanged.

(8) Press the 270° Phase pushbutton. The NEG PHASE light should go out and the Phase meter should indicate the sum of 90° and the angle recorded in step 5. Again, the Phase Quadrant tolerance could introduce as much as 5° of error. The magnitude indication will remain unchanged.

(9) Press the 0° Phase pushbutton and set the Phase dial back to the setting recorded in step 5. The Phase meter should indicate 0°. The NEG PHASE indicator could be either lighted or unlighted (or flickering). As a final step, it is advisable to press the IN PHASE and QUADRATURE METER pushbuttons to restore normal lock-in amplifier operation.

This completes the initial checks. If the instrument performed as indicated, the user can be quite confident that the instrument has arrived in good working order.

SECTION IV
OPERATING INSTRUCTIONS

4.1 INTRODUCTION

Although operation of the Model 5202 is straightforward, there are a number of factors to consider to be assured of optimum performance in every application. This section of the manual treats those factors in some detail. Topics covered include a description of the controls, grounding, noise performance, dynamic range, harmonic sensitivity, operation with options, and others. For an overall quick look at how the instrument should be operated, the operator is referred to Section I, the Condensed Operating Instructions.

4.2 FRONT PANEL

Except for some rotary switches and dials, the front panel "controls" consist of a number of pushbuttons, most of which are arranged in sets. Generally speaking, one pushbutton should be depressed in each set when operating. In some instances, operation with more than one pushbutton depressed in a set will not disable the instrument, but it may result in a function other than the one intended being selected. A description of each control and pushbutton follows.

A. **SENSITIVITY:** This multi-position attenuator determines how large a coherent input signal must be applied to obtain full-scale output. Eight different sensitivities from 100 μV full scale to 250 mV full scale are provided. The equivalent dBm levels are also indicated, where dBm = dB with respect to one milliwatt of signal into the 50 Ω input impedance (1 mW of dissipation occurs with 224 mV of rms signal applied). Note that the input sensitivity can be increased by a factor of ten relative to each output by means of the OUTPUT EXPAND X10 pushbuttons, thereby facilitating analyses where the In Phase and Quadrature components vary greatly in amplitude.

B. **OVLD:** This indicator lamp lights when either the input or the output is overloaded, indicating that corrective action must be taken before valid readings can be taken.

C. **SIGNAL INPUT CONNECTOR:** The signal to be measured is applied to this standard BNC connector. The input impedance is 50 Ω to ground.

D. **GROUND LUG:** This lug facilitates use of a grounding strap to interconnect the front panel of the Model 5202 with signal source ground to minimize the effects of ground-loop interference.

E. **REFERENCE PHASE CONTROLS:** These comprise the Phase Quadrant pushbuttons and the Phase dial. They determine the phase lead introduced in the reference channel. The pushbuttons select increments of 90°, the dial provides a linear range extending from 0° to 100°. Note that 50° must be subtracted from the dial setting to find the dialed phase angle. Also, the indicated angles are with respect to the In Phase Mixer. The drive to the Quadrature Mixer leads by another 90°

F. **FREQUENCY RANGE:** This switch selects the range, in MHz, over which the reference channel will lock to an applied signal.

G. **UNLOCK:** This indicator lamp lights whenever the Reference Channel is not locked. Generally, this is an indication that the applied reference signal is unsuitable (see specs), that the FREQ. RANGE switch is not correctly set, or that the settings of the Reference pushbuttons are incorrect.

H. **REF IN CONNECTOR:** The reference signal is applied to this standard BNC connector. The input impedance is 50 Ω to ground.

I. **REFERENCE PUSHBUTTONS:** There are three. Two are for use if the reference signal is a pulse, the third if it is a sine wave.

J. **SLOPE PUSHBUTTONS:** These pushbuttons allow phase detection with respect to the positive or negative going edge of the applied reference. In other words, 0°, as far as the reference channel phase is concerned, can be positioned on either slope, whichever is more appropriate to the input signal.

K. **IN-PHASE METER and PUSHBUTTONS:** The three pushbuttons immediately to the left of the meter determine its function. When the IN PHASE pushbutton is depressed, the meter indicates the level of the in-phase component of the input signal (assuming phase controls are properly adjusted). Full-scale meter deflection corresponds to ±1 V at the I OUT connector. The ±1.0 scale is used if the selected sensitivity is 100 μV, 1 mV, 10 mV or 100 mV. The ±2.5 scale is used if the selected sensitivity is 250 μV, 2.5 mV, 25 mV, or 250 mV.

The other three In-Phase Meter scales are used when the MAGNITUDE pushbutton is depressed (instrument must be equipped with the Vector Phase Option. The vector magnitude is read from the red scales, both of which are unipolar (only positive magnitudes are possible). On the 100 μV, 1 mV, 10 mV, and 100 mV sensitivity settings, the reading is taken from the 0-1.0 scale. On the 250 μV, 2.5 mV, 25 mV, and 250 mV sensitivity settings, the reading is taken from the red 0-2.5 scale.

A dB scale is also provided to indicate the magnitude relative to full scale independent of the selected sensitivity. It is essential that this scale only be used when the MAGNITUDE pushbutton is depressed. This is because it is a full meter-span scale. For making In-Phase readings, a half meter-span dB scale would be required.

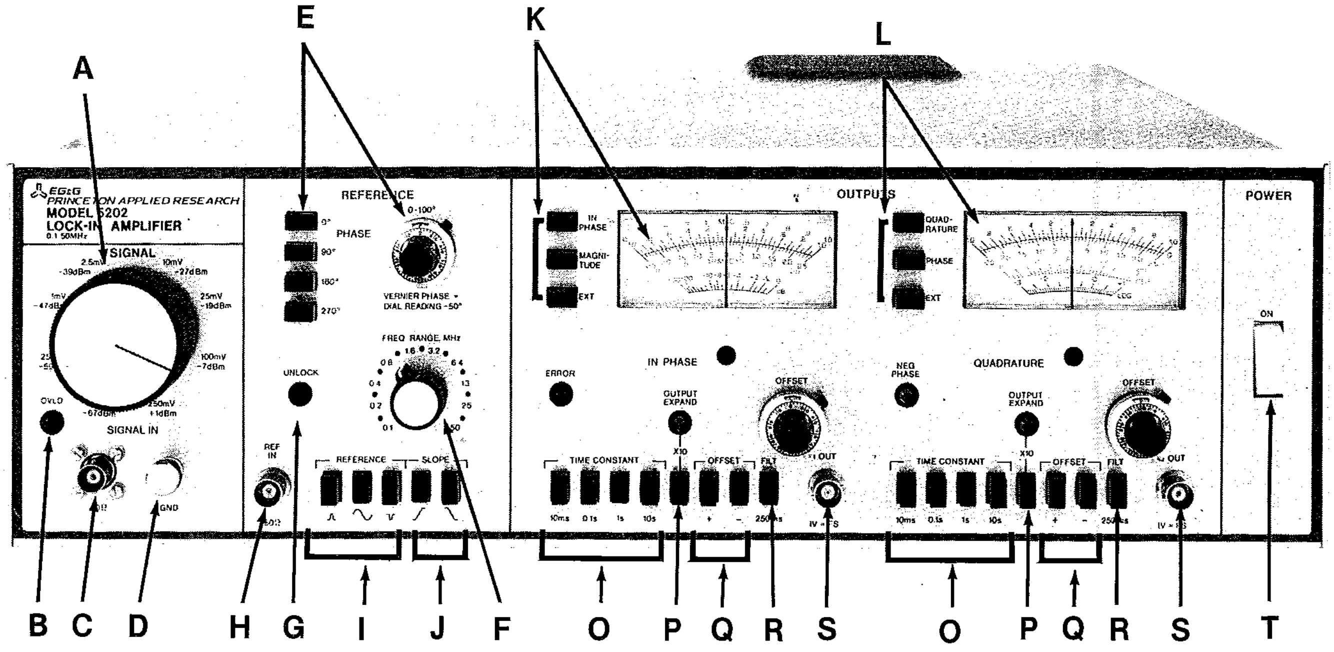


Figure IV-1. MODEL 5202 FRONT PANEL

When the EXT. pushbutton is depressed, the meter indicates the voltage applied to the rear-panel EXT METER IN connector. Full-scale deflection occurs when 1 V is applied. Hence, the uppermost meter scale (±1.0) would normally be used, allowing either negative or positive voltages to be measured. Note that if the Quadrature EXT pushbutton is depressed at the same time, the voltage applied to the EXT METER IN connector will be indicated on the QUADRATURE meter. The Quadrature EXT function, if selected, removes the external voltage from the In Phase meter.

L. **QUADRATURE METER and PUSHBUTTONS:** The three pushbuttons to the left of the Quadrature meter determine its function. When the QUADRATURE pushbutton is depressed, the meter indicates the quadrature component amplitude. These readings are taken from the ±1.0 and ±2.5 scales according to the setting of the Sensitivity switch as described in the preceding discussion of the In Phase meter.

When the PHASE pushbutton is depressed (unit must be equipped with the Vector Phase Option), the vector phase can be read from the Phase scale (unipolar red scale), which has a range of 0° to 180°. If the phase is negative, the NEG PHASE front-panel indicator lamp will glow.

When the EXT. pushbutton is depressed, the meter indicates the level of the voltage applied to the rear-panel EXT METER IN connector. Full scale is ±1 V. Should both the In Phase EXT pushbutton and the Quadrature EXT pushbutton be depressed simultaneously, the Quadrature Channel will dominate and only the Quadrature meter will respond to the voltage at the EXT METER IN connector.

M. **ERROR LIGHT:** This indicator lamp is only active when MAG and/or PHASE meter functions are selected. Error light indicates any of five different operator-controlled conditions (see specs) that can result in invalid readings. Before a measurement can be taken, the error must be determined and corrected.

N. **NEG PHASE:** This indicator lamp is only active in units equipped with the Vector Phase option. It lights whenever the phase of the input signal is negative (lags) with respect to the reference drive signal at the In Phase Mixer. Inclusion of this light allows a 0-180° phase reading scale with discontinuity-free phase readings.

O. **TIME CONSTANT SWITCHES:** These pushbuttons allow any of four different filtering time constants to be selected. Together with the Output Filter, they directly determine the PSD bandwidth, and thereby the theoretical improvement in signal-to-noise ratio. Note that with all four pushbuttons released, the time constant is reduced to the minimum, nominally 1 ms.

P. **OUTPUT EXPAND:** These pushbuttons allow the output gain to be increased by a factor of ten, thereby effectively achieving a tenfold increase in input sensitivity. A lamp provided in each channel lights when the Expand function in that channel is activated.

Q. **OFFSET CONTROLS:** Two Offset dials, one for each channel, can be adjusted for a calibrated dc offset at either output of up to ten times full scale. Either polarity can be selected by pushbuttons. Should both pushbuttons in a set be depressed, the effect is the same as if the "–" pushbutton only had been depressed. The principal utility of the Offset capability is that it allows small variations in an otherwise steady signal to be examined more easily than would otherwise be the case.

R. **FILTER PUSHBUTTONS:** A filter having a time constant of 250 ms can be inserted with this pushbutton. This filter follows the main time constant filter (controlled by the Time Constant pushbuttons). Primary noise reduction is accomplished by the main time constant filter, with the post filter providing some additional smoothing.

S. **I OUT and Q OUT CONNECTORS:** The outputs of the two channels are available at these connectors and at the two corresponding rear-panel connectors. The channel outputs are provided independently of the METER pushbuttons, with agreement between the meter indication and the output voltage occurring only when the IN PHASE and QUADRATURE meter pushbuttons are depressed.

T. **POWER SWITCH:** This switch turns the ac power to the instrument on or off as desired. A light internal to the switch glows when the power is on.

4.3 REAR PANEL

A. **POWER INPUT ASSEMBLY:** The line cord is plugged into this connector. Directly to the right of the connector is the housing for the fuse and for the line voltage selection circuitry. For details, see Subsection 3.3.

B. **EXTERNAL METER INPUT:** A voltage applied to this connector (input resistance 10 kΩ) can be read on either panel meter according to which of the front-panel EXT Meter pushbuttons is depressed. Should both be depressed, the voltage will be read on the QUADRATURE meter. Full-scale deflection results from ±1 V being applied.

C. **I and Q OUTPUT:** These two outputs are in parallel with the corresponding front-panel connectors.

D. **MAGNITUDE:** In units equipped with the Vector/Phase option, the MAGNITUDE output voltage is provided at this connector. Full-scale output is 1 V through 600 Ω.

E. **PHASE:** In units equipped with the Vector Phase option, the Phase output voltage is provided at this connector. The transfer function is 10 mV/° or 1.8 V for 180° (output resistance is 600 Ω).

F. **RATIO OPTION:** There are two input connectors, A and B. A three position toggle switch selects which of the three possible functions is to be computed. This function is made available at the associated RATIO OUT connector. The Ratio can be read on Quadrature Panel meter by connecting the Ratio Out connector to the EXTERNAL METER INPUT connector and then depressing the front-panel Quadrature EXT. Meter pushbutton.

G. **ACCESSORY INTERFACE CONNECTOR:** This connector is provided as a convenience in interfacing the Model 5202 to peripheral apparatus. Units are shipped with ±15 V and ground made available at this connector for powering external apparatus from the Model 5202. Any other signal connections must be made by the user. The function/pin assignments are as given in Table IV-1.

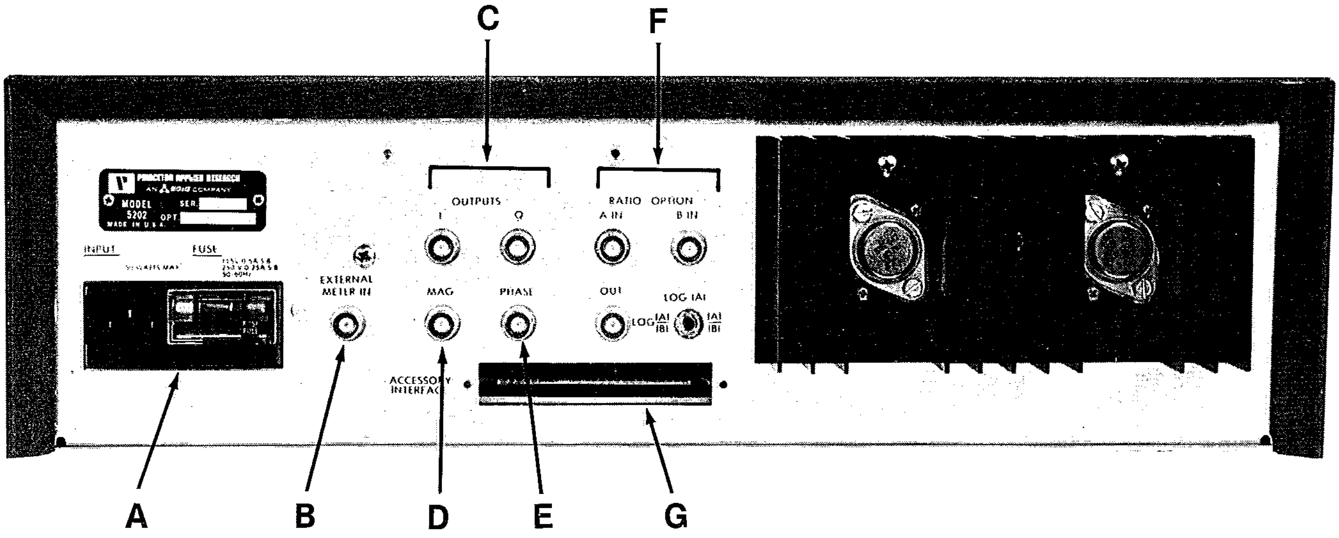


Figure IV-2. MODEL 5202 REAR PANEL

PIN	FUNCTION
9A, 9B, 17A, 17B	+15 V
10A, 10B, 16A, 16B	−15 V
12A, 12B, 14A, 14B	GND

Table IV-1. INTERFACE CONNECTOR PIN ASSIGNMENTS

4.4 PRELIMINARY CONSIDERATIONS

4.4A POWER REQUIREMENTS

The Model 5202 requires 100-130 V ac or 200-260 V ac; 50-60 Hz. The power consumption is 50 watts. Line voltage selection is made by appropriately orienting a circuit card located in the fuse housing at the rear of the instrument (see Subsection 3.3).

4.4B FUSE

The Model 5202 is protected by a single fuse located at the rear panel. A slow-blow 1/2 A fuse is used for operation from a line voltage in the range of 100 V ac to 130 V ac. A 1/4 A fuse is used in the range of 200 V ac to 260 V ac. It may happen that a slow-blow fuse will fail in shipment as a result of shock and vibration. As a result, if the fuse is found to be bad when the instrument is operated for the first time, it is advisable to try to change the fuse. If normal operation follows, chances are there are no other problems. However, if the replacement fuse fails, there is an instrument malfunction that will have to be corrected before proceeding.

4.4C WARMUP

For most applications, five minutes is sufficient. However, where it is necessary to achieve the best possible gain and phase stability, allow an hour.

4.4D FREQUENCY

Although one can, in principle, make equally accurate measurements at any frequency within the instrument's operating range, operation is least subject to error over the "middle" part of the operating range, that is, from about 300 kHz up to about 10 MHz. Above and below this range, the sensitivity calibration is subject to errors larger than ±0.5 dB. Also, at the high end of the band, such factors as radiation interference and phase shift errors can be a problem.

4.4E GROUNDING

In any system processing low-level signals, proper grounding to minimize the effects of ground loop currents is an important consideration. As shown in Figure IV-3, a typical system wiring and cabling configuration gives rise to ground loops. Currents flow in this loop, principally through the braids of coaxial cables and through the third wire ground line of the ac power distribution network. These currents arise in ac fields at various frequencies cutting the loop. The power frequency and its harmonics will be present, and possibly other frequencies as well, according to the operating frequency and shielding of the various system components. Additionally, some signals may be injected directly into the loop, such as could be the case where an inadequately separated reference drive signal finds its way onto the signal line.

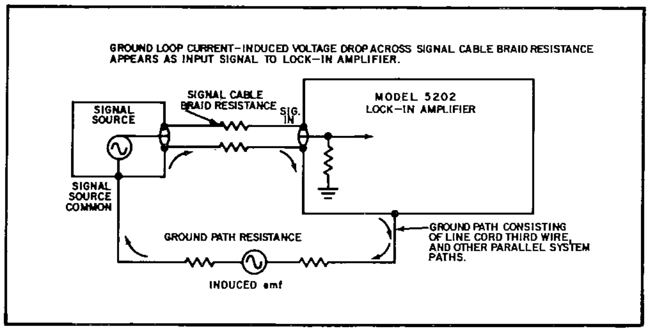
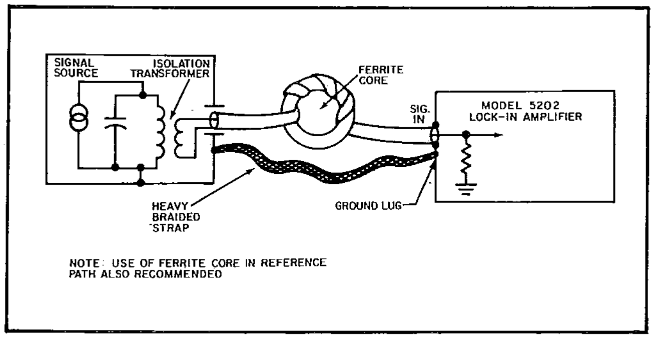

GROUND LOOP CURRENT-INDUCED VOLTAGE DROP ACROSS SIGNAL CABLE BRAID RESISTANCE APPEARS AS INPUT SIGNAL TO LOCK-IN AMPLIFIER.

Figure IV-3. GROUND LOOPS IN MEASUREMENT SYSTEM

Generally speaking, the best one can do in high frequency operation is to shunt the signal cable braid by a much lower resistance, effectively shorting out the ground loop voltage signal in the cable braid, and thereby preventing it from being recognized as "signal" by the lock-in amplifier. A front-panel ground lug adjacent to the Signal Input connector is provided for this purpose. Best results are obtained when this lug is connected to the front panel of the signal source by a low resistance length of copper braid. The braid should be of as heavy a gauge as possible, that is, its resistance should be as small, relative to the braid of the signal cable, as it is possible to make it.

Another technique is to make several turns around a ferrite core with the signal cable, thereby raising the high frequency ground loop impedance without altering the signal impedance. It is frequently worthwhile to use this same technique with the reference cable. It is important, however, that a separate ferrite core be used for each cable; they should not both be wound onto the same core.

Finally, the signal cable ground loop can be effectively broken by using an rf coupling transformer whenever possible. This gives the additional advantage of impedance transformation as required to couple maximum signal into the lock-in amplifier. Figure IV-4 shows all of these techniques in use in a single system for maximum freedom from ground-loop interference.



NOTE: USE OF FERRITE CORE IN REFERENCE PATH ALSO RECOMMENDED

Figure IV-4. SYSTEM WITH GROUND-LOOP MINIMIZATION TECHNIQUES EMPLOYED

4.4F NOISE

Any electronic signal processing system adds noise to that already accompanying the signal to be measured, and the Model 5202 is no exception. However, as stated in the specifications, the internal noise of the Model 5202 is less than 10 nV/Hz½ from 100 kHz to 50 MHz. Since the function of a lock-in amplifier is to accept a noisy signal and to effect an improvement in signal-to-noise ratio, the internal noise is of no consequence unless it is large relative to the noise already accompanying the signal. That should not be the case for the Model 5202 in almost any application. Typically encountered input signals will almost certainly be so large as to make the internally generated noise of no consequence.

More frequently the user will have to be concerned with the noise characteristics of any preamplifier that might be used ahead of the Model 5202. One convenient way of specifying the noise performance of a preamplifier is to speak of its noise figure, which indicates the amount of noise the preamplifier adds to the source thermal noise. Source thermal noise is used as the base for comparison because it is completely predictable, always present, and is the least amount of noise that can possibly accompany any signal. Its value, in volts rms, is given by the following formula.

$$E_n = \sqrt{4kTBR_s}$$

where:

E_n = rms noise voltage within the bandwidth of the measurement

k = Boltzmann's constant = 1.38×10^{-23} joules/kelvin

T = absolute temperature in kelvins

R_s = resistance in ohms of the resistive component of the impedance across which the voltage is measured

B = Bandwidth over which the measurement is made

Mathematically stated, noise figure can be defined as:

$$NF_{dB} = 20 \log_{10} \frac{\text{Noise Voltage at Output of Preamplifier}}{\text{That Portion of Numerator Attributable to Source Thermal Noise}}$$

Noise figure is not constant but varies as a function of the source resistance, frequency, and temperature. When the loci of all points having the same noise figure are plotted as a function of frequency and source resistance (temperature fixed), the result is a noise figure contour. A full set of contours completely specifies the noise characteristics of the preamplifier over its working range. The utility of these contours are, first of all, that they clearly indicate the best noise performance region in terms of operating frequency and source resistance, and secondly, that they allow one to directly compute the total noise accompanying the signal (amplifier noise and source thermal noise considered, other noise source neglected). The relating formula is

$$E_t = \sqrt{4kTBR} \times 10^{NF/20}$$

where E_t is the total noise referred to the input of the preamplifier in volts rms and all other terms are as previously defined. With a noise figure of 3 dB, the amount of noise contributed by the amplifier is 1.4 times the source thermal noise. At 1.4 times the thermal noise, the amplifier noise just begins to be noticeable. At lower noise figures, the preamplifier is, for all practical purposes, noiseless. Generally, if one can operate anywhere inside the 3 dB contour of the preamplifier, its noise behavior can be neglected.

Again, it must be emphasized that source thermal noise and preamplifier noise are purely academic considerations if the input signal is large relative to these noise sources, as is frequently the case. It might also be noted that an input signal may be accompanied by types of noise other than thermal. Where this is the case, the amplifier or preamplifier can only perform "better" than is indicated by the noise figure. The contours are based on the incremental noise the amplifier adds to the *minimum possible* noise accompanying the signal, namely, the source thermal noise. With other types of noise present, the noise added by the amplifier can only appear smaller.

4.5 OPERATING THE 5202

4.5A INTRODUCTION

Operation of the Model 5202 is straightforward. In most instances, the user simply connects the reference signal and the input signal, followed by adjusting the Frequency Range, Sensitivity, and Phase controls as required for the frequency signal level, and the kind of measurement being made. Should an overload occur, the Time Constant is increased and/or the sensitivity is reduced as required to eliminate the overload. The output readings can then be taken. Each of these considerations is discussed in greater detail in the following paragraphs.

4.5B REFERENCE CHANNEL

An outstanding feature of the Model 5202 is its unique reference channel that allows it to lock onto and track a wide range of possible reference input waveforms. Once locked on, the reference remains locked on, even if the reference input signal changes in frequency, provided the frequency change does not exceed the limits of the FREQ. RANGE switch setting. This switch divides the total operating range of the instrument into nine "octave" segments. Unless the actual applied reference signal falls in the selected octave, the reference channel will not lock or track. If the reference signal does fall in the selected octave, frequency lock always occurs within 0.1 s.

The reference channel locks to virtually any signal having amplitude excursions of at least 300 mV pk-pk. Moreover, three different "modes" are provided that allow the reference channel parameters to be tailored to the signal at hand. As indicated by panel symbolization beneath the REFERENCE pushbuttons, either zero-crossing (center pushbutton) or threshold (left and right pushbuttons) detection can be selected. The detection point defines 0°. Signal phase is measured or compensated (Reference Phase controls) with respect to this point. Where the applied reference signal is a sine wave, best results are generally obtained by operating with the center REFERENCE pushbutton depressed, as illustrated in Figure IV-5. Detection takes place near the positive going or negative going crossover, according to which of the two SLOPE pushbuttons is depressed. Where the reference signal is a pulse, or where ringing is present that would give undesired detection points in the sine wave mode, a pulse mode should be

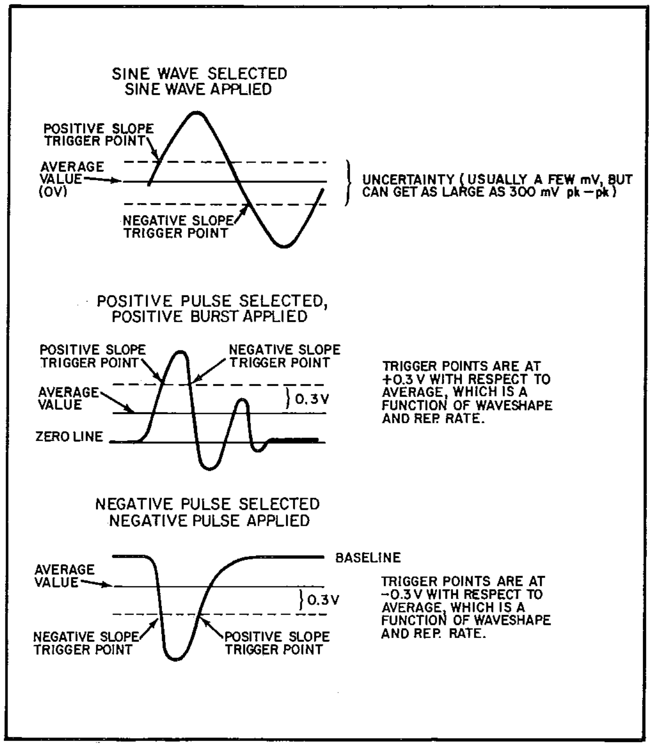


Figure IV-5. REFERENCE DETECTION

selected, either positive or negative according to the characteristics of the applied reference signal.

Even though the Model 5202 can accept and track a wide range of possible reference signals, it is nevertheless important that the reference signal used be relatively noise free. This is particularly true when operating in the sine wave detection Reference mode. Any noise superimposed on the reference signal can cause many small zero crossings to occur in the region of the main waveform zero crossings, with the result that the Reference Channel momentarily "sees" a much higher reference frequency than what is really there. When this happens, the reference "lock" can be lost. Frequently, moderately noisy signals can be cleaned up sufficiently for satisfactory operation by interposing a single-section low-pass filter between the reference signal source and the Reference Input connector. The filter time constant should be such as to attenuate the noise significantly while still passing the reference signal largely unaffected.

PHASE CONTROLS: A high resolution potentiometer covering the range of 0-to-100 degrees works in conjunction with four Quadrant pushbuttons to determine the phase of the synchronous detection process. The Phase controls introduce lead in the drive to the detection circuitry. With a continuous range of 360°, the lead can always be adjusted

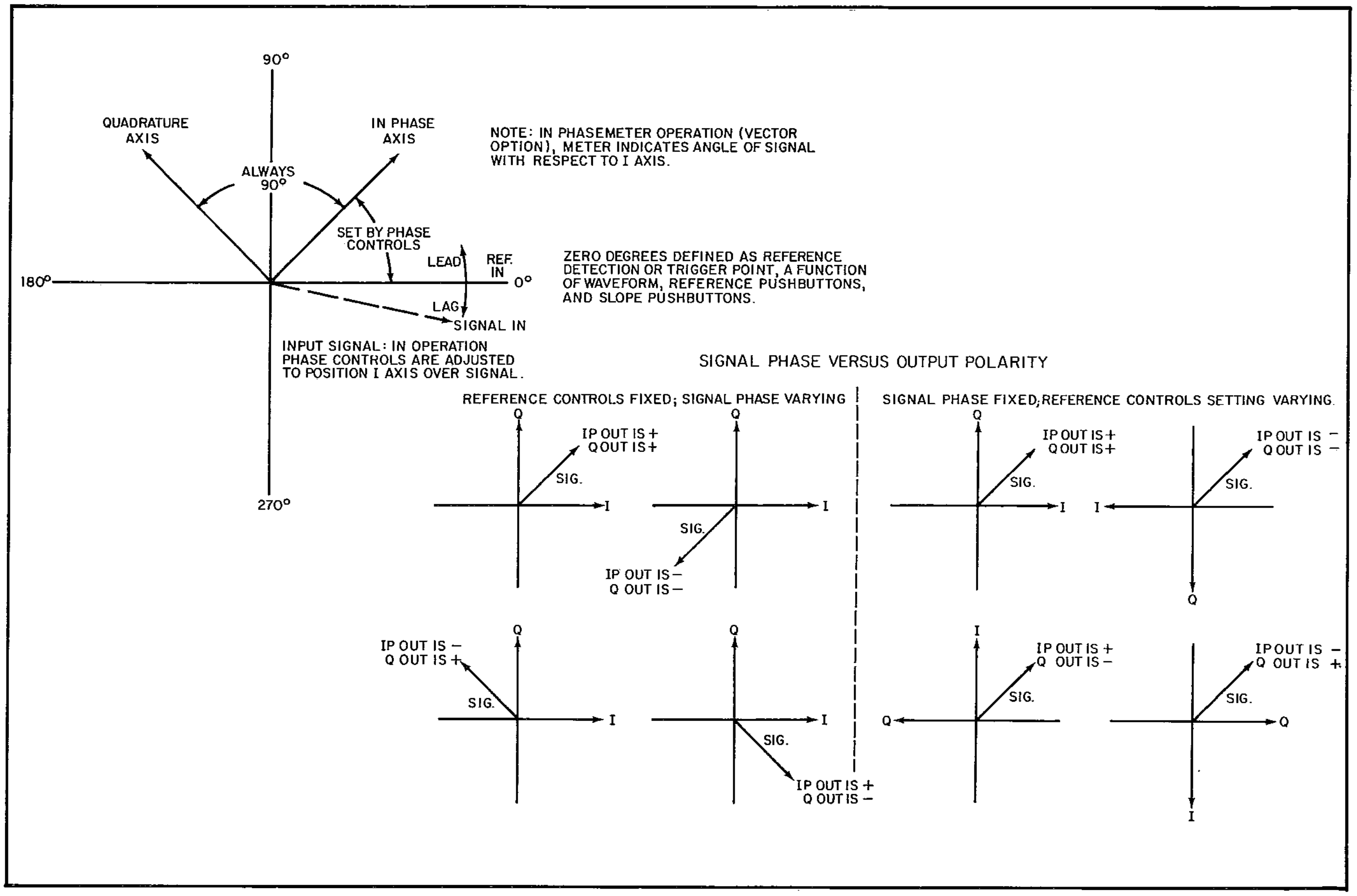


Figure IV-6. LOCK-IN AMPLIFIER PHASE RELATIONSHIPS to where the detection drive is in phase with the input signal. Note that the magnitude of the introduced lead equals the selected Quadrant pushbutton plus the difference of the Vernier setting minus 50°. For example, suppose maximum In Phase indication (identically "0" quadrature indication) occurs with the 90° phase pushbutton depressed and with the Phase Vernier dial set to 7.5 full turns from the fully counterclockwise position. The absolute phase lead would be 90 + (75–50) = 115°. In other words, the reference signal had to be advanced 115° from the detection point to be brought into phase with the input signal. Otherwise stated, the input signal leads the reference detection point by 115°. All of these phases apply to the In Phase detection process only; at the Quadrature detector, the reference phase always leads by an additional 90°.

Note that, whereas the Phase controls are always read in degrees of lead introduced in the *Reference Channel,* the Phase meter (Vector Phase option installed) indicates degrees of lead or lag (range of 180° for each) in the *Signal Channel.* In other words, a bit of care is required in interpreting the two kinds of phase indications. As a final note, the user should bear in mind that even though the phase shift accuracy of the Phase Dial and Phase Quadrant switches is ±5°, the overall phase accuracy of the instrument is ±15°. The prime function of the Reference Phase controls is simply to bring the reference detection process into phase with the input signal and not to measure phase with accuracy and precision. The Phase Detection relationships are illustrated in Figure IV-6.

Both detection channels provide a dc output proportional to the amplitude of the input signal and that varies with the cosine of the angle (at the mixer) between the input signal and the reference. The Phase controls are used to set that angle to 0° at one detector or the other. Assuming the controls were adjusted for peak indication at the In Phase meter, the In Phase meter would indicate the amplitude of the signal component that leads the reference signal by the angle set by the Phase controls. The Quadrature meter would indicate the amplitude of that component which leads by an additional 90°.

Where the phase is to be set for maximum indication on one of the meters while monitoring a noisy signal, meter fluctuations due to the noise could make it difficult to find the Phase setting that gives the desired maximum. If this happens, it will usually prove more accurate and expedient to adjust for null on the other meter. The eye is a much better null detector than peak detector. Also, the rate of change of the cosine near the zero crossing is large relative to what it is near the peak.

In some applications, it may be desirable to know the net phase shift or error through the instrument. This can be determined quite simply if the instrument is equipped with the Vector Phase option. The phase is measured at the operating frequency by applying a noiseless, in-phase signal to both the signal and reference inputs. Provided the Phase controls are set to 0° (in the Model 5202 this is done by pressing the 0° pushbutton and setting the Phase dial to five full turns from the fully counterclockwise position), the Phase meter will indicate the net phase shift through the instrument. This shift can be compensated for in any subsequent real measurements, bearing in mind that frequency shifts and/or changes in the character of the applied reference signal (changes detection point) could introduce new errors.

The phase errors discussed in the preceding paragraphs are defined with respect to the reference input detection point. With a 1 V rms sine wave input or fast pulse input, this detection (reference channel 0°) will coincide with 0° at the Reference Input connector. With lower amplitude sine wave reference inputs, or with waveforms of other shapes, reference detection may not occur at the same point relative to the input signal to be measured. For example, with a sine wave reference of just sufficient amplitude to be detected by the Reference channel, and assuming the input signal is exactly in phase with the reference, there will be a phase error of nearly 90°. With a larger sine wave applied to the reference input, the error will be less, decreasing to a negligibly small level at the "optimum" level of 1 V rms. Similar problems can occur with a pulse input. Also, by triggering on the wrong slope, a delay equal to the width of the applied pulse could be inadvertently introduced. The point of all this is that the phase of the reference relative to the input signal, considered relative to the reference detection point, can differ significantly from the phase of the reference relative to the input signal as observed at the respective input connectors. This phase shift should not prove a problem if it is understood. Trigger-point phase errors are illustrated in Figure IV-7.

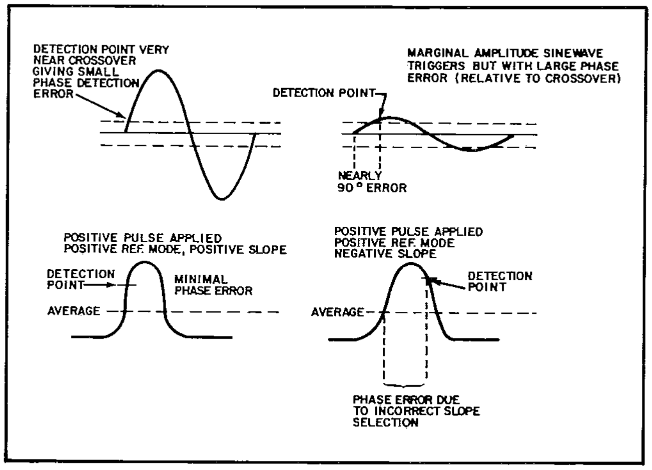


Figure IV-7. TRIGGER POINT PHASE ERRORS

4.5C SIGNAL CHANNEL

Operation of the Model 5202 signal channel is simple. In addition to connecting the signal to be measured to the SIGNAL IN connector, the user need only set the Sensitivity switch for maximum panel meter indication without overload.

As far as connecting to the input is concerned, the important thing to remember is that the Model 5202 input impedance is 50 Ω. Consequently, to prevent the input cable from appearing reactive, a cable having a characteristic impedance of 50 Ω should be used. In some applications, it may be important that there be no net phase shift in the cable, that is, that the phase shift introduced by the signal input cable be the same as that introduced by the reference input cable. This is accomplished by using the same type of cable in both places and by making both the same length. Another cable related problem is that of interfering ground loop currents. As discussed previously, one recommendation is to make the ground path resistance between the front panel of the Model 5202 and signal source common as low as possible. This is done by connecting a heavy ground strap between signal source common and the ground lug located just to the right of the Signal Input connector. Other techniques can also be used to minimize or eliminate ground loop problems. One is to take the signal input cable and make several turns on a ferrite core before connecting it to the Model 5202 input. The effect will be to raise the impedance seen by the ground loop currents while having no effect on the signal itself. With the ground loop impedance elevated, the benefit of the parallel ground strap will be enhanced. Still another recommendation is, whenever possible, to drive the Signal Input cable with an rf transformer. This applies whether or not the source is a tuned circuit. The transformer provides a ground loop "break", one degraded only by the stray capacitive coupling from primary to secondary.

Overload prevention involves not only the input channel, but the output channels as well. A lock-in amplifier has a specific passband as determined by the time constant filter. Signals at the reference frequency are converted to dc; the amplitude transfer function is such that a coherent input signal of the amplitude selected with the SIGNAL INPUT selector will be a converted to a full-scale output dc level. Should the coherent input signal exceed that level, output overload will occur as indicated by the OVLD light. Non-synchronous input signals (noise) are not converted to dc. The sum and difference frequencies produced by mixing them with the reference do, however, appear. These are attenuated by the time constant filters; the longer the selected time constant, the greater the attenuation. In other words, the amplitude of non-synchronous signals not at the reference frequency can be higher than input full scale without introducing output overload. The further these signals are from the reference signal, the greater they will be attenuated by the time constant filters, and the greater their input amplitude can be without causing output overload. The limiting amplitude is that which causes the input amplifiers to overload. As indicated in the specifications, input overload occurs at 200 times full scale. This limit is defined in terms of the maximum peak noise voltage before input overload to the peak voltage of a full-scale synchronous sine wave. For example, on the 100 μV sensitivity setting, the peak amplitude of a full-scale synchronous sine wave would be 141 μV. Far from the reference frequency, input overload occurs at 200 times this level, that is, noise peaks as high as 282 mV can be tolerated. Note that there is an absolute input limit of 5 V peak, which would limit the maximum input to much less than 200 times full scale at the lower sensitivities.

Another factor to consider is the OUTPUT EXPAND X10 function, which increases the output gain by a factor of ten. As a result of this increase in output gain, the instrument sensitivity is increased by a factor of ten as well. The synchronous signal that yields full-scale output need only be one tenth the amplitude indicated by the Sensitivity switch. Although the tolerance to noise as a function of switch position remains the same, the tolerance as a function of input full-scale signal is increased from X200 to X2000. The absolute limit of 5 V peak always applies.

Given this background, the user should have little difficulty in minimizing overload as a source of difficulty in signal measurements. If the OVLD indicator lights when the input signal is applied, first make sure that the overload is not taking place at the output. Increase the time constant to where meter fluctuations are reduced to an acceptable level. If necessary, press the FILT pushbutton as well, bearing in mind that the time constant filters are the most important in preventing overload. If one or both panel meters deflects offscale, it is a clear indication that the synchronous input signal exceeds full scale and that the input sensitivity should be reduced.

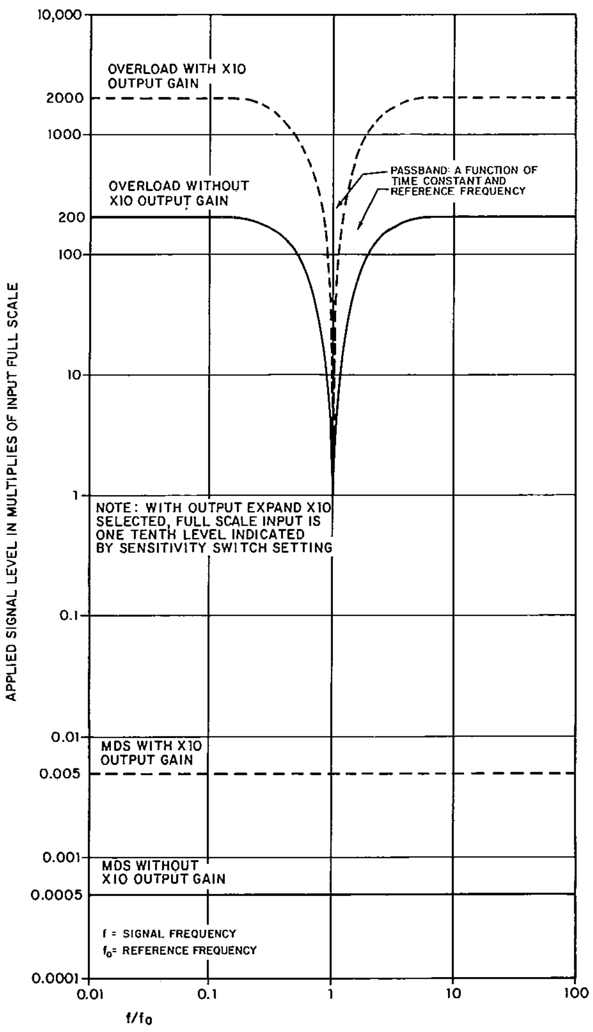


Figure IV-8. MODEL 5202 DYNAMIC RANGE

When all these remedies have been tried, that is, the time constant filtering is high enough to "smooth" the output and the meter indications are on scale, then the problem is probably one of input overload. If the overload results from broadband noise, the frequency of the overload peaks may be greatly reduced by employing a tuned filter ahead of the lock-in amplifier. In many instances, a simple high-pass low-pass RC filter may do the job. The goal is not necessarily to eliminate the noise altogether, but to reduce the number of overload indications to an "acceptable" level. Although this is impossible to quantify, an occasional flicker of the overload light is ordinarily no cause for concern. It is when it is "hard on" that significant measurement error occurs. Sometimes the noise will be concentrated at a single frequency or in a narrow band of frequencies well removed from the signal frequency. Again, use of a tuned filter ahead of the Model 5202 may be the best solution. If all of these techniques are used, and input overload still occurs, there is no further remedy other than to reduce the input sensitivity. Although the internal noise and drift of the instrument as a fraction of the output will be increased, the measurement accuracy degradation should be insignificant, particularly given the fact that an extremely noisy signal is being measured in the first place. The output fluctuations resulting from the input noise will far exceed those stemming from the internal noise of the instrument. The X200 overload factor (X2000 with OUTPUT X10 EXPAND selected) is really a measure of dynamic reserve. Dynamic range, the real limiting parameter of a lock-in amplifier capability to make difficult signal measurements, is the ratio of the peak input (X200 f.s.) to the minimum discernible signal (MDS) as determined by the output stability (±0.05%). Thus the real dynamic range of the Model 5202 is 200/0.0005 = 400,000. With the X10 OUTPUT EXPAND function selected, the dynamic range is unchanged; the dynamic reserve increases by an order of magnitude to 2000 and the MDS increases from .05% to .5%, giving 2000/0.005 = 400,000 as the total dynamic range. Figure IV-8 illustrates the Model 5202 dynamic range relationships.

Summarizing, a recommended technique for dealing with overload is to proceed as follows.

(1) Increase the Time Constant. Go to the maximum of 10 s if necessary. If the observed meter fluctuations are unacceptably high, press the FILT pushbuttons as well.

(2) With the high time constant still in, note the meter indications. Should either meter exceed full-scale deflection, reduce the input sensitivity as required to bring the meter indication(s) on scale.

(3) If the overload persists, select the X10 OUTPUT EXPAND function. Watch the meters, if they deflect beyond full scale, reduce the sensitivity again.

(4) If the overload persists, monitor the input signal with an oscilloscope. See if an external filter can be used to narrow the bandwidth about the signal frequency, or to eliminate some strong single frequency interference if that is the problem.

(5) If the overload still persists, further reduce the input sensitivity. If the input noise peaks are "bumping" the 5 V peak limit, use an external attenuator as required so that operation on the 25 mV, 100 mV, or 250 mV Sensitivity switch positions will not be necessary. In these positions the full X200 (or X2000) reserve is not available because of the 5 V peak limit. As long as the signal is large relative to the MDS of the instrument, it should be possible to make the measurement.

4.5D OUTPUT CONTROLS

The coherent signal at the input of a lock-in amplifier is converted to dc by the synchronous detection process. All the noise that accompanies the signal at the input will be frequency shifted by $\pm f_r$ and will appear at the detector output as well. Thus, post-detector noise elimination is an important consideration. Low-pass filters controlled by the operator are used to reduce the output bandwidth as required to achieve an acceptable output noise level. Since the signal of interest is at dc, the filter time constant can be made extremely large without affecting the signal amplitude indication in any way. In principle, the signal-to-noise ratio can be improved to any arbitrary degree simply by making the filter time constant long enough. Practical considerations, however, generally set the limit to what can be achieved. The improvement in signal-to-noise ratio varies with the square root of the time constant. As a result, the measurement time becomes exceedingly lengthy as the time constant is increased to obtain better signal-to-noise ratios. As a practical guide, the correct filtering time constant is the one that reduces the noise to an "acceptable level".

Two separate dc filters are provided for each of the dc channels. There is TIME CONSTANT filter, with pushbutton selectable time constants of 10 ms, 0.1 s, 1 s, 10 s, and <1 ms (all pushbuttons released). In addition, there is the post filter controlled by the FILT pushbuttons. This additional 250 ms time constant filter provides additional smoothing useful for reducing "recorder jitter". With relatively quiet input signals, its use is seldom necessary. Both the Time Constant filter and the post filter have rolloff rates of 6 dB/octave. The equivalent noise bandwidth of a single section 6 dB/octave filter is 1/4 TC. Its rise time from 10% to 90% of full amplitude is 2.2 TC (0% to 95% is 3 TC).

When both filters are used, the relationship defining the equivalent noise bandwidth and rise time as a function of time constant is more complex. For all practical purposes, if the time constant of one is a factor of three or more longer than the time constant of the other, the longer one will dominate and the single section expression using the longer time constant will characterize the rise time and equivalent noise bandwidth reasonably well. Figure IV-9 illustrates the filter interactions.

There is a constraint that applies to the use of the Time Constant and Post-filters in units equipped with the Vector Phase option, namely, that the filtering in both output channels must be the same. If the post filter is selected in one channel, it must be selected in the other. If the Time Constant in one channel is 1 s, it must be 1 s in the other. Similarly, the gain in both output channels must be the same. Practically stated, this simply means that if the OUTPUT EXPAND X10 is selected in one channel, it must be selected in the other as well. Failure to adhere to these strictures will result in invalid magnitude and phase readings. **NOTE:** These errors are specifically detected internally, as indicated by the ERROR indicator lighting.

ZERO OFFSET DIALS: These ten-turn dials and their associated polarity pushbuttons allow calibrated offsets of up to ten times full scale to be applied. This feature, in addition to allowing small amplitude variations in a signal to be expanded and examined in detail, allows a signal amplitude to be read with greater resolution than is possible with the panel meters alone. For example, suppose one had some positive meter indication. To read the amplitude with the greatest resolution, the "+" ZERO OFFSET pushbutton would be depressed and the dial adjusted for meter null, at which time the signal amplitude could be read directly from the dial. Operation with both polarity pushbuttons depressed is the same as with the "–" pushbutton alone depressed. If both pushbuttons are released, the offset function is turned off.

The following example illustrates how the OFFSET feature can be used to facilitate the measurement of small changes in signal amplitude. Suppose one had a 70 μV signal. Assuming this were measured on the 100 μV sensitivity range with no output expansion, the resulting meter indication would be 70% of full scale. To examine small variations in this signal, one would first set the polarity switch to "+" (assume initial meter indication were positive), followed by adjusting the Offset dial for meter null. The Offset dial setting required would be 0.70 and the meter sensitivity would be ±100 μV with respect to the 70 μV ambient level. A recorder connected to the output would allow the amplitude variations as a function of some experimental parameter to be recorded.

If X10 Output Expansion were then selected, the sensitivity of the measurement could be expanded. The signal amplitude (70 μV) would still be less than 10X full scale (range of Offset dial is ten times new input full scale of 10 μV), and so would fall within range of the Offset dial. If the dial were adjusted for null (setting of 7.00), the meter would read ±10 μV full scale with respect to the 70 μV ambient signal level, allowing very small signal amplitude changes to be easily recorded.

I and Q OUTPUTS: There are two front-panel Output connectors, one for the In Phase channel and the other for the Quadrature channel. The output resistance of both is 600 ohms and full-scale output is ±1 V. The rear-panel In Phase and Quadrature connectors parallel those on the front panel. These connectors always carry the In Phase and Quadrature outputs, regardless of the selected meter functions. If the IN PHASE and QUADRATURE Meter pushbuttons are depressed, the meter indications relative to full scale will be the same as the voltage at these two connectors. However, with any of the other meter functions selected, the meter indication will differ from the In Phase and Quadrature output voltages as appropriate for the selected meter function. In other words, the instrument always functions as a two phase lock-in amplifier and the In Phase and Quadrature outputs are always provided at the I OUT and Q OUT connectors. Other instrument functions may be possible, according to the options installed, but selection of an optional function will not affect the I OUT and Q OUT levels. The meters will indicate the option output, if appropriate, or the corresponding analog voltage can be measured at the rear-panel Output connector provided for the option in question.

4.6 HARMONIC SENSITIVITY

Coherent signals harmonically related to the input signal fundamental influence the output indication and must be

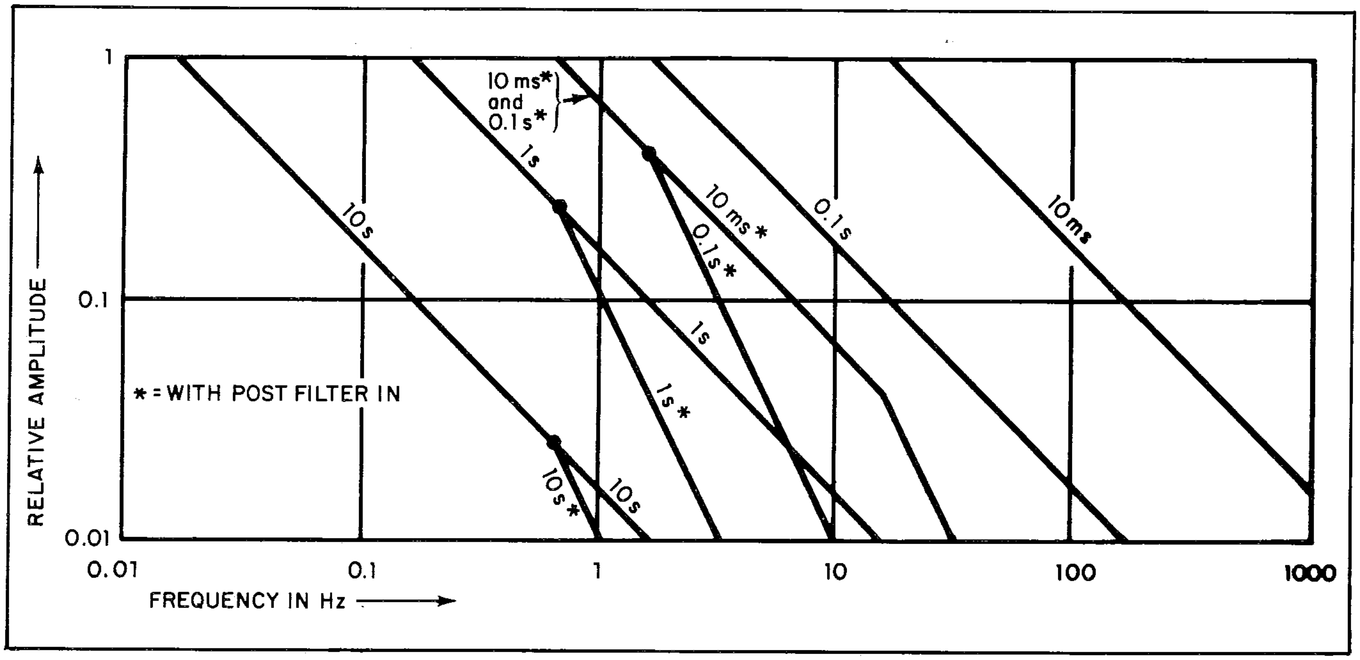


Figure IV-9. TIME CONSTANT AND POST-FILTER INTERACTIONS taken into account when processing non-sinusoidal signals. Although the output meters of the Model 5202 are rms calibrated, the instrument itself is average responding and so provides "true" readings only when the input signal is a sine wave. The response to any given harmonic is exactly proportional to the amplitude of the corresponding component of the reference drive to the RF Mixers. Since the reference drive signal is a square wave (this is true regardless of the shape of the waveform applied to the Reference Input connector), the Mixers have an odd harmonic response of 1/n, where n is the order of the harmonic. It follows that there should be no response at all to even harmonics (they do not contribute to the square wave). Unfortunately, no square wave is absolutely symmetrical, and any residual dissymmetry gives the demodulators a net response to even harmonics. In the case of the Model 5202, the worst case even harmonic response of the demodulators is about 1%.

The Model 5202 signal channel has a flat response, which means that all input harmonics that fall in the passband of the instrument are applied to the demodulators without attenuation or phase shift. However, since the reference drives to the two demodulators are 90° out of phase, the harmonic response is not the same at each demodulator. In the case of a square wave input signal, which consists of the fundamental and its odd harmonics only, all of the harmonics are in phase with the fundamental. As a result, assuming the Phase controls are adjusted for maximum In Phase meter deflection, these harmonics arrive at the In Phase Mixer in phase with the reference drive to the In Phase Mixer, and the harmonics add to the output of the In Phase channel. At the Quadrature Mixer, both the fundamental and the odd harmonics arrive in quadrature with the reference drive to that mixer and there is no Quadrature output. If passband limiting of some kind is used ahead of the instrument, other phase relationships will occur, with resultant different harmonic responses.

The following examples should help to summarize the preceding discussion into some useful numbers. With a pure sine wave input, the panel meters indicate the rms amplitude of the input signal. This is true whether or not passband-limiting is used ahead of the instrument. If, of course, the signal fundamental is attenuated ahead of the instrument, that attenuation will have to be taken into account.

If the input signal is a square wave, the instrument will read "high" due to the harmonic response. A square wave having a pk-pk amplitude of 1.8 times the selected rms sensitivity will yield full-scale output. In other words, if one were operating with the Sensitivity set to 100 mV, a 180 mV pk-pk input square wave would yield full-scale output. If a low-pass or bandpass filter were used ahead of the lock-in amplifier to remove the harmonics from the square wave, the lock-in amplifier would see a sine wave input and its rms value would be accurately indicated. Note that the rms amplitude of the fundamental frequency component of a square wave is $\sqrt{2}/\pi$ times the pk-pk amplitude of the square wave. If the square wave has a pk-pk amplitude of 1 V rms, the amplitude of its fundamental frequency component will be 0.45 V rms. Normalizing differently, if the rms amplitude of the fundamental frequency component of a square wave is 1 V rms, the pk-pk amplitude of the square wave will be 2.22 V pk-pk.

With input signals other than square waves, the response would be different, and would have to be separately determined for each case.

These same considerations apply to magnitude readings taken when operating with the Vector Phase option.

4.7 RACK MOUNTING

The Model 5202 can be conveniently mounted in a standard 19 inch equipment rack by means of the mounting brackets supplied with each instrument. These brackets are easily attached to the instrument. The procedure follows.

(1) Note that the front panel is framed on each side and at the top by decorative extrusions. Before the rack mounting brackets can be installed, it is first necessary to remove the screws that secure the two side extrusions (do not try to actually remove the extrusions). The screws that secure the top extrusions should not be disturbed.

(2) With the screws removed, position the mounting brackets over the side extrusions and secure them to the instrument using the counter-sunk screws supplied with the mounting brackets. (The screws removed in the preceding step can be saved or disposed of, as convenient.)

Once the brackets are in place, the instrument can be rack mounted. However, the user should provide for some means of supporting the instrument toward the rear. A shelf or possibly some kind of slide assembly can satisfactorily meet this requirement.

4.8 VECTOR PHASE OPTION (5202/95)

4.8A DESCRIPTION AND OPERATION

This option is always active. It continuously computes the magnitude and phase of the input signal from the Quadrature and In Phase outputs. The magnitude is calculated by computing the square root of the sum of the squares of the two detector outputs, and so is independent of the phase. The computed phase is that of the signal at the Signal Input with respect to the reference detection point (see Subsection 4.5B), provided the Phase controls are set to 0°. Any phase shift introduced by the Phase controls will cause a corresponding change in the phase indicated by the panel meter. Recall that the Phase controls introduce lead into the reference channel, equivalent to lagging the phase of the input signal. This "lag" is reflected in the Phase meter reading, and the Phase Control setting must be added to the Phase Meter indication to find the true signal phase. Analog outputs of the magnitude and phase levels are provided at two rear-panel connectors. The impedance at both is 600 ohms, but the full-scale output levels differ. At the Magnitude output full scale is 1 V (output is unipolar). The transfer function to the Phase output is 10 mV/°, giving a maximum output of 1.8 V. This output is also unipolar.

Even though these functions are continuously computed, they are not indicated on the panel meters unless specifically selected with the MAGNITUDE and PHASE meter switches respectively. Magnitude is read from either of two linear red scales or from the –dB scale on the IN PHASE meter. Phase is read from a red scale on the QUADRATURE meter. Note that the linear magnitude scales are zero-left; since the magnitude indication must be positive, there is no need to allow for possible bipolar indications, and the entire meter range can be used for improved reading resolution. The Phase indication is also unipolar, allowing a zero-left phase scale that extends the range of the meter to 180°. The meter indication varies linearly with the angle between 0° and 180°. From 180° to 360°, the NEGATIVE PHASE light glows to assure correct reading. Thus an angle of 180° would give a meter indication of 180° (NEGATIVE PHASE light flickering), an angle of 270° would give a meter indication of 90° (NEGATIVE PHASE light on), and an angle of 360° would give a meter indication of 0° (NEGATIVE PHASE light flickering).

Phase readings are ordinarily conducted with the phase controls set to 0°. If the phase setting is other than 0°, the phase shift introduced by the controls will have to be taken into account in reading the meter, as previously explained. The Phase controls (dial plus pushbuttons) indicate the amount of lead introduced in the reference drive to the In Phase detector. The phase meter indicates the angle of the signal at the input relative to the reference detection point (Phase controls set to 0°), with a positive phase denoting lead and a NEG PHASE indication denoting lag.

The unipolar phase output makes it particularly easy to make a continuous recording of the signal phase because there are no discontinuities. A special output pulse is provided to mark the transition from the region of positive phase to that of negative phase. The amplitude of this pulse is typically 30-40 mV and it is superimposed on the phase output potential. The polarity of the pulse indicates the direction of the phase transition. For example, assume a steadily increasing phase indication. As the phase approaches 180°, the potential at the Phase connector will track, approaching +1.8 V. The output voltage will peak at exactly 180°. At the same time, a negative pulse will be provided, indicating that the phase is moving into the

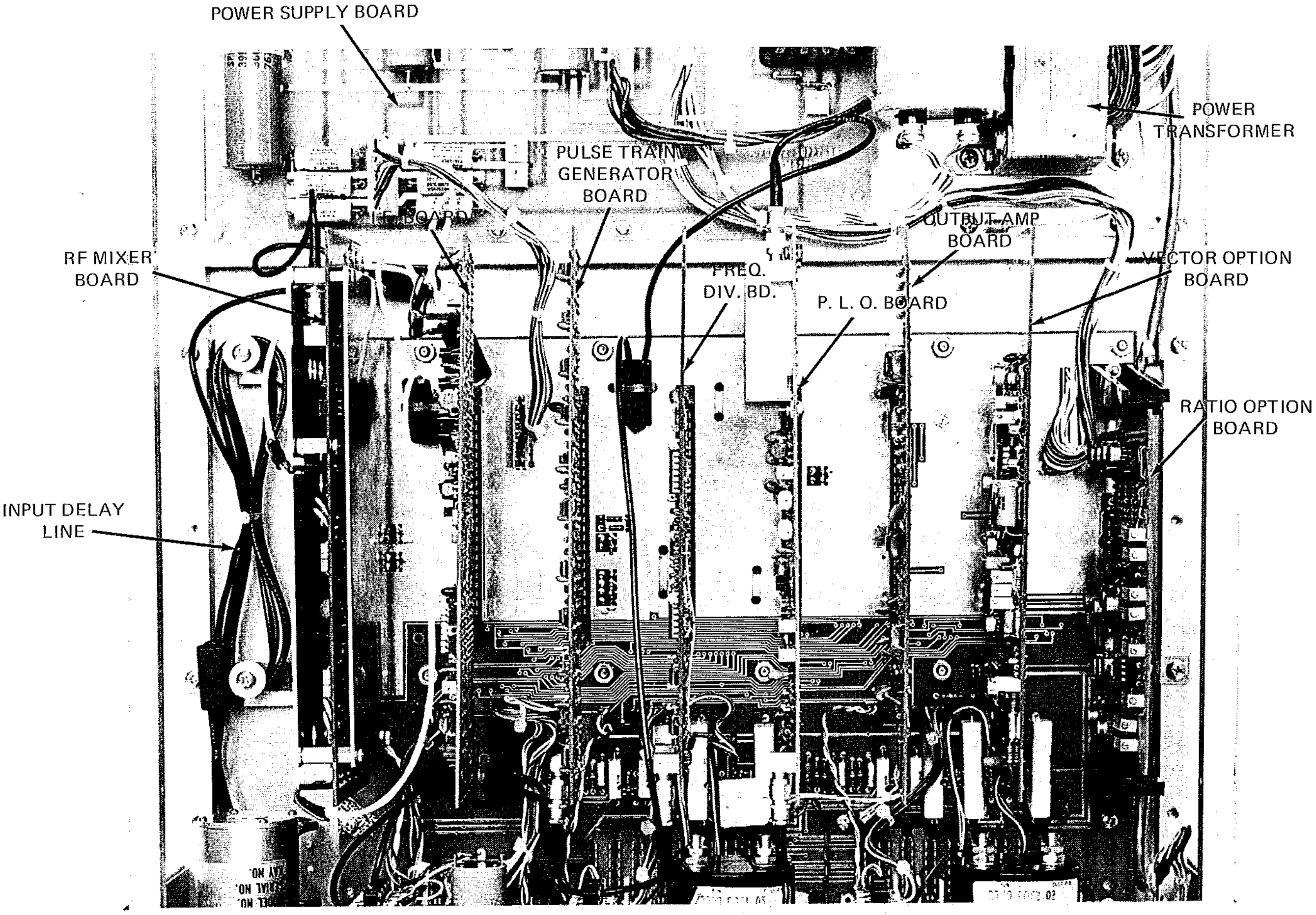


Figure IV-10. OPTION BOARD LOCATIONS

negative phase region. As the phase angle continues to change in the same direction, the phase reading will gradually decrease, approaching zero. If the phase, still changing in the same direction, passes through zero, a positive output pulse will be provided so that the recording will indicate the transition into the positive phase region. Should a phase shift in the other direction then take place, a negative pulse would be generated as the phase slipped through 0° moving into the region of negative phase. Thus, it is a simple matter to examine the discontinuity-free recordings that have been produced over a period of hours and to determine the phase at all times.

It should be mentioned that the Model 5202 always functions as a lock-in amplifier and that the normal I and Q outputs are always available at the corresponding front and rear-panel connectors. The Phase and Magnitude outputs are provided at the rear panel only, although they can be read from the front-panel meters if the MAGNITUDE and PHASE meter pushbuttons are depressed.

4.8B INSTALLATION

Installation of the Vector Phase option is very simple. All units are furnished with all option cables and connectors already installed. Installing the option consists of nothing more than removing the top cover (secured by six screws), followed by plugging the Option board into the proper socket as indicated in Figure IV-10. Removal of the cover may prove impossible unless the screws that secure the decorative extrusions (top and each side) are loosened. They need not be removed, just loosened. Once the board is in place, simply reverse the procedure.

4.9 RATIO OPTION (5202/96)

4.9A DESCRIPTION AND OPERATION

This option allows any of three different ratio functions to be computed and the result displayed on the front-panel QUADRATURE meter or measured at a rear-panel connector. A toggle switch at the rear panel determines the computed function, which is calculated from the levels applied to the Ratio Option "A" and "B" Input connectors (input resistance 10 MΩ). Any dc levels in the required range can act as inputs, including the I OUT and Q OUT signals. To display the computed function on the front-panel QUADRATURE meter, it is necessary that the Ratio OUT signal (source resistance 600 Ω) be cabled to the rear-panel METER INPUT connector and that the front-panel EXTERNAL Meter pushbutton be depressed. A special log scale is provided on the right-hand meter for convenient reading of the log ratio functions. The uppermost scale is suitable for reading the linear ratio function. Consider operation with each of the three functions separately.

(1) |A|/|B|: Full scale output in this mode is +1 V, and it corresponds to a ratio of 1:1. Note that "B" must be equal to or greater than "A". Otherwise overload will occur. The transfer function is linear; 1:1 gives 1 V out, 0.1:1 gives 100 mV out, and 0.01:1 gives 10 mV out. The basic computation accuracy is nominally 1%. However, under conditions where the inherent input drift and offset of the ratio option are significant relative to the applied signal level, these sources of error dominate. Note that the linear ratio function, like the two log functions, is computed on the absolute value of the applied voltages. Negative inputs can be applied. However, the output obtained will be the same as with positive inputs.

(2) LOG |A|: In the two log modes there is half a volt of output offset. In other words, if the input ratio is 1:1 ("B" is internally set at "1" in this mode), the output is +0.5 V instead of zero (log 1 = 0). Note however that the log scale on the panel meter is laid out such that the correct "0" indication will be obtained. The transfer function is +0.5 V/decade. Thus, if "A" should decrease to "0.1", the ratio will be 0.1:1, and the log of the ratio will be –1. Because of the existing +0.5 V of offset (0.5 V/decade transfer function), the net output will be 0 V instead of –0.5 V. However, the panel meter log scale will correctly indicate –1. Should the ratio go to .001:1, the log would be –3, as indicated on the panel meter, and the Ratio OUT voltage would be –1 V (+0.5 V of offset combined with –1.5 V of log output at –0.5 V/decade). It might be noted that the Meter Input impedance, though nominally 10 kΩ, is precisely that required to obtain accurate panel meter readings (EXT Meter pushbutton depressed) when the Ratio OUT signal is applied. The log |A| output voltage will be: V_O = 0.5 Log|A| + 0.5 V.

(3) Log |A|/|B|: This mode functions much the same as the log |A| mode except that in this case the value in B is given by the voltage applied to the "B" Input connector. The maximum input for both A and B is 1 V, and, as for the other modes, either polarity input can be applied. However, the function is computed on the absolute value in each case. Again, there is +0.5 V of offset. This is taken into account by the log scale on the panel meter so that the correct log is indicated. If the Ratio OUT voltage is used for some other purpose, it may prove convenient to subtract 0.5 V from each reading so that the voltage will truly reflect the log of the ratio. The log |A|/|B| output voltage is given by the expression: V_O = 0.5 Log |A|/|B| + 0.5 V.

Note that operation over a wider range is possible in Log |A|/|B| operation than in log |A| operation, where the fixed value of B, and the always present input constraint of 1 V maximum, limit the ratio to 1:1. In the Log |A|/|B| mode, "B" can take smaller values, allowing higher A/B ratios without running into the 1 V maximum input constraint. A ratio of 10:1 will give a log-scale indication of +1 corresponding to +1 V OUT (half of that volt is the aforementioned offset). A ratio of 100:1 will give +1.5 V out (0.5 V of which is offset) and an offscale meter indication. Going in the other direction, with increasingly small ratios, there is no absolute limit, but the meter scale extends only to –3 (ratio of 0.001:1), and the accuracy of the measurement will fall off rapidly for smaller measurements. Again, it is always necessary to keep the input offset and temperature coefficient specifications in mind. These become the dominant sources of error for increasingly small inputs.

4.9B INSTALLATION

Installation of the Ratio Option is very simple. All units are furnished with all option cables and connectors already installed. Installing the option consists of nothing more than removing the top cover (secured by six screws), followed by plugging the Option board into the proper socket as indicated in Figure IV-10. Removal of the cover may prove impossible unless the screws that secure the decorative extrusions (top and each side) are loosened. They need not be removed, just loosened. Once the board is in place, simply reverse the procedure.

4.10 OPERATION WITH THE MODEL 115 PREAMPLIFIER

The effective sensitivity of a system incorporating the Model 5202 can be increased by interposing the Model 115 Preamplifier between the signal source and the lock-in amplifier. In addition to providing gain, the preamplifier gives the user the choice of 1 MΩ input impedance or a 50 Ω input impedance, whichever is best suited to the measurement application. With a frequency response that extends to 70 MHz (50 Ω input; with 1 MΩ input, frequency response extends to 50 MHz), the bandpass of this instrument is more than wide enough for use at the highest working frequencies of the Model 5202. The gain is either X10 or X100, as selected by a front-panel switch. A 10 MΩ 10:1 probe is provided for increased flexibility. When the probe is in use, the Model 115 gain is effectively reduced to X1 or X10.

As in any other synchronous, high frequency, signal-processing system, users can expect to encounter coherent pickup. Such pickup, usually coupled via ground loops, will produce offset at the output of the lock-in amplifier. Such offset is most readily observed by making the signal-cable ground connections without making the signal connections (simply touch the shell of the BNC connector at the end of the signal cable to the shell of the front panel). Any resulting offset can be nulled out with the OFFSET control or simply subtracted from the signal readings obtained when the cables are connectors mated. Pickup-related offsets are always maximum with high gain and at the highest frequencies. With respect to the Model 115, this means that little difficulty will be expected at frequencies above 10 MHz and with a preamplifier gain-switch setting of X100.

There is no problem with regard to interfacing the Model 115 with the Model 5202. The necessary cable (6020-0131-05; drawing 11197-C-ESA) can be purchased from P.A.R.C. This cable mates with the Interface connector at the rear panel of the Model 5202. Note that the cable is not keyed. The necessary power and ground assignments are arranged such that the Model 115 is powered regardless of which of the two ways the cable is plugged in.

SECTION V SAFETY NOTICE

WARNING!

POTENTIALLY LETHAL VOLTAGES ARE PRESENT INSIDE THIS APPARATUS. THESE SERVICE INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS YOU ARE QUALIFIED TO DO SO.

Any adjustment, maintenance, or repair of the opened apparatus under voltage shall be avoided as far as possible and, if unavoidable, shall be carried out only by a skilled person who is aware of the hazard involved. When the apparatus is connected to a power source, terminals may be live, and the opening of covers or removal of parts is likely to expose live parts. The apparatus shall be disconnected from all voltage sources before it is opened for any adjustment, maintenance, or repair. Once opened, power can be reconnected as necessary for the required maintenance. Note that capacitors inside the apparatus may still be charged, even if the apparatus has been disconnected from all voltage sources. Service personnel are thus advised to wait several minutes after unplugging the instrument before assuming that all capacitors are discharged. If any fuses are replaced, be sure to replace them with fuses of the same current and voltage rating and of the same type. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

SECTION V
ALIGNMENT

SEE SAFETY NOTICE ON FACING PAGE BEFORE PROCEEDING.

5.1 INTRODUCTION

The Model 5202 is a reliable, conservatively designed instrument. Care has been taken to use stable, high-quality components in all critical circuits. Such adjustments as are provided simply set the operating point of the associated stable circuits, and it is unlikely that any need to systematically align the instrument will develop over its life.

However, should the instrument ever require repair in the field, parts might be replaced that will shift the operating point of one or more circuits away from the optimum. Under such circumstances, it may prove advisable to run through the following procedure.

Note that this procedure is not intended to be used as a troubleshooting aid. If the instrument is suspected of malfunctioning, go directly to Section VI, which contains a detailed block-diagram discussion with suggested troubleshooting procedures. The instrument must be working normally before it can be aligned, which is nothing more than an optimization process. The location of the various adjustments is indicated in the Parts Location Diagrams (Section VII).

5.2 REQUIRED EQUIPMENT

(1) Digital Voltmeter (referred to hereafter as DVM): Four or more places.

(2) Signal Generator: .1 MHz to 60 MHz, ±0.5 dB, 50 Ω output impedance.

(3) Oscilloscope: Deflection factor of 50 mV/cm or better and bandwidth of at least 50 MHz. Provision should be made for externally terminating the applied signal in 50 Ω at the oscilloscope vertical input connector.

(4) Directional Coupler: 0.2 MHz to 250 MHz, 19.3 dB coupling, 50 Ω. MINI-CIRCUITS LABORATORIES type ZDC20-3 or equivalent.

(5) Splitter: 50 Ω, one input port and two output ports. MINI-CIRCUITS LABORATORIES type ZSC2-1. **NOTE:** To obtain 250 mV output from the splitter, apply 362 mV to its "sum" input.

(6) Such cables, probes, and jumpers as may be required. Only 50 Ω coaxial cable (RG 58C/U or equivalent) should be used. One short jumper with miniature clips should suffice.

(7) A plastic "TV" alignment with metal blade at tip.

(8) Extender card, EG&G PARC type EB-0020.

5.3 INITIAL STEPS

(1) Remove the top cover, which is secured by six screws, three on each side. In addition to removing these screws, it will probably be necessary to loosen the screws that secure the decorative strips (top and each side) that frame the front panel. Once these extrusions are loose, the cover will easily slide back and up, giving access to the internal adjustments.

(2) Check and, if necessary, adjust the mechanical zero of each of the panel meters (the power should not yet be on). The screwdriver adjustment for each is located directly below the corresponding meter.

(3) Check the orientation of the line voltage selector card as described in Subsection 3.3. If the card needs to be repositioned to match the available line voltage, do the repositioning now. As part of the same procedure, check the fuse rating to be sure it is correct for the operating line voltage range.

(4) Check that no overload damage of the Model 5202 Input Attenuator has occurred. This is simply done by measuring the input resistance with an ohmmeter at each setting of the Sensitivity switch while a 50 Ω resistor is connected across the signal Input connector on the RF MIXER board. The measured resistance should be 50 Ω ±1% at all sensitivities.

(5) Plug in the line cord, turn on the power, and allow a fifteen minute warmup.

(6) Set the controls as follows. These settings should be maintained throughout the procedure except when otherwise specified.

REFERENCE CHANNEL
Phase pushbuttons: 0° depressed
Phase dial: 5 full turns from fully counterclockwise position
Frequency Range switch: As required to extinguish UNLOCK light (not possible until reference is applied)
Trigger switches: Sine wave and positive slope selected

IN PHASE CONTROLS
Meter switch: IN PHASE depressed
Time Constant: 10 ms depressed
X10: not depressed
Offset pushbuttons: not depressed
FILT pushbutton: not depressed

QUADRATURE CONTROLS
Meter switch: QUADRATURE depressed
Time Constant: 10 ms depressed
X10: not depressed
Offset pushbuttons: not depressed
FILT pushbutton: not depressed

POWER
Power switch: ON

5.4 POWER SUPPLY ADJUSTMENTS

(1) –5.2 V Supplies (3 to be adjusted)

(a) Monitor TP315 on the PULSE TRAIN GENERATOR board with the DVM. Throughout these measurements the DVM may be connected to any convenient chassis ground. Specifically, the inside ground lug of the rear-panel PHASE connector should prove suitable.

(b) Adjust R805 (–5.2 V ADJ I) for a DVM indication of –5.2 V ±0.02 V.

(c) Monitor the top of r.f. choke L401 on the FREQUENCY DIVIDER board with the DVM. Then adjust R803 (–5.2 V ADJ II) for a DVM indication of –5.2 V ±0.02 V.

(d) Monitor the voltage at the negative end of capacitor C17 on the R.F. MIXER board. Then adjust R801 (–5.2 V ADJ III) for a DVM indication of –5.2 V ±0.02 V.

(2) +15 V Supply

(a) Monitor TP203 of the I.F. Board with the DVM.

(b) Adjust R812 (+15 V ADJ) on the Power Supply board for a DVM indication of +15 V ±0.02 V.

(3) –15 V Supply

(a) Monitor TP204 of the I.F. Board with the DVM.

(b) Adjust R811 (–15 V ADJ) on the Power Supply board for a DVM indication of –15 V ±0.02 V.

5.5 OUTPUT AMPLIFIER ADJUSTMENT
(Prerequisite: Power Supplies Adjusted)

(1) With the power off, remove the OUTPUT AMPLIFIER board and connect a jumper from TP603 to TP604 (both on Output Amplifier board). Then plug the board back in, taking care not to disturb the jumper, and turn the power back on.

(2) Set the front-panel FREQ. RANGE switch to its fully counterclockwise position and press the In Phase OUTPUT EXPAND X10 pushbutton.

(3) Monitor the I OUTPUT connector with the DVM and adjust R626 (I ZERO) for a DVM indication of 0.0 V. (If necessary, remove the three PC boards immediately to the left of the OUTPUT board to allow more space for the alignment tool.)

(4) Again, with the power off, remove the OUTPUT AMPLIFIER board, and transfer the jumper installed earlier so that it now connects between TP605 and TP606. Then return the board to the unit and turn the power back on.

(5) Release the In Phase OUTPUT EXPAND X10 pushbutton and depress the Quadrature OUTPUT EXPAND X10 pushbutton.

(6) Transfer the DVM from the I OUTPUT to the Q OUTPUT and adjust R627 (Q ZERO) for a DVM indication of 0.0 V. Then release the Q Output Expand X10 pushbutton. (See note in step 3.) If boards were removed, return them to their sockets now.

(7) With the power off, remove the OUTPUT AMPLIFIER board. Then remove the jumper installed earlier. When this has been done, install the board back in the unit and turn the power back on. Before proceeding, re-establish the control settings listed in step 6 of Subsection 5.3.

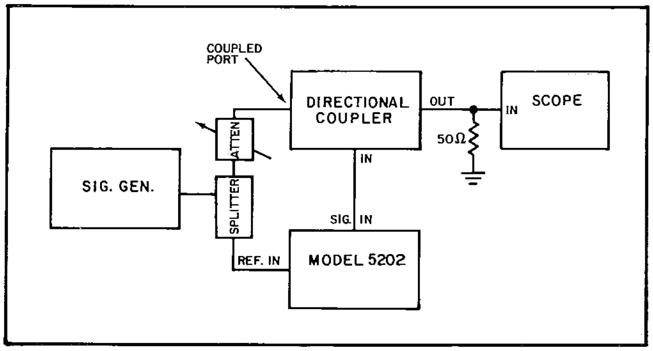


Figure V-1. VSWR MEASUREMENTS SETUP

5.6 VSWR CHECK

(1) Configure the system as shown in Figure V-1. The signal generator output should be 1 MHz. If separate signal and reference outputs are not provided, use splitters and attenuators as required to maintain proper Model 5202 reference channel operation while setting the signal input to the Model 5202 to the specified level. Be sure to use 50 Ω cable throughout and to terminate the scope input in 50 Ω if the scope input impedance is not already 50 Ω.

(2) Set the Model 5202 Sensitivity switch to 25 mV. The Model 5202 FREQ. RANGE switch should be set to 0.8-1.6 MHz and the signal generator output frequency should be 1 MHz.

(3) Adjust the signal generator output for some deflection of the Model 5202 panel meters. Then carefully adjust the Model 5202 Phase controls for exactly "0" on the QUADRATURE panel meter. This will correspond to maximum deflection at the IN PHASE meter. When the Phase adjustment is finished, adjust the signal generator output for exactly full-scale indication at the lock-in IN PHASE meter.

(4) Set the Model 5202 Sensitivity switch to 100 μV. The instrument will go into overload. This is as it should be.

(5) Read and record the peak-to-peak amplitude of the scope display. It should be less than 7 mV pk-pk.

(6) Repeat this procedure at each of the following frequencies. At each, select the bracketing FREQ. RANGE setting, and, with the Sensitivity switch set to 25 mV, adjust the Phase controls as described in step 3 above. Then reduce the sensitivity setting to 100 µV and note the pk-pk amplitude of the displayed signal. It should be less than 7 mV pk-pk in each case. The test frequencies are: 0.1 MHz, 0.3 MHz, 3 MHz, 10 MHz, 20 MHz, 40 MHz, 50 MHz. When the measurements are completed, disassemble the setup to where the lock-in amplifier is a free-standing instrument again.

5.7 R.F. BALANCE ADJUSTMENTS (Prerequisite: Power Supplies Adjusted)

(1) Remove any cables from the signal and reference inputs of the lock-in amplifier.

(2) Turn off the power and remove the FREQUENCY DIVIDER board from its socket. Then turn the power back on.

(3) Observe the front-panel meters. Both will probably go off scale one direction or the other.

(4) While observing the IN PHASE panel meter, adjust R146 (I BAL) for an on-scale indication.

(5) While observing the QUADRATURE panel meter, adjust R167 (A BAL) for an on-scale indication.

NOTE: Ideally these adjustments should result in stable "0" meter indications. In practice, this may be a difficult goal to achieve. When no further improvement can be made, turn the power off, insert the FREQUENCY DIVIDER board back into its socket, and turn the power back on again.

5.8 RF MIXER OVERLOAD SENSITIVITY ADJUST

(1) Apply a 200 mV rms 1 MHz sine wave to the Signal Input connector. No reference signal is necessary for this test.

(2) Set the Sensitivity switch to 1 mV.

(3) Adjust R174 (+OVL) and R170 (—OVL) on the RF MIXER board such that the front-panel OVERLOAD light barely glows, and such that a slight advance of *either* R174 or R170 will cause the light to glow brightly.

5.9 TRIGGER ZERO ADJUSTMENT

(1) Set up the signal generator and splitter to supply a 30 MHz 250 mV rms signal to both the signal and reference inputs of the Model 5202. Be sure the Reference sine wave pushbutton is depressed. Set FREQ. RANGE switch to 25-50 MHz.

(2) With the Sensitivity switch set to 250 mV, carefully adjust the Phase controls for exactly "0" on the QUADRATURE panel meter (IN PHASE meter indication will be maximum).

(3) Reduce the amplitude of the signal applied to the signal and reference inputs to 25 mV rms (set M5202 Sensitivity switch to 25 mV).

(4) Adjust R513 (TRIGGER ZERO) on the Phase Locked Oscillator board for "0" indication on the QUADRATURE panel meter.

5.10 UNLOCK SENSITIVITY ADJUSTMENT

(1) Set the signal generator output to 50 MHz and connect its output to the input of the splitter. Of the two splitter outputs, one goes to the Model 5202 Reference Input and the other to the Ext. Trigger input of the oscilloscope. If the Ext. Trig. Input impedance of the oscilloscope is not 50 Ω, be sure to use an external 50 Ω terminator. Establish proper oscilloscope triggering by adjusting the Trigger Level control of the scope while monitoring the signal generator output.

(2) Monitor TP503 on the PLO board with the oscilloscope. Then increase the signal generator frequency until the observed signal is no longer synchronized. **NOTE:** M5202 FREQ. RANGE switch should be set to 25-50 MHz.

(3) Reduce the generator frequency until the observed signal just becomes synchronized again.

(4) Adjust R519 (UNLOCK SENSITIVITY) on the PLO board such that the UNLOCK light on the front panel is just on the verge of lighting.

(5) Increase the frequency until the observed waveform just goes out of synchronization. The UNLOCK light should glow.

(6) Reduce the frequency of the generator back to 50 MHz. Then adjust the front-panel PHASE VERNIER dial over its full range and ascertain that the UNLOCK light remains out while this is done. Some readjustment of UNLOCK SENSITIVITY (R519) may be necessary.

5.11 PHASE VERNIER RANGE

(1) Connect the signal generator output to both the signal and reference inputs of the Model 5202. The path to the Reference Input must be about 78 inches longer than the path to the Signal Input. Use a splitter so that a common signal source drives both connectors. The signal frequency should be 11 MHz and the FREQ. RANGE switch should be set to 6.4-13 MHz.

(2) Press the 90° Phase pushbutton and rotate the Phase Vernier dial fully counterclockwise. Then adjust the signal generator frequency to where the QUADRATURE meter indication is exactly "0".

(3) Press the 0° Phase pushbutton and adjust the Phase dial as required to obtain "0" indication on the Quadrature meter. Read the Phase dial setting. It should be in the range of 88°-92°*. If it is not, set the Phase dial to 90° and adjust R537 (PHASE VERNIER RANGE) on the PLO board until the error indicated on the Quadrature meter is reduced by 50%. Then repeat steps 2 and 3 until the desired reading (in range of 88° to 92°) is obtained, that is, until 90° of phase shift as set by the Phase dial is equal to a 90° increment introduced with a Phase pushbutton. Leave the 0° Phase pushbutton depressed and the Phase dial set five turns from the fully counterclockwise position (mid-range).

5.12 AC BALANCE ADJUSTMENTS

NOTE: When working with I.F. Board, take care not to disturb the twisted wire "gimmick" capacitors at TP205 and TP206 of the I.F. Board.

(1) Turn off the power and remove the I.F. Board. Then install the Extender card** in the socket from which the I.F. Board was removed. When this has been done, plug the I.F. Board into the Extender and turn the power back on again.

(2) Apply a 1 MHz signal to the reference input (FREQ. RANGE switch set to 0.8-1.6 MHz).

(3) While monitoring TP601 on the OUTPUT Board with the DVM, adjust R250 (I AC BAL) on the I.F. Board for a +9.4 V reading on the DVM.

(4) Transfer the DVM to TP602 on the OUTPUT Board. Then adjust R249 (Q AC BAL) on the I.F. Board for a +9.4 V reading on the DVM.

(5) For a finer adjustment, select the 0.1 s TIME CONSTANT pushbuttons, release the FILTER pushbuttons, and depress the OUTPUT EXPAND X10 pushbuttons. Then, while observing the I OUTPUT connector with the oscilloscope, adjust R250 (I AC BAL) for minimum observed ripple. The scope should then be transferred to the Q OUTPUT connector and R249 (Q AC BAL) adjusted for minimum observed ripple at that connector. These ripple adjustments should not cause TP601 or TP602 on the OUTPUT board to be more than 1 V from the nominal 9.4 V setting.

Leave the OUTPUT EXPAND off and the 10 ms TC selected.

NOTE: If going on to Subsection 5.13, leave the I.F. Board on the Extender.

5.13 DC BALANCE ADJUSTMENTS

(1) The I.F. Board should be mounted on an Extender card. Use a reference input signal of 1 MHz.

(2) Monitor TP205 on the I.F. Board with the oscilloscope and adjust R203 (Q DC BAL) on the I.F. Board to eliminate any observed 122 Hz square-wave signal.

(3) Transfer the oscilloscope to TP206 on the I.F. Board. Then adjust R204 (I DC BAL) on the I.F. Board to eliminate any observed square-wave signal.

(4) Turn the power off. Then remove the I.F. Board from the Extender and the Extender from the socket. The I.F. Board should then be plugged back into its socket and the power turned back on.

5.14 GAIN ADJUSTMENTS

(Prerequisite: Power Supply, I.F. Board, and Output Amplifier Board adjustments completed)

NOTES: Before proceeding, be sure the generator's output amplitude is accurate to within 0.5 dB. Also, do not make the gain adjustments unless satisfied that the Input Attenuator has not been damaged through overload. The necessary check is described in step 4 of Subsection 5.3. In making the zero adjustments (steps 4 and 6), the OUTPUT EXPAND X10 pushbutton may be depressed to increase the adjustment sensitivity. However, it *must* be released during the other steps.

(1) Set the generator frequency to 4 MHz (FREQ. RANGE to 3.2-6.4 MHz).

(2) Use a splitter (M.C.L. #ZSC 2-1) after the signal generator so that the generator output is applied to both the Signal and Reference inputs.

(3) Adjust the Generator output level for 100 mV rms at the Signal Input connector (with specified splitter, this occurs with 145 mV rms generator output).

(4) Adjust the Phase Vernier dial for "0" Quadrature panel-meter indication. Alternatively adjust for 0.0 V at the Q OUTPUT connector as measured with the DVM.

(5) Adjust R153 (I GAIN) on the R.F. MIXER Board for full-scale deflection of the In Phase panel meter (alternatively 1.0 V ±0.01 V at the I OUT connector as measured with the DVM).

(6) Depress the 90° Phase pushbutton. Then adjust the Phase vernier dial for "0" on the In Phase panel meter (alternatively, 0.0 V at the I OUTPUT connector as measured with the DVM).

(7) Adjust R168 (Q GAIN) on the R.F. Mixer board for full-scale deflection of the Quadrature panel meter (alternatively, 1.0 V ±0.01 V at the Q OUTPUT connector as measured with the DVM).

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*This phase is with respect to the dial range, i.e., dial should be in range of 8.8 to 9.2 full turns from the fully counterclockwise position.

**Not essential, but helpful.

(8) Leave the 0° pushbutton depressed and the Phase dial set to mid range.

5.15 HIGH FREQUENCY PEAKING ADJUSTMENTS (only to be undertaken after the Gain Adjustments have been made)

(1) With the generator driving both the Signal and Reference inputs via the splitter, adjust the generator for 100 mV rms signal input (145 mV rms generator output) at 45 MHz (FREQ. RANGE 25-50 MHz).

(2) Adjust the Phase Vernier dial for "0" on the Quadrature panel meter (alternatively 0.0 V at the Q OUTPUT connector as measured with the DVM). **NOTE:** X10 OUTPUT EXPAND may be depressed for making this adjustment. However, be sure to release this pushbutton when the adjustment is completed.

(3) Adjust C121 (I PEAK) on the R.F. MIXER Board for full-scale deflection of the In Phase panel meter (alternatively for 1.0 V ±0.01 V at the I OUT connector as measured with the DVM).

(4) Depress the 90° Phase pushbutton. Then adjust the Phase Vernier dial for "0" on the In Phase panel meter (alternatively, 0.0 V at the I OUTPUT connector as measured with the DVM). **NOTE:** X10 OUTPUT EXPAND may be depressed for making this adjustment. However, be sure to release this pushbutton when the adjustment is completed.

(5) Adjust C127 (Q PEAK) on the RF MIXER board for full-scale deflection of the Quadrature panel meter (alternatively 1.0 V ±0.01 V at the Q OUTPUT connector as measured with the DVM).

(6) Leave the 0° pushbutton depressed and the Phase dial set to 5.00.

NOTE: If either peaking control will not reduce the output. to the desired level, both should be made exactly equal. This is extremely important for properly making the orthogonality adjustment.

5.16 ORTHOGONALITY ADJUSTMENTS

(1) With the generator driving both the Signal and Reference inputs via the splitter, adjust the generator for 100 mV rms signal input (145 mV rms generator output) at 45 MHz (FREQ. RANGE switch to 25-50 MHz). The Model 5202 Sensitivity switch should be set to 100 mV.

(2) Press the 90° Phase pushbutton. Then adjust the phase dial for "0" In Phase meter indication (Quadrature meter will indicate negative full scale).

(3) Press the 0° Phase pushbutton. The In Phase meter should indicate positive full scale and the Quadrature meter should indicate "0". If the Quadrature meter doesn't indicate exactly "0", adjust C2 (ORTHOG ADJUST) on the RF Mixer board for the desired "0" indication.

5.17 VECTOR OPTION BOARD ALIGNMENT

To align this board (Schematic 11252-D-SD), it is necessary that it be mounted on another extender (can be purchased from PARC). Also, take note that the front-panel ERROR light will be lighted at various times in this procedure. This is a normal indication with respect to the alignment parameters and should be ignored.

(1) Turn the power off. Then remove the Vector board, plug in the extender, and plug the Vector board into the extender. Leave the signal generator connected to the REFERENCE INPUT but disconnect it from the SIGNAL INPUT. Before turning the power back on, remove the I.F. board (will be returned at end of procedure).

(2) I ZERO (R6043), Q ZERO (R6048) & M ZERO (R6063)

(a) Check that the power is on and that all four OFFSET pushbuttons are released. Also check that the X10 pushbuttons are released.

(b) Connect the oscilloscope to pin 7 of Integrated Circuit U6012. **NOTE:** It may be physically easier to connect to C6031 or R6005.

(c) Alternate between I ZERO (R6043) and Q ZERO (R6048), adjusting for minimum ripple as observed on the oscilloscope. It should be possible to reduce the ripple to less than 1 mV pk-pk. Remove the oscilloscope.

(d) Connect the DVM to the MAG OUT connector. Then adjust M ZERO (R6063) for 0 V at the MAG OUT connector.

(3) MAGNITUDE FULL SCALE (R6040)

(a) Depress the In Phase (—) Offset pushbutton and adjust the In Phase Offset dial for 1.00 V at the I OUT connector.

(b) Transfer the DVM to the MAG OUT connector and adjust R6040 (MAG. F.S.) for exactly 1 V at the MAG OUT connector.

(c) Release the In Phase (—) Offset pushbutton.

(4) DC BALANCE (R6020)

(a) Depress the Quadrature (—) Offset pushbutton.

(b) Adjust the Quadrature Offset dial for 1.00 V at the Q OUT connector.

(c) Adjust R6020 (DC BAL) for exactly 1 V at the MAG OUT connector.

(5) MAGNITUDE METER CAL (R6072)

(a) Press the MAGNITUDE Meter function pushbutton.

(b) Adjust R6072 (MAG. METER CAL) for exactly full-scale deflection of the IN PHASE panel meter.

(c) Press the IN PHASE Meter function pushbutton.

(6) PHASE ZERO (R6009)

(a) Press the In Phase (–) OFFSET pushbutton and release the Quadrature OFFSET pushbutton.

(b) Connect the oscilloscope to pin 7 of integrated circuit U6007. The observed signal should be a square wave. Gradually reduce the setting of the In Phase Offset dial. As the offset is reduced, a point will be reached where the symmetry of the observed square wave is degraded. As this occurs, adjust R6009 (PHASE ZERO) to maintain symmetry. Keep reducing the offset in each instance followed by adjusting R6009 until no further improvement can be made. (Ideally the wave should be at 0 V 50% of the time.) Then restore the Offset signal to its original 1 V level as measured at the I OUT connector.

(7) FREQUENCY (R6082)

(a) Transfer the oscilloscope to the cathode of CR6009.

(b) Adjust R6082 (FREQUENCY) to where no TTL logic 0 excursions in the observed signal are seen. **NOTE:** A logic 0 excursion is one that goes below 1 V. Excursions above that level will continue.

(8) OUTPUT PHASE ZERO (R6029)

(a) Transfer the DVM to the PHASE OUT connector.

(b) Adjust R6029 (OUTPUT PHASE ZERO) for 0 V at the PHASE OUT connector.

(c) Release the In Phase OFFSET pushbutton.

(9) PHASE FULL SCALE ADJUST (R6028)

(a) Depress the In Phase (+) Offset pushbutton.

(b) Adjust R6028 (PHASE FULL SCALE ADJ) for exactly 1.800 V at the PHASE OUT connector.

(10) PHASE METER (R6033)

(a) Press the PHASE Meter function pushbutton.

(b) Adjust R6033 (PHASE METER ADJ) for exactly full-scale deflection on the Quadrature (Phase) panel meter.

(c) Press the QUADRATURE Meter Function pushbutton.

(d) Release the In Phase Offset pushbutton.

This completes the option alignment. All that remains is to turn off the power and to return the Vector Option board and the I.F. Board, each to its proper connector.

SECTION VI SAFETY NOTICE

WARNING!

POTENTIALLY LETHAL VOLTAGES ARE PRESENT INSIDE THIS APPARATUS. THESE SERVICE INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS YOU ARE QUALIFIED TO DO SO.

Any adjustment, maintenance, or repair of the opened apparatus under voltage shall be avoided as far as possible and, if unavoidable, shall be carried out only by a skilled person who is aware of the hazard involved. When the apparatus is connected to a power source, terminals may be live, and the opening of covers or removal of parts is likely to expose live parts. The apparatus shall be disconnected from all voltage sources before it is opened for any adjustment, maintenance, or repair. Once opened, power can be reconnected as necessary for the required maintenance. Note that capacitors inside the apparatus may still be charged, even if the apparatus has been disconnected from all voltage sources. Service personnel are thus advised to wait several minutes after unplugging the instrument before assuming that all capacitors are discharged. If any fuses are replaced, be sure to replace them with fuses of the same current and voltage rating and of the same type. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

SECTION VI
TROUBLESHOOTING
SEE SAFETY NOTICE ON FACING PAGE BEFORE PROCEEDING.

6.1 INTRODUCTION

This section should serve as a guide to troubleshooting the Model 5202. By making voltage and waveform checks at critical points, it should be possible to narrow the trouble down to one of the circuit boards. Once the faulty board has been identified, the operator should contact the factory or the authorized representative in his area for advice on how to get the instrument back into operation in the shortest possible time. In the case of units still in warranty, it is particularly important that this be done before doing any work on the board itself, as any damage incurred from unauthorized work could invalidate the warranty.

Although past experience indicates that most instrument failures are caused by a board component failure, it is certainly possible that a component other than one mounted on a circuit board will go bad. Where this is the case, it will be necessary to appropriately adapt the procedure to isolate the faulty component.

6.2 BLOCK DIAGRAM DISCUSSION

As can be seen from Figure VI-1, the instrument can be thought of as consisting of three sections. The first is the Signal Section, which includes the Input Step Attenuator (Sensitivity switch), and a Delay Line. This section simply sets the signal amplitude at the input to the RF Mixers.

The second section is the Reference Section, which consists of a Phase Locked Oscillator, a Frequency Divider, and a Pulse Train Generator. These circuits lock onto the input reference signal and develop the various "reference" signals required by the circuits that follow. Note that a feedback loop is employed to maintain frequency/phase lock. The instrument's Phase controls (dial and pushbuttons) are incorporated into this section such that the Reference Section output signals carry the reference information set with these controls. There are three Reference Section outputs. Two of these are at $f_r - f_r/8193$ Hz, and differ only with respect to phase; that which drives the Quadrature RF Mixer leads that which drives the In Phase RF Mixer by 90°. The third output is at $f_r/8193$ Hz, the I.F. Frequency. This signal drives the two I.F. Synchronous Rectifiers in the Output Section.

The third section includes the RF Mixers, the I.F. Amplifiers, the Phase Sensitive Detectors, and the dc Output Amplifiers. Each component is dual, one for the In Phase Channel and the other for the Quadrature Channel. As shown in the figure, the input signal is applied to the RF Mixers. Also applied is the $f_r - f_r/8193$ output of the Pulse Train Generator. These two signals are mixed, and the difference frequency at $f_r/8193$ is provided at the output of the RF Mixers. Note that the input signal to the RF Mixer is simply that applied to the SIGNAL INPUT connector, and may be of any shape and amplitude. The drive pulse train is a square wave series at very near the same frequency. If we assume these two signals are in phase, the result would be a dc output. If they are out of phase, the output would still be a dc output, but of the opposite polarity. The Model 5202 takes advantage of this property by periodically flipping the phase of the drive pulse train. This is done at the I.F. frequency rate of $f_r/8193$. Thus the input signal is demodulated at one phase for half of an I.F. period, and at 180° for the other half. The output of the R.F. Mixer follows, flipping at the I.F. rate, and developing an I.F. frequency signal at that point. The amplitude of this signal varies linearly with the amplitude of the input signal. (Note that the I.F. signal is a square wave in the range of 12.2 Hz to 6103 Hz.)

Its phase, assuming the Phase controls have been adjusted for maximum In Phase output, is that of the input signal. The I.F. Drive signal to the I.F. Board is at the same phase so that no phase adjustments are required at the I.F. Board Synchronous Rectifiers. It might be noted that the 0° and 270° pushbuttons, together with the Phase dial, all work on the earlier discussed Phase-locked loop to bring the phase of the reference into agreement with that of the signal at the RF Mixers. Pressing the 180° or 90° Phase pushbutton introduces an additional 180° shift in the drive to the I.F. Phase Sensitive Detectors without having any effect on the phase-locked loop.

In any case, the RF Mixers are followed by amplifiers that buffer and amplify the $f_r/8193$ Hz signal. This signal is then demodulated by the I.F. Synchronous Rectifiers to develop the dc outputs applied to the meters and provided at the front and rear-panel I and Q Output connectors respectively.

6.3 CIRCUIT BOARD DISCUSSIONS

6.3A PHASE LOCKED OSCILLATOR BOARD (Page VII-11)

Several circuits in addition to the Phase Locked Oscillator are located on this circuit board. Referring to the schematic (page VII-11), note that the incoming reference signal is applied to a series of amplifiers followed by some gates. These circuits provide buffering. They also "square up" the reference, implement the threshold selection provided by the front-panel REFERENCE pushbuttons, and allow slope selection. The resulting reference is applied as one input to the Frequency/Phase Comparator circuit, U3, where it is compared with the feedback signal taken from the Reference Pulse Train Generator Board. Note that the Comparator does not drive the Voltage Controlled Oscillator directly. Interposed between the two circuits is the VCO Control Filter. This circuit has two functions, the first to smooth the Comparator output, and the second to allow Phase shift to be introduced via the front-panel Phase dial. This dial introduces a current offset that is nulled by the Comparator output at equilibrium. Thus the Voltage Controlled Oscillator that follows is driven to the frequency/phase that satisfies the null requirement. That this is so becomes clear when the remainder of the Phase

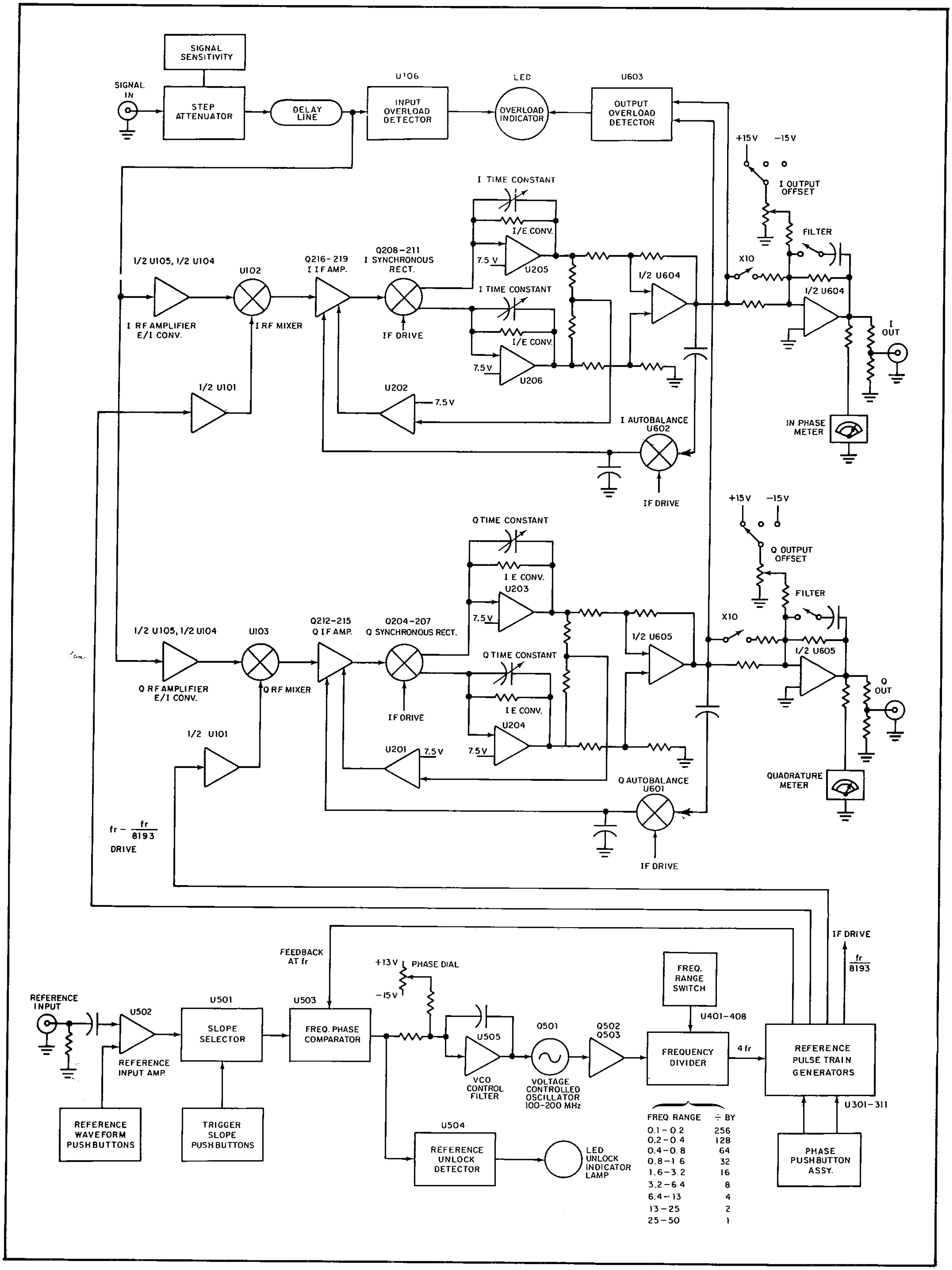


Figure VI-1. MODEL 5202 BLOCK DIAGRAM

Locked Loop circuits are reviewed. The earlier mentioned feedback signal is derived from the oscillator output (via a series of dividers). The oscillator's frequency range is 100 MHz to 200 MHz, corresponding to a reference frequency range of 0.1 MHz to 50 MHz.

6.3B FREQUENCY DIVIDER BOARD (Page VII-9)

As shown in the schematic, the circuitry on this board consists of nothing more than a series of frequency dividers controlled by the front-panel FREQ. RANGE switch. The sole function of these dividers is to develop the $4f_r$ signal. The input frequency to the dividers is always in the range of 100 MHz to 200 MHz, according to the frequency of the applied reference. The dividers' output is a square-wave pulse train at $4f_r$, where f_r is the frequency of the signal applied to the REFERENCE INPUT connector. Thus the frequency range at the output of this board will be 0.4 MHz to 200 MHz, corresponding to a reference input range of 0.1 MHz to 50 MHz.

6.3C REFERENCE PULSE TRAIN GENERATORS BOARD (Page VII-7)

Both the RF Mixer and I.F. Phase Sensitive Detector drives are developed at this board, as well as the feedback signal to the Comparator on the Phase Locked Oscillator board. Referring to the schematic, note that the output of the Divider Board is first routed through some gates. Two of these drive the two cascaded divide-by-two scalers of U3. The output of the first divider is used to develop both the I.F. Drive and the RF Drive. The output of the second is also used to develop these two drives, and additionally, is used to develop the feedback signal to the Oscillator board.

First consider the feedback signal. As shown in the schematic, the frequency of the signal applied to the U4 Clocked Buffer will be at frequency f_r due to the action of the two dividers mentioned in the previous paragraph. This signal, following buffering, is applied to another D flip-flop of U4. This circuit, together with some gates, allows an additional 90° phase shift to be introduced in the feedback signal when the 90° or 270° pushbutton is depressed. The feedback signal is brought out to pin 9 of the card-edge connector. The complementary signal at pin 8 is also routed to the Oscillator board, but is not used.

Next consider the I.F. Drive. As shown in the schematic, the output of the first U3 divide-by-two drives the clock input of D flip-flop U8. The D input of this flip-flop is driven by exclusive OR U6. Note that U8 is followed by a series of dividers, and that feedback from the output of U7 is applied to the pin 9 input of the U6 exclusive OR. The net effect of the feedback is to give a U7 output frequency of $f_r/8193$, the I.F. Frequency. The exclusive OR following U7 provides a 180° Phase inversion when the 180° or 90° pushbutton is depressed. As mentioned in the block diagram discussion, the 180° Reference Phase function is performed at the I.F. Phase Sensitive Detectors by inverting the drive to them.

The R.F. Mixer Drive is developed from the f_r signal at the output of the second U3 divider. This signal is routed through the first U6 Exclusive OR and from there is routed through U8 to the Clocked Buffer U2. The function of the Exclusive OR is to provide a periodic 180° phase shift in the pulse stream. Since the pin 9 input of the Exclusive OR is driven by the $f_r/8193$ signal, this phase reversal takes place at the I.F. Frequency. The effect is to give a frequency at the output of the Exclusive OR of $f_r - f_r/8193$. This signal, following buffering by one section of U8, is applied to Clocked Buffer U2. The two sections of U2 provide outputs separated by 90°. As shown, these quadrature related signals drive the R.F. Mixers.

6.3D RF MIXERS (Page VII-3)

Heterodyning of the input signal with the reference-derived $f_r - f_r/8193$ signal takes place in these mixers, of which there are two, one for the In Phase Channel and one for the Quadrature Channel. This heterodyning may be looked at from two different points of view. The simplest is to just accept that, when the input signal at f_r is mixed with the reference at $f_r - f_r/8193$, the difference, $f_r/8193$, will be available at the output of the mixers. Alternatively, one can take a more "mechanistic" viewpoint in which the circuit behavior is examined on a cycle-by-cycle basis. The input signal will be at the reference frequency (assuming the instrument is being properly operated), but it may be of any waveform. Analysis of the reference is more difficult. Recall that the reference drive undergoes a phase reversal at the I.F. frequency rate. Practically, this means that after each sequence of 8192 half cycles of the reference drive, one half cycle is lost as the phase reversal occurs. Thus, even though each cycle of the reference drive has exactly the same period as the input signal (both f_r), the lost half cycle that occurs with each phase reversal makes the overall reference drive frequency "low" by one cycle out of each 8193 cycles. This is where the reference drive frequency of $f_r - f_r/8193$ comes from. The Input signal and Mixer Drive signal are both applied to each of the mixers, with the drive to the Quadrature Mixer leading that applied to the In Phase Mixer by 90°. Each mixer acts as a synchronous detector, providing a dc voltage out that varies with the cosine of the angle between the applied drive and signal. If the Phase controls have been properly adjusted during half the I.F. wave, the reference drive to the In Phase mixer will be exactly in phase with the In-Phase component of the applied input signal, and the reference drive to the Quadrature mixer will be exactly in phase with the Quadrature component of the applied input signal. In effect, the individual cycles of the input signal undergo a phase-sensitive full-wave rectification at each mixer. Because of the reference drive phase reversal that occurs at $f_r/8193$, the polarity of the dc output at each mixer will reverse polarity at that rate. The result is that a square wave at $f_r/8193$ will appear at the rf mixer output. The amplitude of this square wave will be proportional to the amplitude of the input signal. Phase considerations will, of course, determine the amplitude of this I.F. signal as well. Typically, lock-in amplifiers are adjusted to set the phase of the reference drive at 0° with respect to the In Phase component of the input signal. When this is done, the output of the In Phase Mixer will be maximum and there will be zero average output from the Quadrature Mixer. Note that the Mixer output square wave will contain ripple at f_r. This ripple is filtered at the output of the mixers.

In addition to the mixers, the input overload detection circuits are also located on the RF Mixer board. These circuits directly monitor the input signal. Should excursions of either polarity exceed the overload threshold, the front-panel OVERLOAD indicator will light.

6.3E I.F. BOARD (Page VII-5)

Observing the schematic, note that the mixer outputs are applied to amplifiers on this board. The In Phase Mixer output drives the In Phase I.F. SIG. AMPlifier and the Quadrature Mixer output drives the Quadrature I.F. SIG. AMPlifier. The signal is at the I.F. Frequency, $f_r/8193$. Its amplitude depends on the amplitude and phase relationships at the RF Mixers, as explained in the preceding section.

Following amplification and buffering by the I.F. Amplifiers, the signal is applied to the two synchronous rectifiers for demodulation (conversion to dc). The I.F. demodulators, although they are far simpler than the RF Mixers, work in much the same way. The input signal is demodulated with respect to the I.F. Drive, providing dc output proportional to the amplitude of the I.F. signal applied. As previously mentioned, the I.F. drive is phase shifted if the 180° or 90° Phase pushbutton is depressed. This is the only phase difference that can occur at the I.F. Demodulators. The two signals are either in phase or 180° out of phase. Thus the output is always maximized; the only question with regard to phase effects on the output dc being one of polarity.

Note that the I.F. Drive from the Reference Pulse train generator board is routed through a simple amplifier (Q1 and Q2) prior to driving the I.F. Demodulators.

Each of the Synchronous Rectifiers is followed by an Amplifier/Filter stage. Note that the feedback resistor around each of these amplifiers is 5 MΩ. These resistors are paralleled by the time constant filter capacitors, which are not located on the board. The magnitude of the capacitor connected in parallel with the feedback resistors depends on which of the front-panel Time Constant pushbuttons is depressed, with the selected RC product being equal to the selected time constant.

The only other circuits on the I.F. Board are the two Bias Correctors, U1 and U2. They balance the outputs of each pair of DC Amplifiers with respect to +7.5 V, thereby assuring that the average value of the amplifier outputs is +7.5 V. This off-ground processing is required for optimum performance of the Synchronous Rectifiers.

6.3F OUTPUT AMPLIFIER BOARD (Page VII-13)

This board contains some dc amplifiers that buffer the I.F. Board output levels and that additionally provide the ancillary functions that are selected at the front panel for each channel. Observing the schematic, note that there are two parallel channels, one for the In Phase Channel, the other for the Quadrature Channel. They are identical and this discussion of the In Phase Channel applies as well to the Quadrature Channel except that the component numbers are different. The I.F. Board output is applied to gain-of-one buffer U4. The single-ended output of this amplifier is then applied to the second U4 amplifier, where the OFFSET, OUTPUT EXPAND, and FILTER functions are provided. Since these functions are selected by means of the front-panel pushbuttons, and the involved components are not located on the Output Amplifier board, it is necessary to refer to Sheet 1 of the Mother Board Schematic (page VII-21) to see in detail how these functions are provided. However, the relationship of these functions to U4 can be easily explained. Note that this amplifier has a gain of one (inverting) as determined by the ratio of R20 to R22. When the OUTPUT EXPAND X10 pushbutton is depressed, a 13.7 kΩ resistor is connected in parallel with R22, increasing the amplifier gain to X10. Similarly, when the front-panel FILTER pushbutton is connected, a 2 μF capacitor is connected in parallel with the R20, giving a filter time constant of 250 ms. Last, when the OFFSET pushbutton is depressed, a calibrated offset current is applied directly to the summing junction (pin 6) of the U4 amplifier. The magnitude of the offset depends on the setting of the OFFSET dial. Its polarity depends on which of the two polarity pushbuttons is depressed.

An Overload Detect circuit monitors the output of the first U4 amplifier. If overload levels are detected, current is supplied to the OVERLOAD LED, which lights to indicate the overload condition to the user. Note that the OVL light can be operated either by this circuit or by the overload detector on the RF Mixer board.

The only other circuit on the Output Amplifier board provides the Auto-Balance function. If there is any dc current unbalance ahead of the I.F. Demodulators (I.F. Board), it will be converted to an I.F. Frequency square wave by the I.F. Demodulator, causing unwanted I.F. ripple to appear at the output. Any I.F. ripple at U4-1 is applied to Auto-Balance Demodulator U2. Because any ripple at U4-1 will have a triangular waveshape due to the main Time Constant filtering, a differentiating network controlled by the FREQ. RANGE switch is interposed between U4-1 and U2 to restore the rectangular waveform. This ripple is demodulated at U2 with respect to the I.F. Reference Drive. The resultant dc error voltage is then fed back to the I.F. Board to the emitter of Q18, one side of the differential current source in the In Phase I.F. Signal Amplifier. The feedback polarity is such as to automatically balance the current sources such that there will be zero I.F. Frequency component at the output of the first U4 amplifier on the Output Amplifier Board. Because the gain of this circuit is purposely limited, an AC BALANCE adjustment is required at the I.F. Board for optimum performance.

Note that the meters, output connectors, and options, if incorporated, are driven from the output of the second Output Board amplifier in each channel.

6.3G VECTOR OPTION BOARD (Page VII-15)

This option accepts the dc outputs from the I and Q channels respectively and from them develops the vector sum (magnitude) and a dc voltage proportional to the phase. It should be noted that the technique used will only give accurate outputs with sinusoidal input signals.

In any case, as indicated in Figure VI-2, the two dc levels

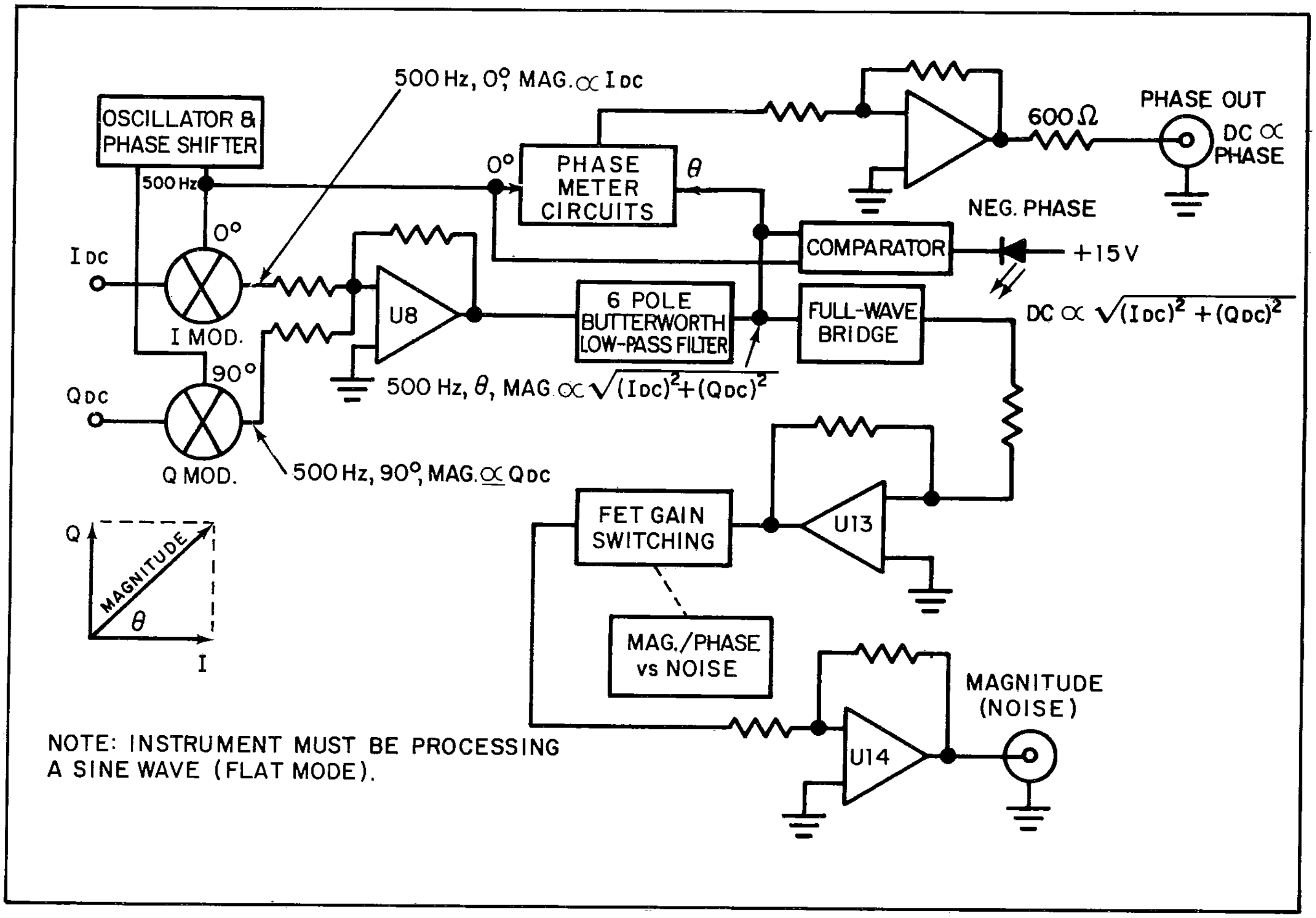


Figure VI-2. VECTOR OPTION BLOCK DIAGRAM

are each applied to a mixer. The modulation signals are 500 Hz stepped "sine waves", with the In Phase Mixer driven at 0° and the Q Mixer at 90°. The output of each mixer is a 500 Hz sine wave proportional in amplitude to the dc input to the mixer. Since the two sine waves are by definition forced into quadrature because mixer drive signals are in quadrature, the vector sum of the two can be developed by adding them in a conventional operational amplifier. This is done in Amplifier U8, and the output of this amplifier is a 500 Hz vector sum of the applied sine waves. The phase (θ) is the angle between the sum vector and the in-phase component. The amplitude is proportional to the square root of the sum of the squares of the two input dc levels. To remove any harmonic induced errors, the vector sum signal is followed by a 6-pole Butterworth filter. The resultant clean sine wave is then applied to the phase-meter circuit, where it is compared with the 0° drive to the I mixer. On the basis of the comparison results, the Phase Meter is able to develop a dc voltage proportional to the difference angle. The transfer function is 10 mV/ °, up to a maximum of 1.8 V. With greater angles, the voltage decreases linearly so that the phase output exhibits no discontinuities as a function of phase. Another comparator determines whether the angle is between 0° and 180° or between 180° and 360°. In the latter case this comparator supplies current to the front-panel NEGATIVE PHASE light.

The magnitude output voltage is also developed from the sine wave at the output of the Butterworth filter. This signal is applied to a full-wave bridge rectifier to develop a dc vector sum level. This voltage in turn is amplified, first by U13 and then by U14, prior to being routed to the MAGNITUDE connector.

6.3H RATIO OPTION BOARD (Page VII-19)

Although complex from a circuitry point of view, the ratio option is quite simple on the block diagram level as indicated in Figure VI-3. Each input is followed by an absolute value circuit, which in turn drives a log converter. Thus there is a log converter for the "A" channel (U5) and one for the "B" channel (U7). Note that there is a FET switch interposed between the output of the "B" Absolute Value circuit and the "B" log converter. This switch serves to block the "B" path in Log A operation, and substitutes a fixed full-scale "B" level in its place. In any case, whether operating in the Log A or Log A/B mode, the two log signals are combined (subtracted) in the following amplifier, and the difference signal (Log A/B) is developed. There are two possible signal paths from this point, one through a FET switch to the RATIO OUTPUT (Log A/B or Log A) and the other downwards to another amplifier (second half of U8). This amplifier drives the antilog circuit, developing A/B from the Log A/B level, and providing a proportional voltage at the output of U10. In A/B operation, this signal

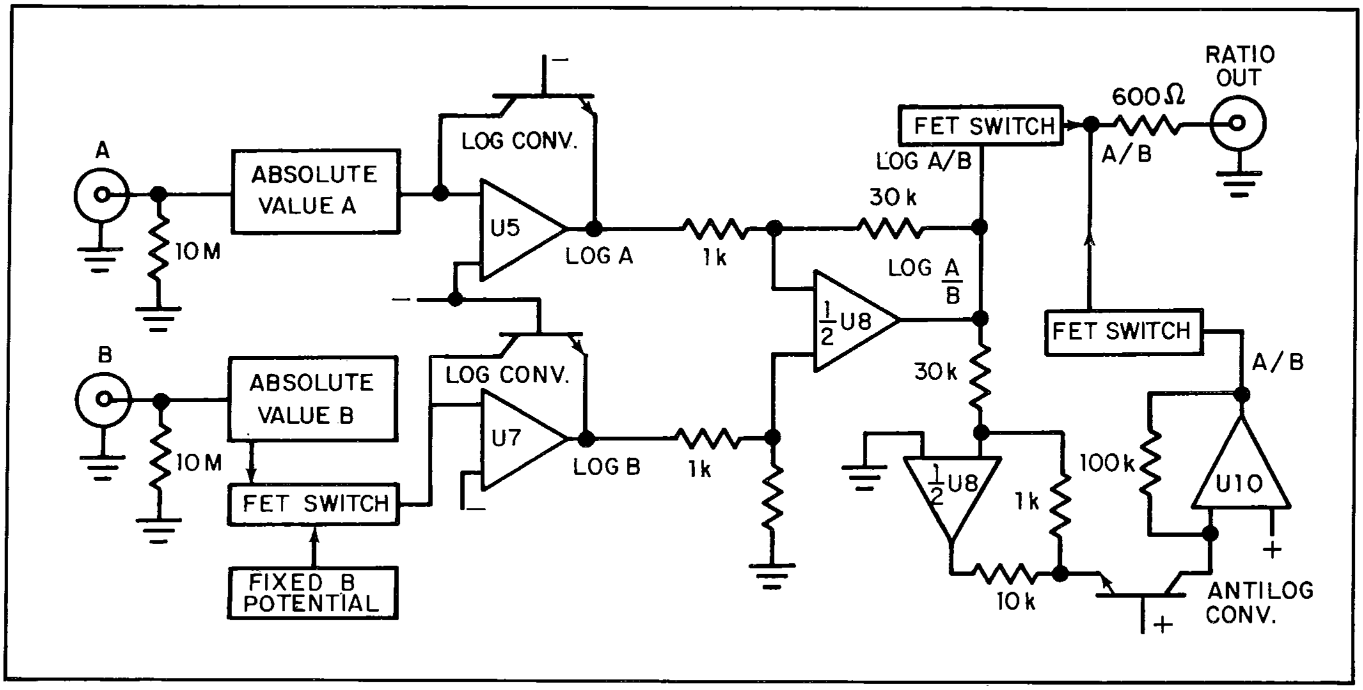


Figure VI-3. RATIO OPTION BLOCK DIAGRAM

is routed through a FET switch to the RATIO OUTPUT (the path from Log A/B is blocked). In Log A or Log A/B operation, the path from U10 is blocked and the Log A/B level is provided at the RATIO OUTPUT as previously described.

6.4 TROUBLESHOOTING PROCEDURES

6.4A TROUBLESHOOTING THE REFERENCE CHANNEL

Of all the Model 5202 circuitry, that in the Reference Channel is the most difficult to troubleshoot. Not only is it necessary to deal with and measure frequencies as high as 200 MHz, but it is necessary as well to signal trace a phase-locked loop.

Troubleshooting is most conveniently accomplished by applying a reference signal of known frequency and amplitude followed by signal tracing with an oscilloscope through the reference channel circuits. A good initial choice is a 1 V rms sine wave at 1 MHz. This signal will be routed by internal signal lines to the Reference Input Amplifier (page VII-11). The output of this stage can be examined at TP1 on the PLO board. **NOTE:** Signal tracing at the indicated test points will frequently require use of an extender board (1710-00-1403S). The TP1 signal should be a square wave at the applied frequency. Its phase relative to the input reference will depend on the selected slope. The front-panel Reference pushbuttons will determine precisely where the trigger detection occurs. With the sine wave pushbutton depressed, the TP1 signal will be square wave. With either of the pulse pushbuttons depressed, it will be rectangular with the actual aspect ratio a function of the reference input amplitude. ECL logic is used throughout. Thus the logic levels at TP1 should be −0.8 V and −1.6 V, although the observed signals will not quite make the full swing at the higher frequencies.

The TP1 signal is one of the two inputs to the FREQ/PHASE COMPARATOR, the other being the feedback signal from the PULSE TRAIN GENERATOR board. Both signals will be at the same frequency, f_r, but will differ in phase if the front-panel Phase Vernier is set to any phase other than 0°. If the feedback signal is not as described, the

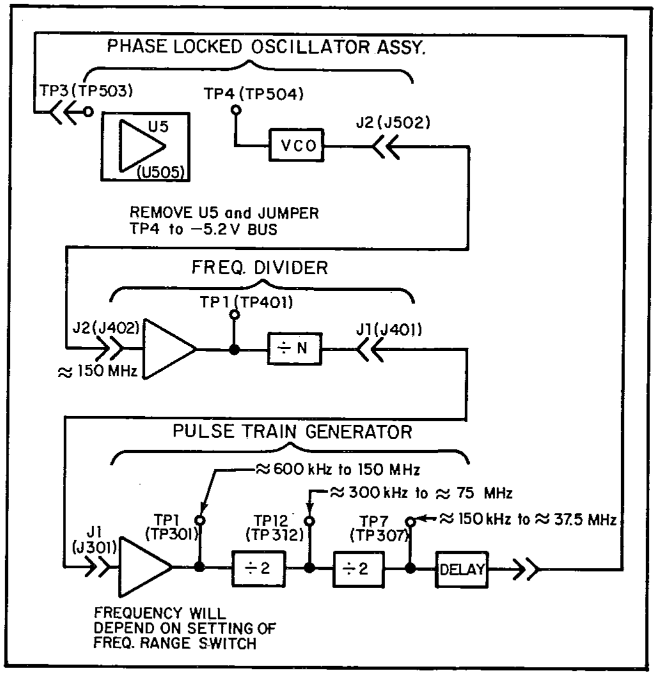


Figure VI-4. REFERENCE CHANNEL SIGNALS WITH LOOP BROKEN trouble could be anywhere in the phase locked loop circuits that follow. One technique that may prove helpful is to break the loop by removing U5. If TP4 is then jumpered to the −5.2 V bus, the behavior of the remaining circuits becomes predictable, allowing any fault to be isolated to the malfunctioning stage. As shown in Figure IV-4, the output of the Voltage Controlled Oscillator under these test conditions should be about 150 MHz. It is suggested that this signal be measured at U1 pin 14 on the FREQUENCY DIVIDER board. If this signal is missing, the problem probably lies with the VCO or with the buffer (three parallel sections of U1) interposed between the output of the VCO and TP1 on the Freq. Divider board. Note that this 150 MHz will be neither accurate nor stable because the loop has been opened. Assuming the signal at U1 pin 14 is correct, the individual dividers should be checked. Because test points haven't been provided for each, it will be necessary to check the frequency on the output bus, the line common to pin 15 of U1 and pin 2 of U2. The observed frequency will depend on the setting of the front-panel FREQUENCY RANGE switch and on the VCO output frequency, which, as pointed out earlier, will be nominally 150 MHz. Table VI-1 below indicates the frequency as a function of switch setting.

FREQUENCY RANGE SETTING	DIVIDER OUTPUT FREQUENCY
25 - 50 MHz	Same as VCO (150 MHz)
12 - 25 MHz	75 MHz (1/2 VCO)
6.4 - 13 MHz	37.5 MHz (1/4 VCO)
3.2 - 6.4 MHz	18.8 MHz (1/8 VCO)
1.6 - 3.2 MHz	9.4 MHz (1/16 VCO)
0.8 - 1.6 MHz	4.7 MHz (1/32 VCO)
0.4 - 0.8 MHz	2.34 MHz (1/64 VCO)
0.2 - 0.4 MHz	1.2 MHz (1/128 VCO)
0.1 - 0.2 MHz	0.59 MHz (1/256 VCO)

Table VI-1. DIVIDER OUTPUT FREQUENCY IN TEST CONFIGURATION

If these frequency measurements are made and found to be correct, the user can conclude that the Divider board is functioning normally. If not, isolating the defective divider circuit should be a relatively straightforward task.

Leave the Freq. Range switch set to the 25-50 MHz position and go on to the REFERENCE PULSE-TRAIN GENERATORS board (schematic on page VII-7). The 150 MHz signal should next be checked at TP1 of that board where it should appear unchanged. TP7 is the next convenient checkpoint. As shown in the schematic, the two divide-by-two circuits between TP1 and TP7 should reduce the frequency from 150 MHz to 37.5 MHz. A Clocked Buffer, 90° Delay, and some gates follow that provide isolation and a 90° phase shift in the output signal if the 90° or 270° pushbutton is depressed. These circuits are easily checked by monitoring TP8 or TP9 with the oscilloscope. If the scope is triggered with the TP7 signal, the 90° phase shift that occurs as the 90° or 270° pushbutton is depressed or released can be easily observed. The signal at TP9 is the actual feedback signal to the Frequency/Phase Comparator on the VCO board. If this signal is normal, the basic Phase Locked Loop should function correctly. All circuits have been checked with the exception of the Freq/Phase Comparator itself and the VCO Control Filter that follows it. If all circuits check good so far and the loop doesn't work, these two circuits remain the prime suspects by elimination.

There still remains the problem of the many additional circuits located on the Reference Pulse Train Generator board that are not involved in the loop operation. If the loop is intact and working, and assuming a 1 MHz reference signal is applied with the Freq. Range switch set to 0.8 - 1.6 MHz, the frequency at TP1 of the Ref. Pulse Gen. board will be 4 MHz (4f_r). The signal at TP7, TP8, and TP9 will be at f_r (1 MHz). However, if the loop has been broken as prescribed earlier, and the FREQ. RANGE switch left at 25-50 MHz, the TP1 frequency will be nominally 150 MHz. At TP7, TP8, and TP9 the frequency will be 37.5 MHz. Given either set of circumstances, the remaining circuits can be easily checked. The I.F. Drive is developed from a series of frequency dividers as shown on the schematic. These dividers can be checked by examining the signal at TP10 or TP11. In either case, the observed signal should be 1/8193 f_r, where f_r is the input reference frequency. In the case of broken-loop operation, the equivalent f_r is 150 MHz ÷ 4 = 37.5 MHz. Whether the reference is 1 MHz or the equivalent reference, 37.5 MHz, the I.F. Drive will be a factor of 8193 lower. If the signal is not as indicated, the problem probably lies with the divider string.

If the divider string is working properly, the next step is to check the R.F. Mixer Drive circuits. These drives are developed by the two "D" flip-flops of I.C. U2. Their outputs can be checked at TP3, TP4, TP5, and TP6. Except for phase differences, these signals should all be the same. As indicated, the frequency is 8192/8193 f_r. For all practical purposes, the frequency is f_r, except that every 8192 half cycles a phase reversal occurs with the loss of one half cycle. This phase reversal can be observed with an oscilloscope. To do so, the scope must be triggered by the I.F. Drive signal, with the sweep time adjusted so that four or five RF Drive cycles fill the sweep. Properly triggered, the scope should show (dimly) a square wave except that the first pulse will be twice the duration of those that follow. It may be easier to use a frequency counter than an oscilloscope to verify the correctness of these drives. Simply measure the frequency at TP3, TP4, TP5, and TP6, and compare with the frequency at TP7, TP8, or TP9. The ratio should be equal to 8192/8193.

6.4B TROUBLESHOOTING THE RF MIXER

If any single subsystem can be called the heart of the Model 5202, it is the RF Mixers. It is in these mixers that the input signal undergoes the phase-sensitive demodulation that converts it to a square wave at the I.F. frequency (f_r/8193). Before checks can be made to verify proper operation of the mixers, it is absolutely necessary that the RF Drive from the Reference Pulse Train Generators board be present. Thus the Reference Channel must be functioning normally before the RF Mixers can be checked. However, if the Reference Channel is functioning normally, troubleshooting the RF Mixers should be relatively straightforward. It is suggested that a 1 MHz input signal and reference signal be applied, with the Freq. Range switch set to 0.8 - 1.6 MHz. A convenient amplitude might be 250 mV rms for both.

Referring to the schematic on page VII-3, note that the input signal is transformer coupled to both mixers where it is applied differentially to a pair of current sources in each. Thus the input signal voltage is immediately converted to a signal current. The differential signal current amplitude is approximately E/100 amperes, where E is the amplitude of the differential voltage applied. The current is demodulated with respect to the RF Drive to produce the I.F. frequency current signal routed to the I.F. Board. Because these are current signals, it is difficult to monitor them with an oscilloscope. However, by setting the signal sensitivity to the 1 mV range, it should be possible to monitor the signals across C4, C5, C15 and C16. Note that there is a common mode voltage of nominally 4.4 V on these lines. As previously mentioned, these signals should be at the I.F. frequency. Their amplitude will be proportional to the input signal level. With the Phase controls adjusted for maximum output from the In Phase Mixer, there will be zero output from the Quadrature Mixer. Similarly, if the Phase controls are adjusted for maximum Quadrature Mixer output, there will be zero In Phase Mixer output. If the indicated behavior is observed, the RF Mixers may be presumed to be operating correctly.

The Overload circuits can be checked individually by observing the voltages at pins 1 and 7 of U106. A level of −12 V (approx.) indicates full on. Note that the OUTPUT Board's overload circuit also drives the OVL lamp.

6.4C TROUBLESHOOTING THE I.F. BOARD

The current-mode signals from the RF Mixers are demodulated with respect to the I.F. Drive at this board. Referring to the schematic, note that one of the differential outputs is applied to the In Phase I.F. Signal Amplifier via Q17 and Q19. The other is applied to the Quadrature I.F. Signal Amplifier via Q13 and Q15. These signals, still the same magnitude, are raised to a common mode level of +7.5 V and then applied to the current-mode synchronous rectifiers for conversion to dc. The current-to-voltage converter stages that follow (U5 and U6 for the In Phase Channel; U3 and U4 for the Quadrature Channel) transfer the signal back to voltage mode so that it can be easily examined. In checking the outputs of these converters, bear in mind that they are balanced with respect to +7.5 V, and it is the differential output level that carries the signal amplitude information.

Bias correctors U1 and U2 monitor the common-mode output level and automatically adjust the common mode current in the I.F. Signal Amplifiers as required to maintain the +7.5 V balance. The In Phase Channel can be checked by monitoring differentially between pin 8 of U5 and pin 8 of U6 as the input signal level is changed (assuming Phase controls are adjusted for maximum output from the In Phase RF Mixer). The Quadrature Channel can be similarly checked. If the differential output tracks the signal level, while maintaining the required +7.5 V average, these circuits can be presumed to be working correctly.

Note that an AUTO-BAL signal is applied to each of the I.F. Signal Amplifiers (emitter of Q18 in one case and emitter of Q14 in the other). In each case the Auto-Bal voltage automatically balances the I.F. Signal Amplifier. Without the auto-bal feedback, which is produced on the Output Amplifier Board, any unbalance dc would be converted to ripple at the I.F. frequency by the I.F. Synchronous Rectifier. This ripple would degrade the output circuits' performance. A high ripple level in one of the differential outputs of the I.F. Board would be indicative of failure in the auto-bal circuit or of a need to make the AC BAL adjustments (Subsection 5.12). However, this circuit is treated in the discussion of the Output Amplifier Board. Another possible cause would be dc unbalance in the output current of the RF Mixer Board.

One last circuit that should be mentioned is the I.F. Reference Amplifier, which accepts the I.F. Drive signal produced by the Reference Pulse Train Generators Board and adjusts the drive levels as required by the two I.F. Synchronous Rectifiers. The correct signal levels are indicated on the schematic. (If the drive to the synchronous rectifier exceeds the +7.5 V bus potential, the FET gates conduct, producing erratic behavior in the associated circuits.)

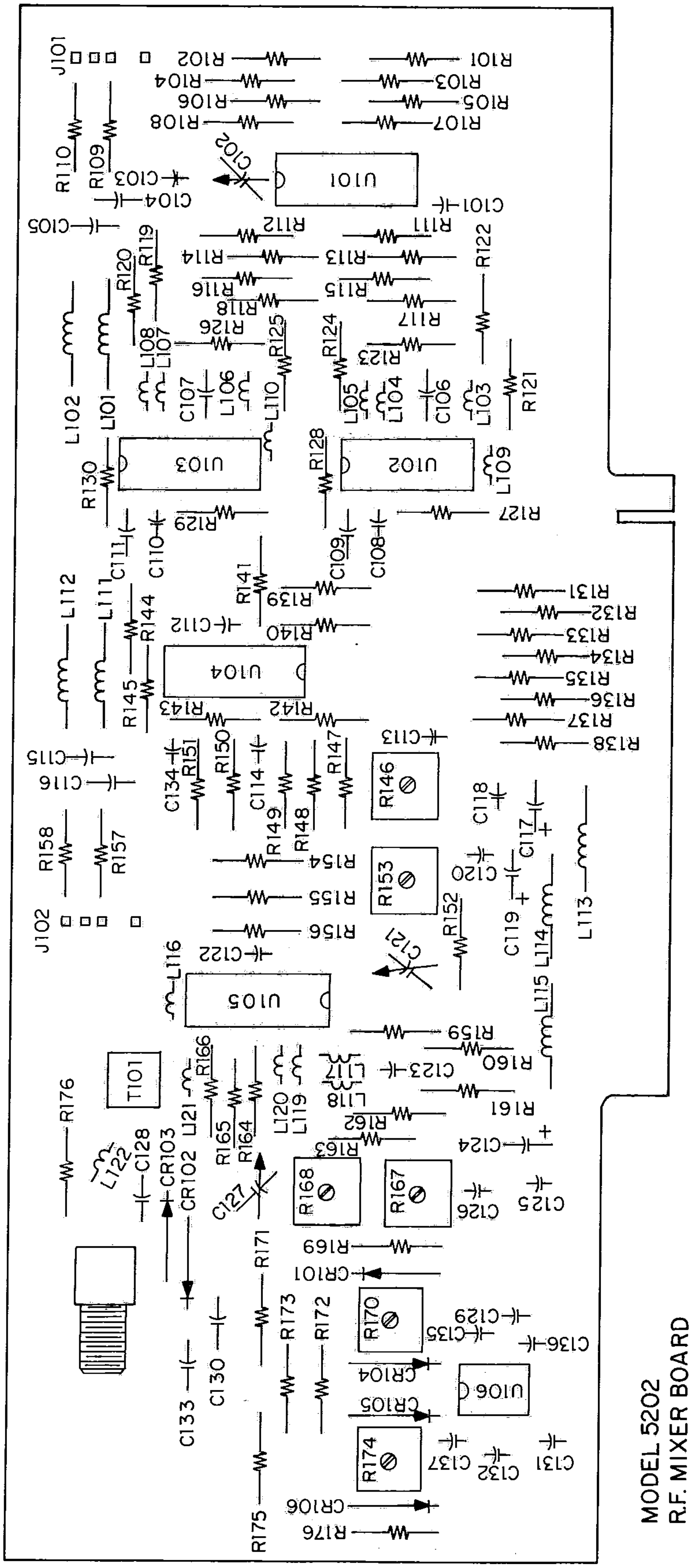
Also as yet unmentioned is the 7.5 V Power Supply, which is nothing more than an emitter-follower type regulator that provides 7.5 V from +15 V.

6.4D TROUBLESHOOTING THE OUTPUT AMPLIFIER BOARD

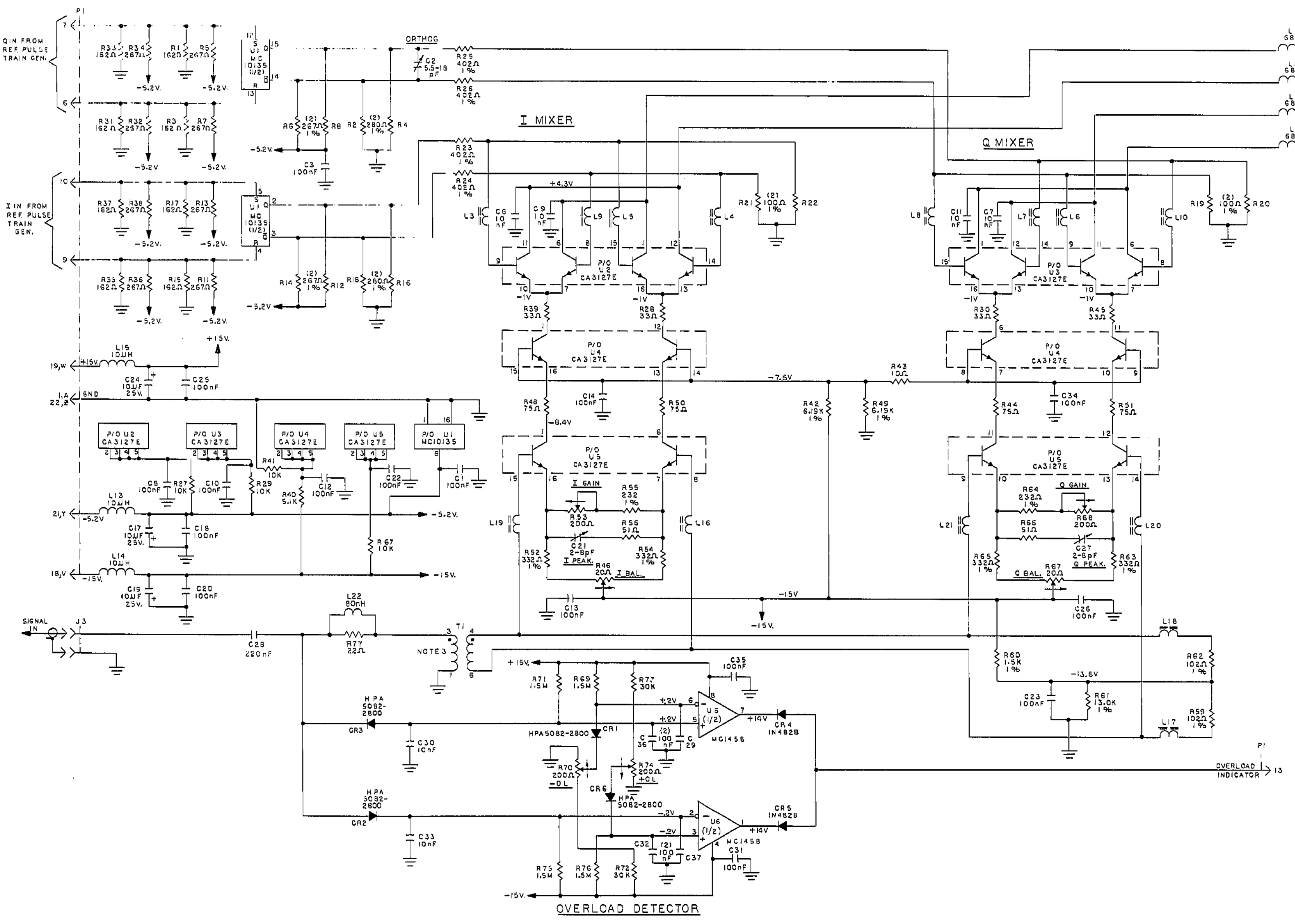
There is relatively little circuitry on this board, principally some output amplifiers with a net gain of X1 or X10 (Output Expand X10 depressed). Referring to the schematic, note that pin 1 of U4 is a convenient check point for the In Phase Channel while pin 1 of U5 is a corresponding check point for the Quadrature Channel. With a full-scale sine wave input and assuming that all the previously discussed circuits are working properly, the voltage at each of these points should be −6.3 V (Phase controls properly adjusted for each measurement). Amplifiers U4 and U5 provide isolation and allow the OFFSET, FILT, and X10 functions (see discussions in Subsection 6.3F). Note that the U4 and U5 outputs are referenced to ground, the +7.5 V common-mode level being subtracted out. The first section of U3 senses output overload in both channels. The second amplifier in U3 drives the Overload lamp circuit. When on, the output voltage of this circuit is −12 V (the OVL lamp is also operated by the RF Mixer Board's overload detector).

The only other circuits on the board are the auto-balance circuits U1 and U2. They monitor the U4 and U5 output levels respectively, which are differentiated to square up any ripple (which will have a triangular shape due to the main time constant filtering), and demodulate them with respect to the I.F. Drive. The differentiation time constant depends on the setting of the FREQ. RANGE switch. Any ripple present will be rectified and the resultant dc, applied to the proper I.F. Amplifier on the I.F. Board, will automatically tend to balance the I.F. Amplifier for zero ripple (AC Balance adjustments also affect ripple).

SECTION VII
SCHEMATICS



MODEL 5202
R.F. MIXER BOARD



NOTES

1. ALL RESISTORS ARE 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/8W METAL FILM.
3. PIN NO'S OF T1 ARE NOT MANUFACTURERS NUMBERING, BUT CONVENTIONAL I.C. NUMBER PATTERN.
4. ADD 100 TO ALL COMPONENT PART NO'S.

SH 1 OF 1 | 11723 | D | SD | C

R.F. MIXER

MODEL 5202

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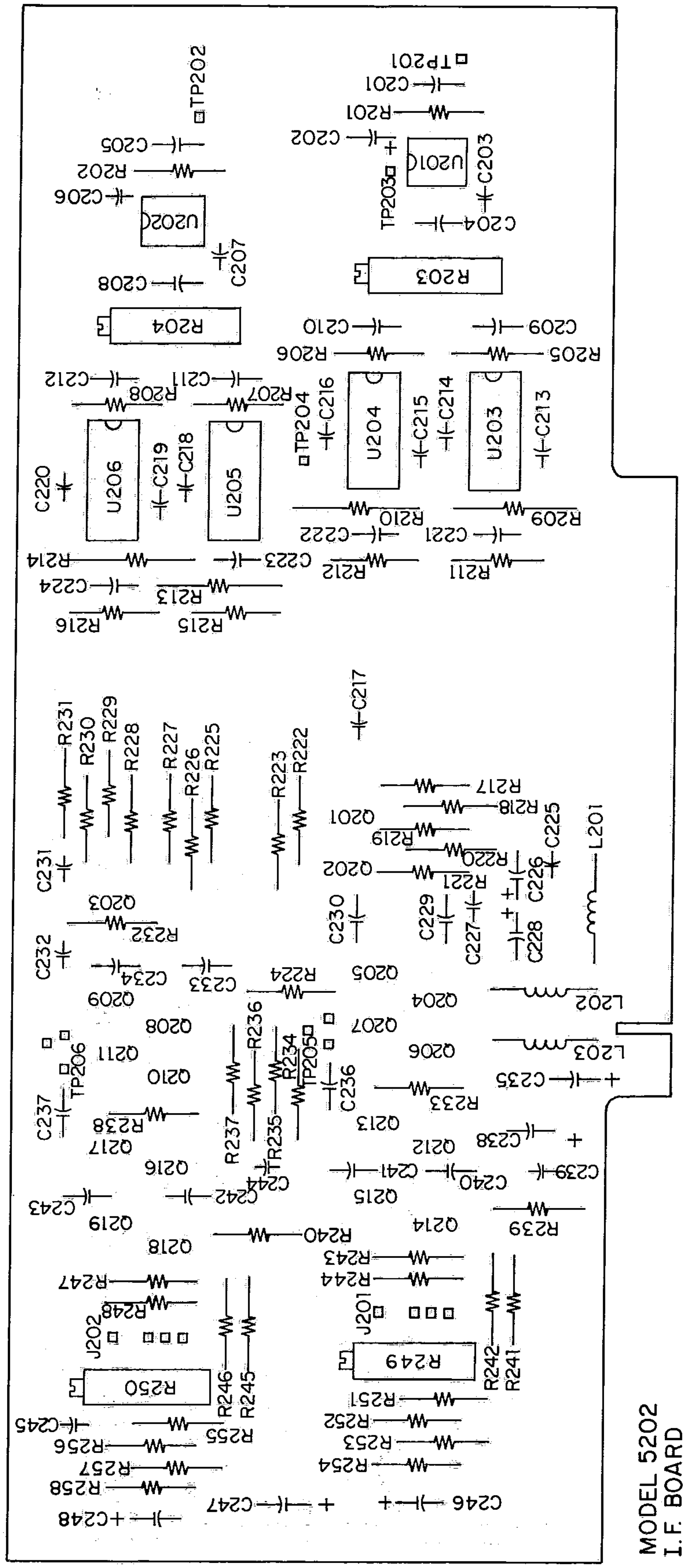
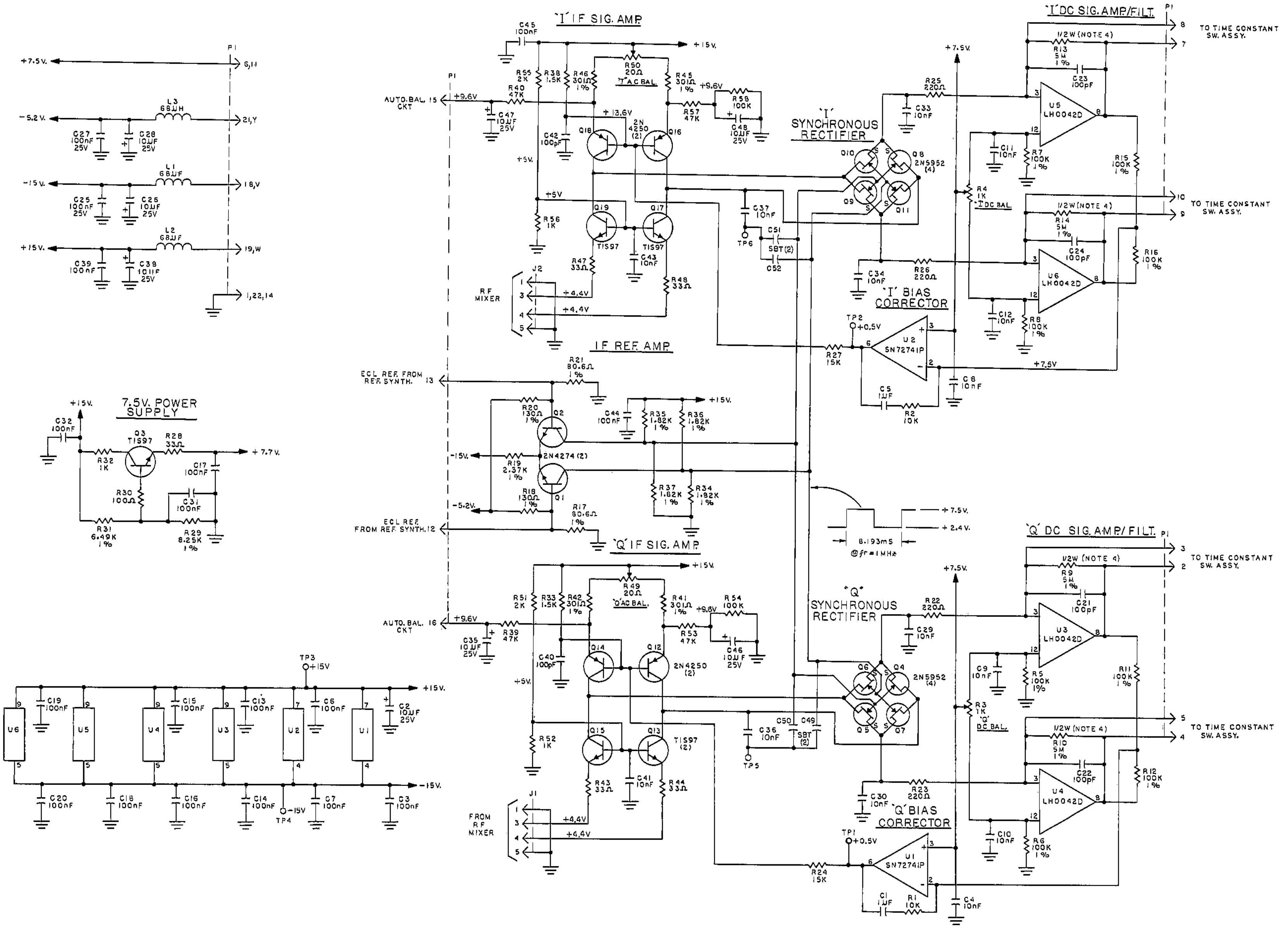
SHT. 1 OF 1 | 117_3 | D | SD | C



MODEL 5202
I.F. BOARD



NOTES:

1. ALL RESISTORS ARE 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/8W METAL FILM UNLESS OTHERWISE NOTED
3. ADD 200 TO ALL COMPONENT PART NO'S.
4. R9,10,13 AND R14 ARE CARBON FILM.

I.F. BOARD

MODEL 5202

SH. 1 OF 1 | 11727 | D | SD | A

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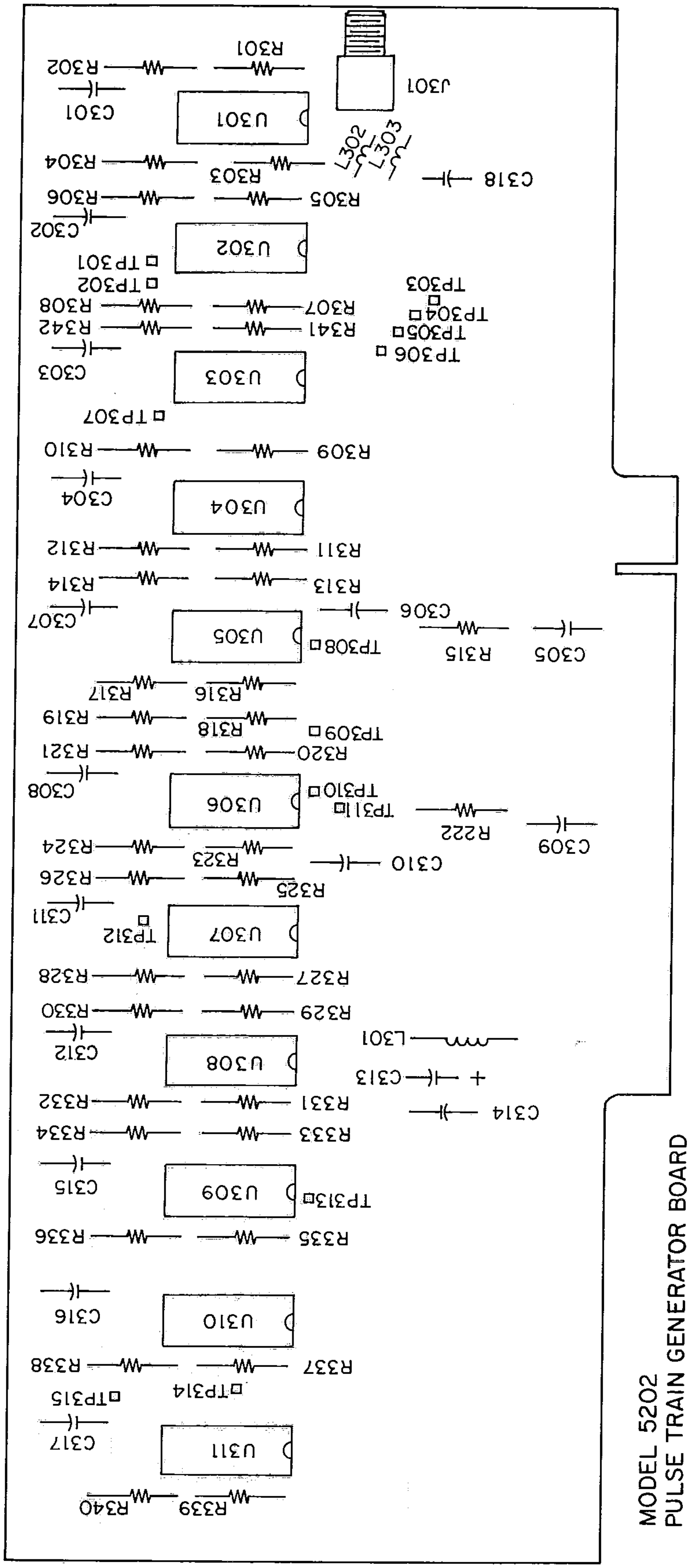
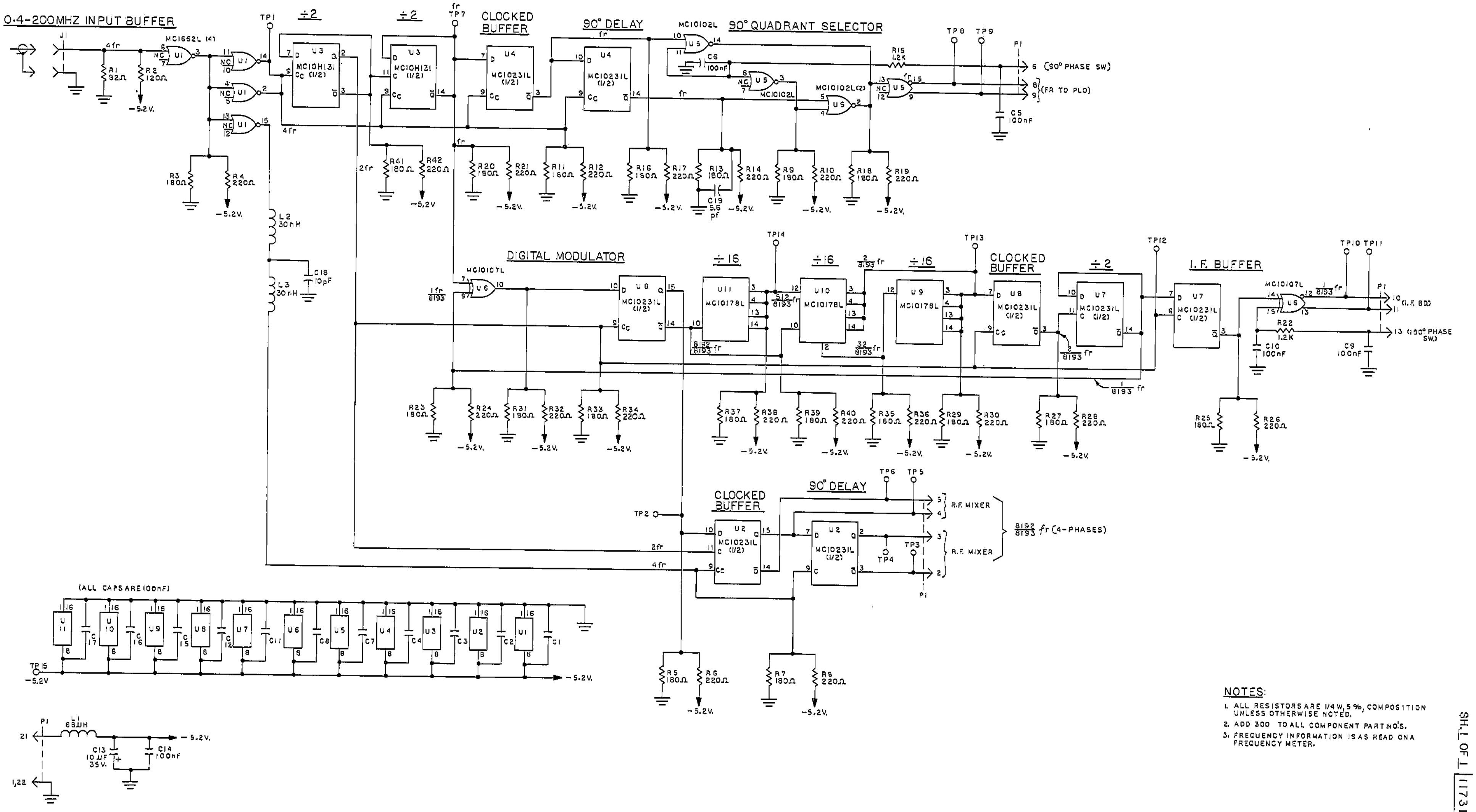
SHT. 1 OF 1 | 11727 | D | SD | A



MODEL 5202
PULSE TRAIN GENERATOR BOARD



NOTES:

1. ALL RESISTORS ARE 1/4 W, 5 %, COMPOSITION UNLESS OTHERWISE NOTED.
2. ADD 300 TO ALL COMPONENT PART NO'S.
3. FREQUENCY INFORMATION IS AS READ ON A FREQUENCY METER.

SH. 1 OF 1 | 11731 | D | SD | D

REFERENCE PULSETRAIN GENERATORS

MODEL 5202

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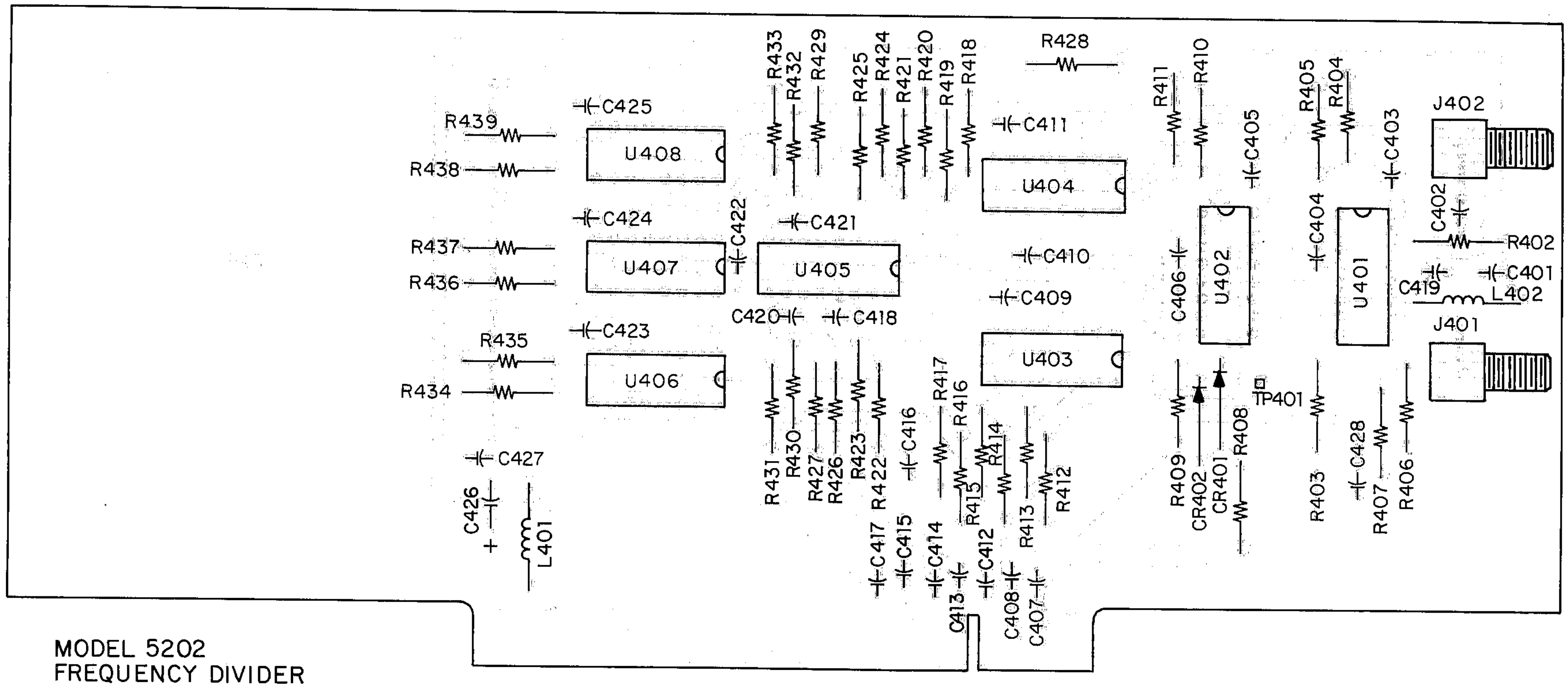
JWR 8-17-77

SHT. 1 OF 1 | 11731 | D | SD | D



MODEL 5202
FREQUENCY DIVIDER

SH. 1 OF 1 11735 D SD B

MODEL 5202

FREQUENCY DIVIDER

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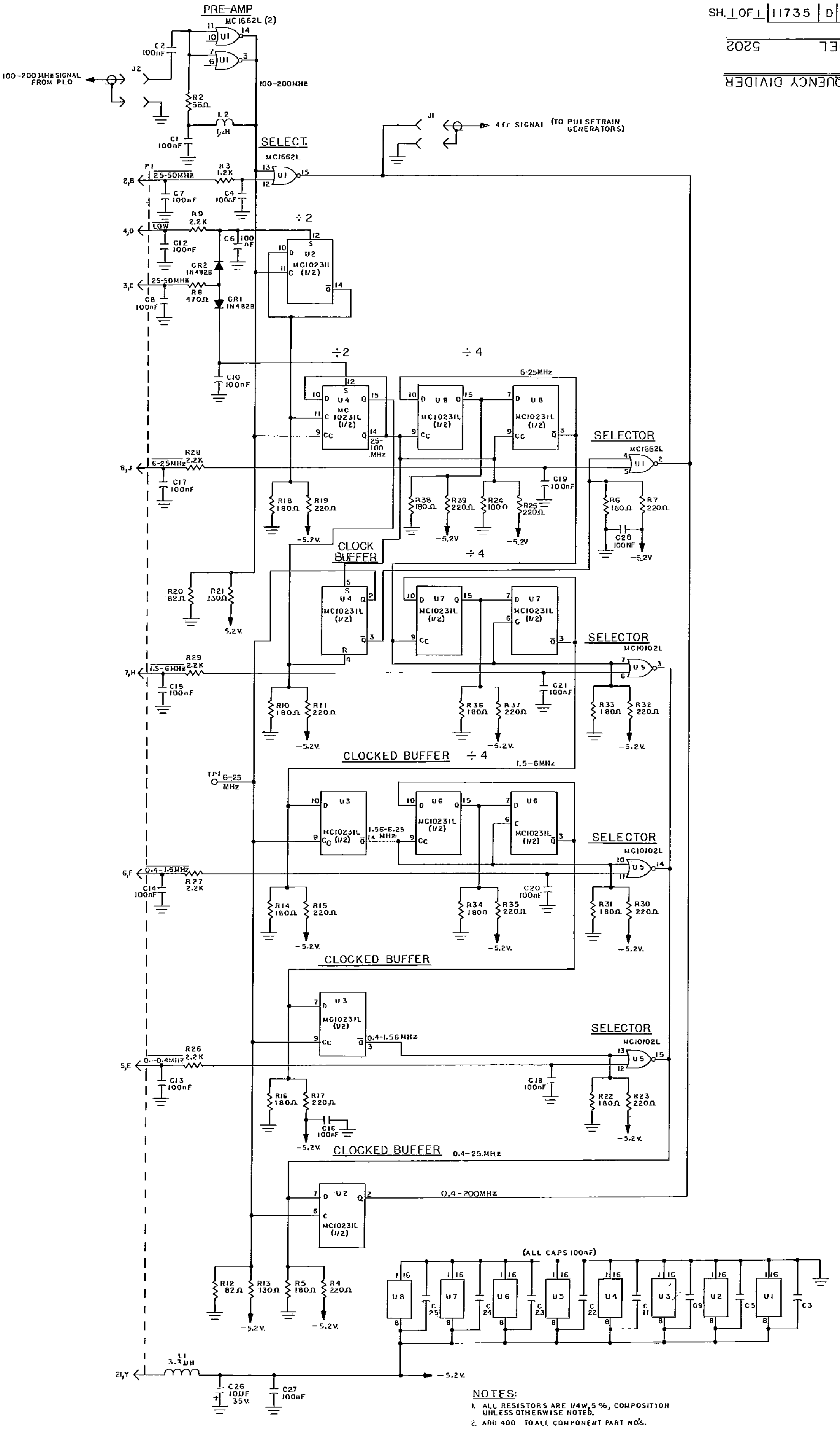
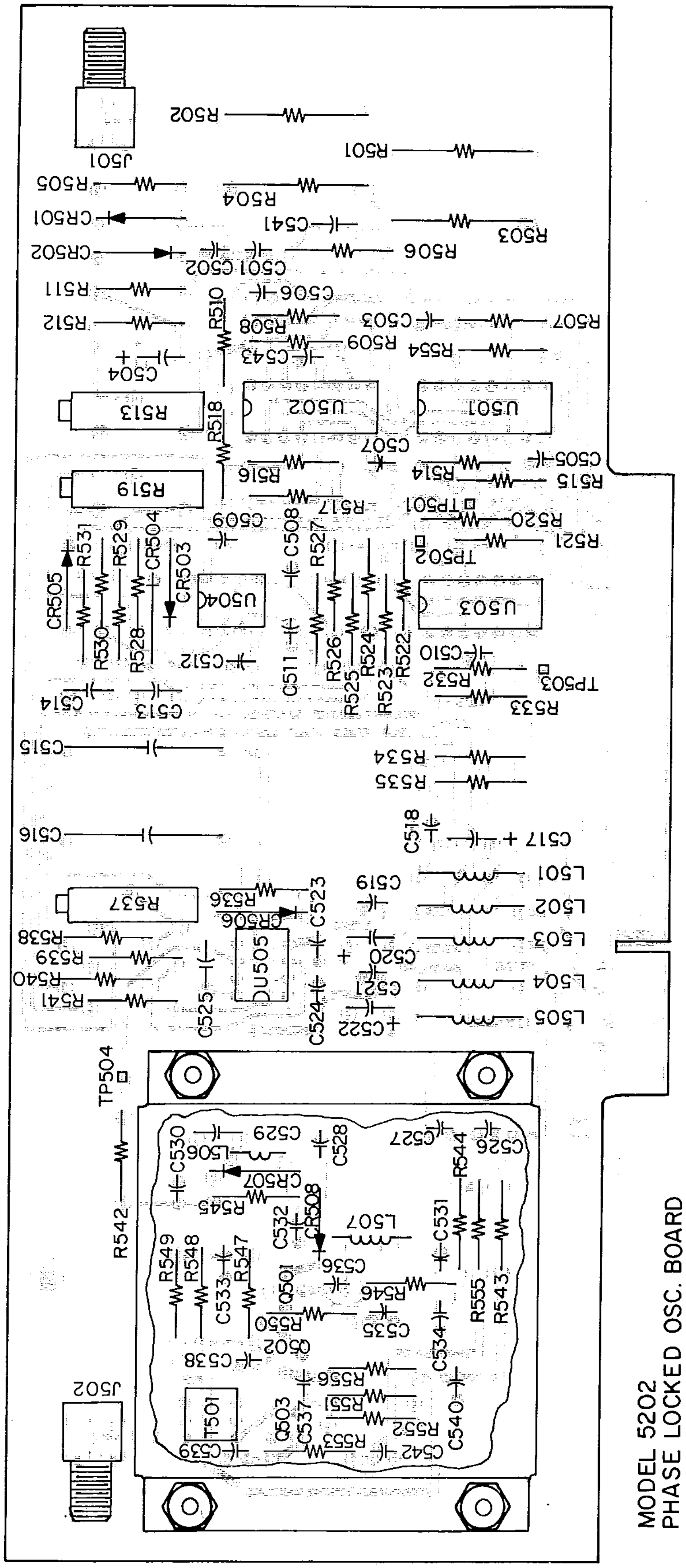
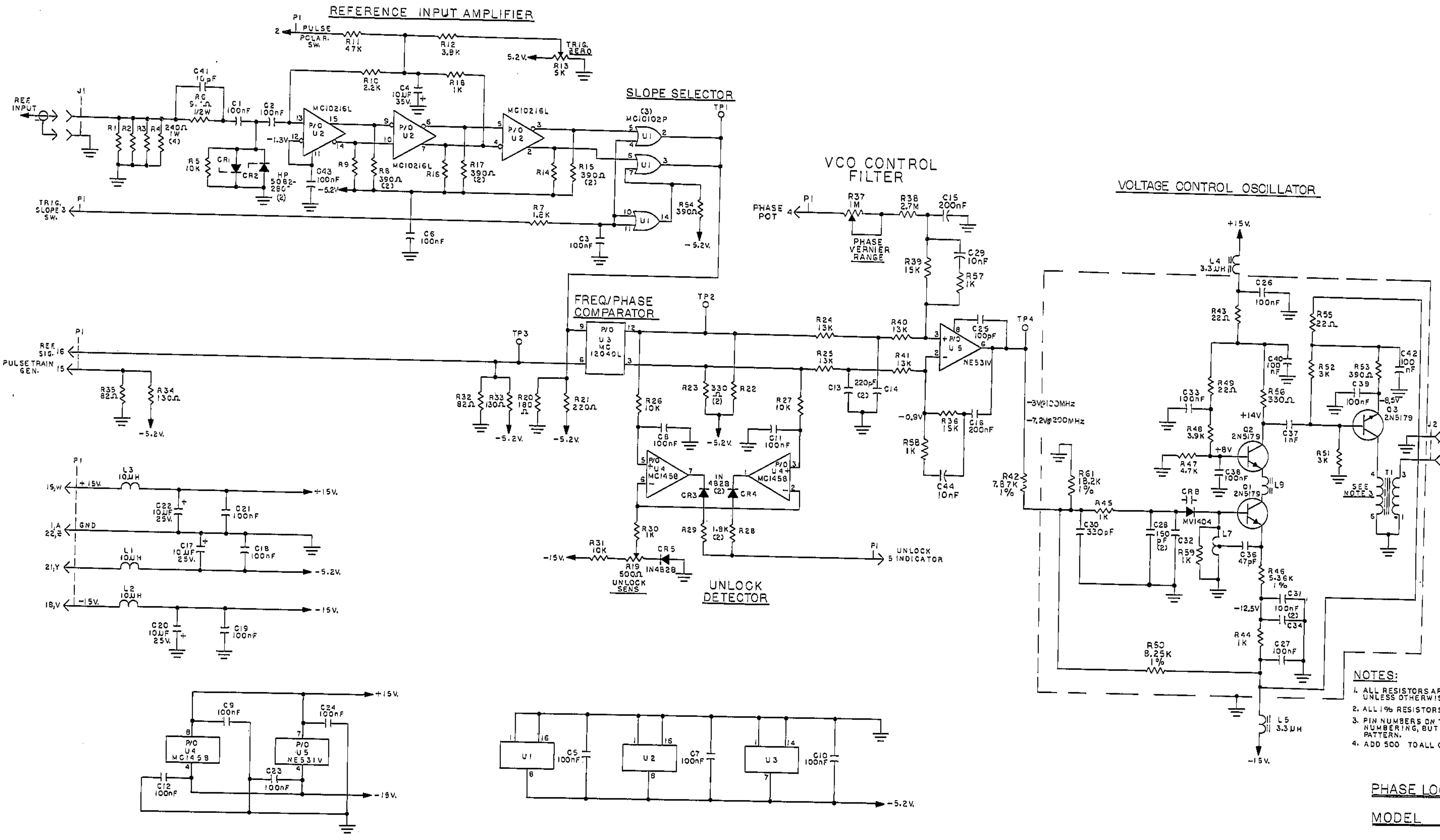
SHT. 1 OF 1 11735 D SD B



NOTES:
1. ALL RESISTORS ARE 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ADD 400 TO ALL COMPONENT PART NO'S.



MODEL 5202
PHASE LOCKED OSC. BOARD



NOTES:

1. ALL RESISTORS ARE 5%, 1/4W, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/8W METAL FILM.,
3. PIN NUMBERS ON T1 ARE NOT MANUFACTURERS NUMBERING, BUT CONVENTIONAL I.C. NUMBER PATTERN.
4. ADD 500 TO ALL COMPONENT PART NO'S.

SH. 1 OF 1 | 11739 | D | SD | H

PHASE LOCKED OSC.

MODEL 5202

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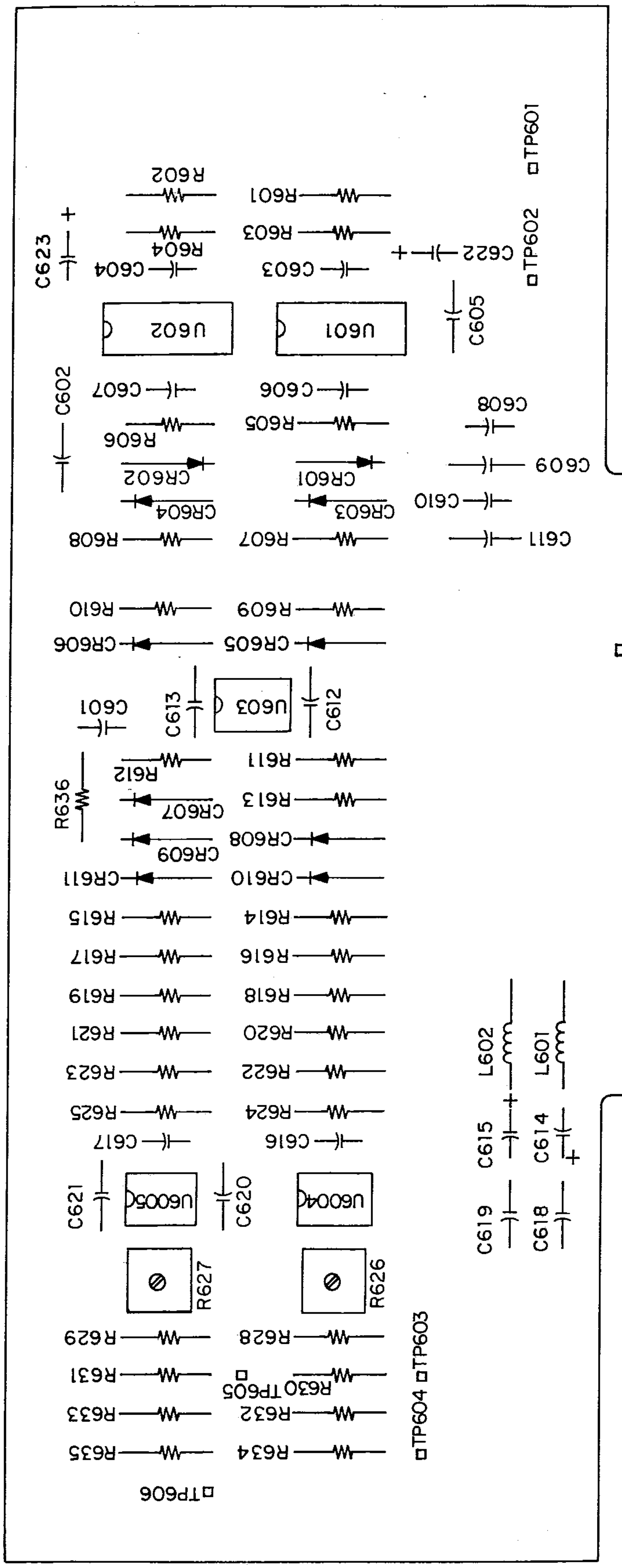
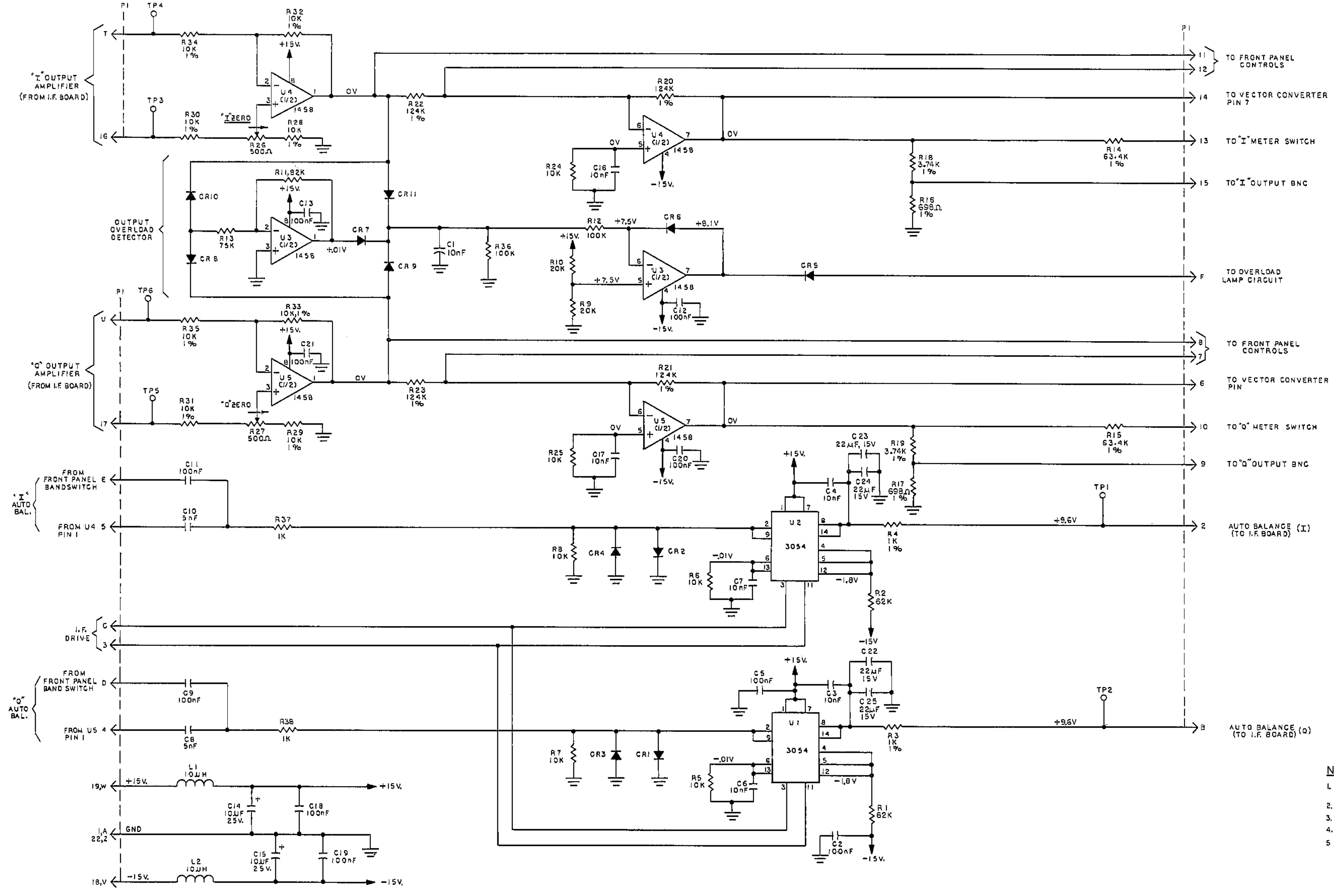
SHT. 1 OF 1 | 11739 | D | SD | F



MODEL 5202
OUTPUT AMPLIFIER BOARD

SH. 1 OF 1 | 11743 | D | SD | D



NOTES:

1. ALL RESISTORS ARE 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE 1/8W. METAL FILM.
3. ALL DIODES ARE IN462B.
4. ADD 600 TO ALL COMPONENT PART NO'S.
5 VOLTAGES READ WITH NO SIGNAL APPLIED.

OUTPUT AMPLIFIER BD.

MODEL 5202

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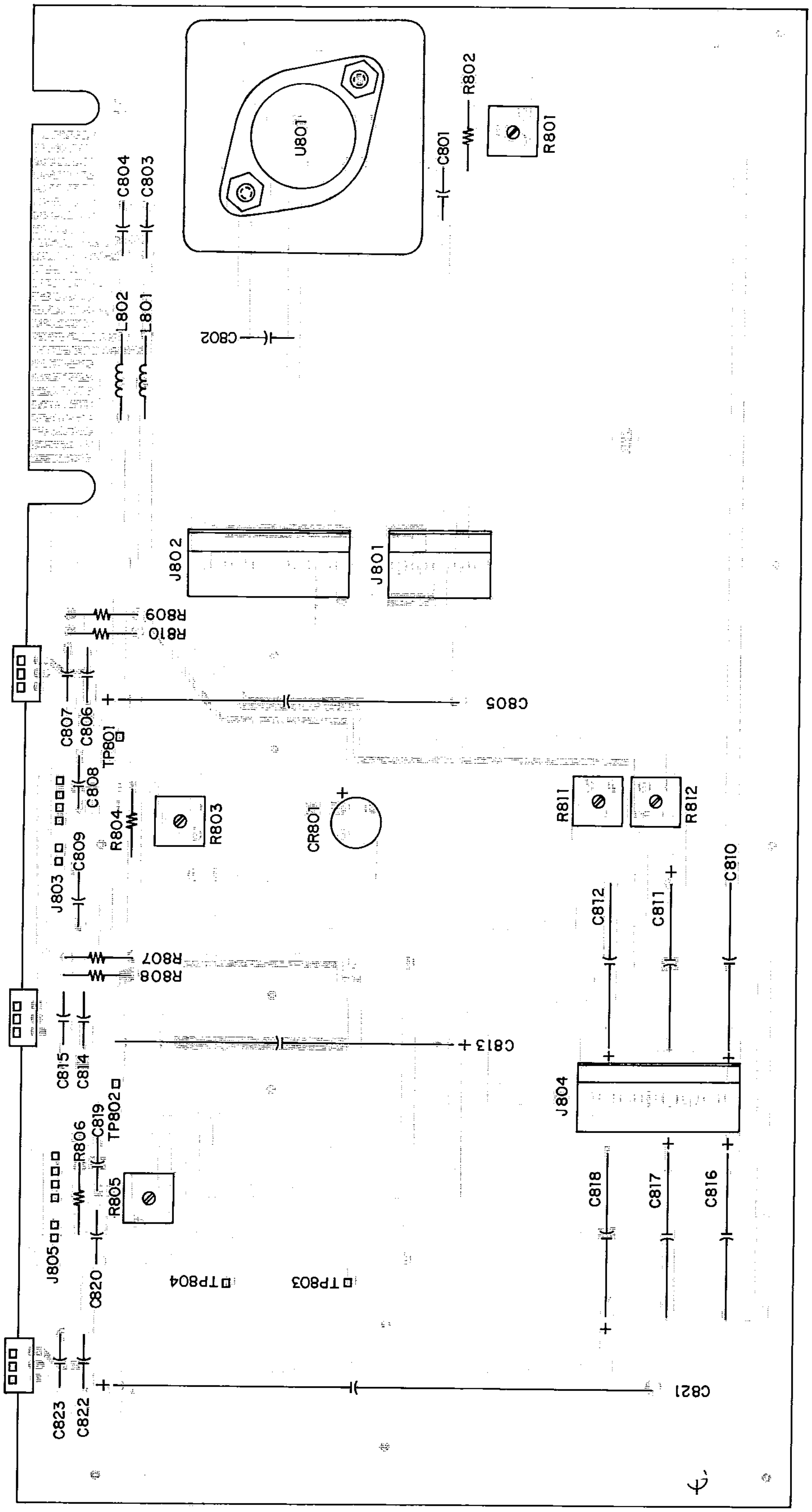
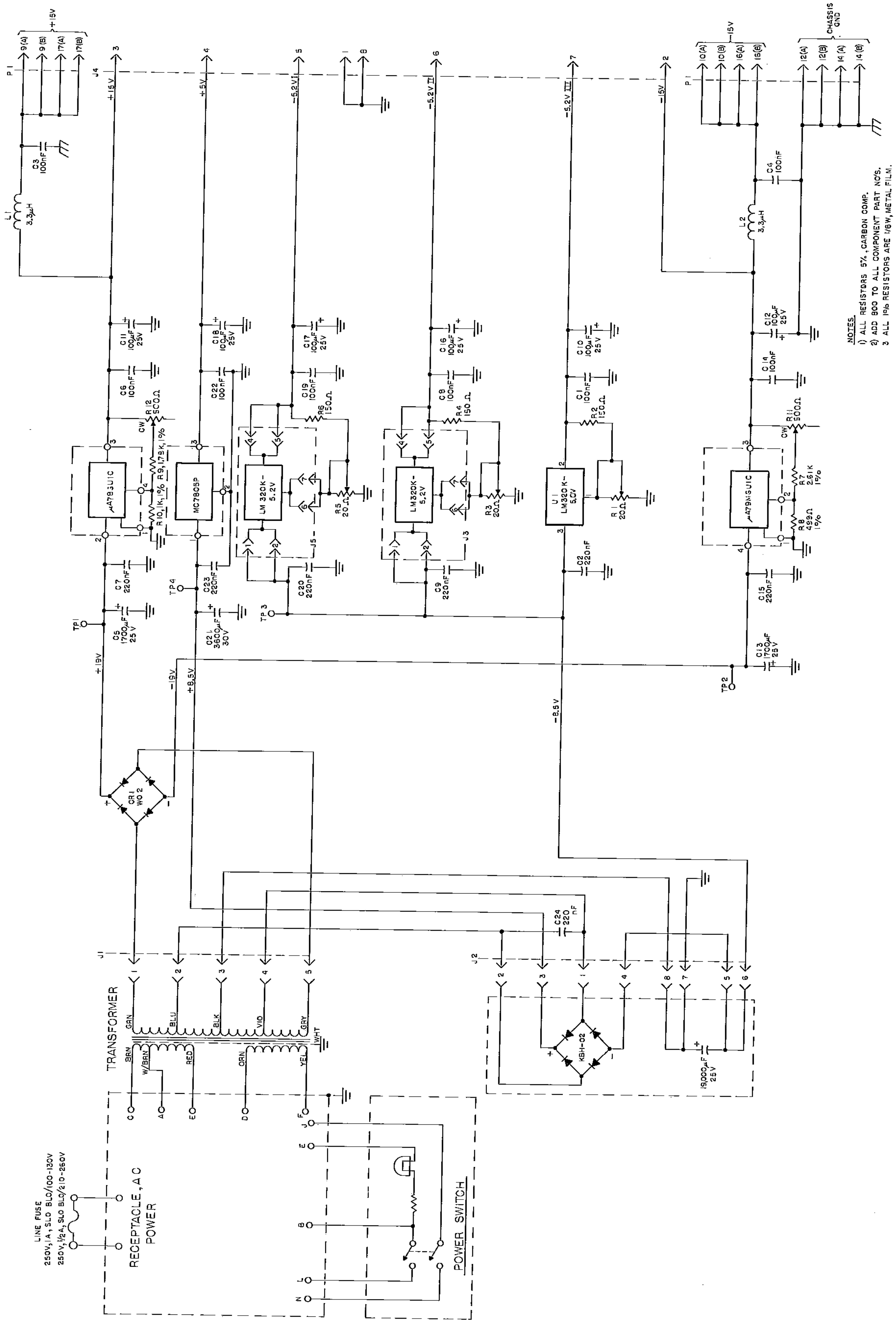
SHT. 1 OF 1 | 11743 | D | SD | 1



MODEL 5202
POWER SUPPLY BOARD



NOTES
1) ALL RESISTORS 5%, CARBON COMP.
2) ADD 800 TO ALL COMPONENT PART NO'S.
3 ALL 1% RESISTORS ARE 1/6W, METAL FILM.

POWER SUPPLY
MODEL-5202

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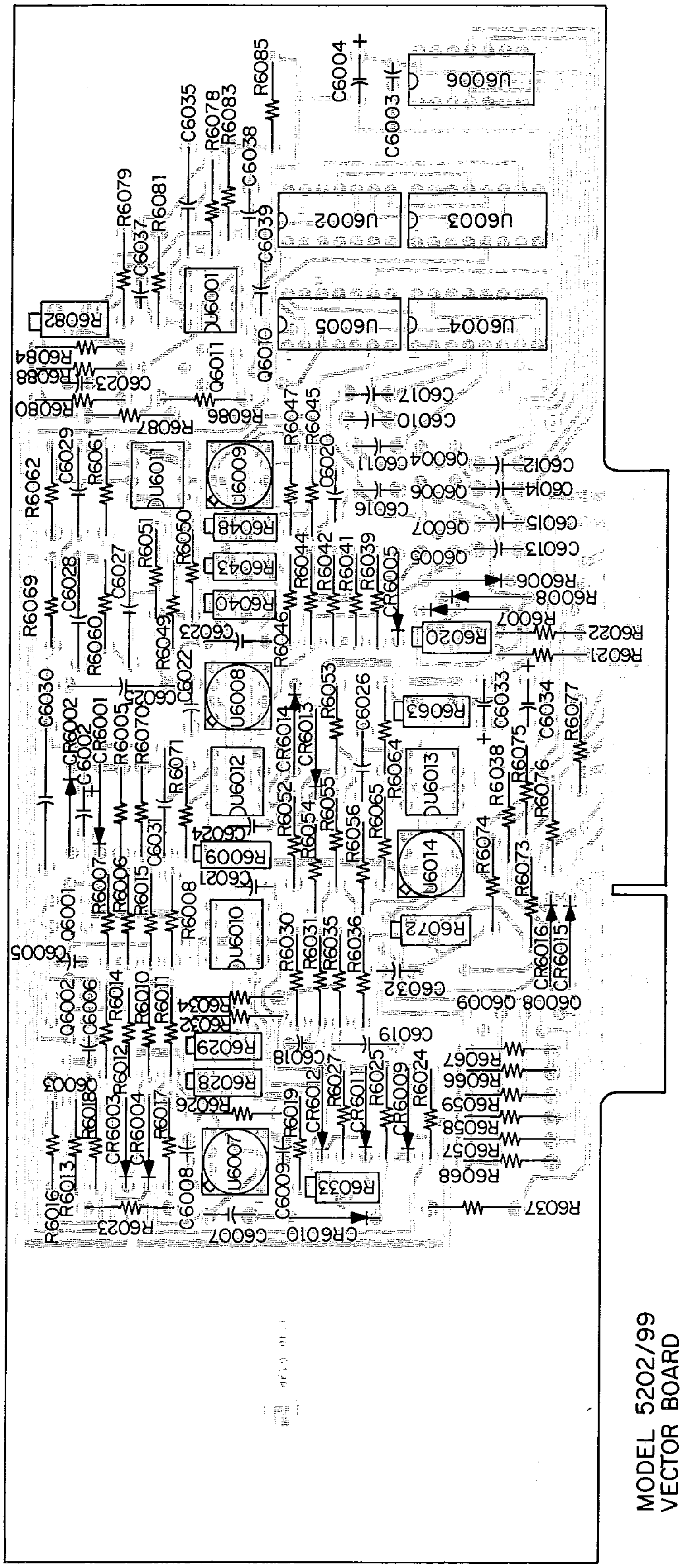
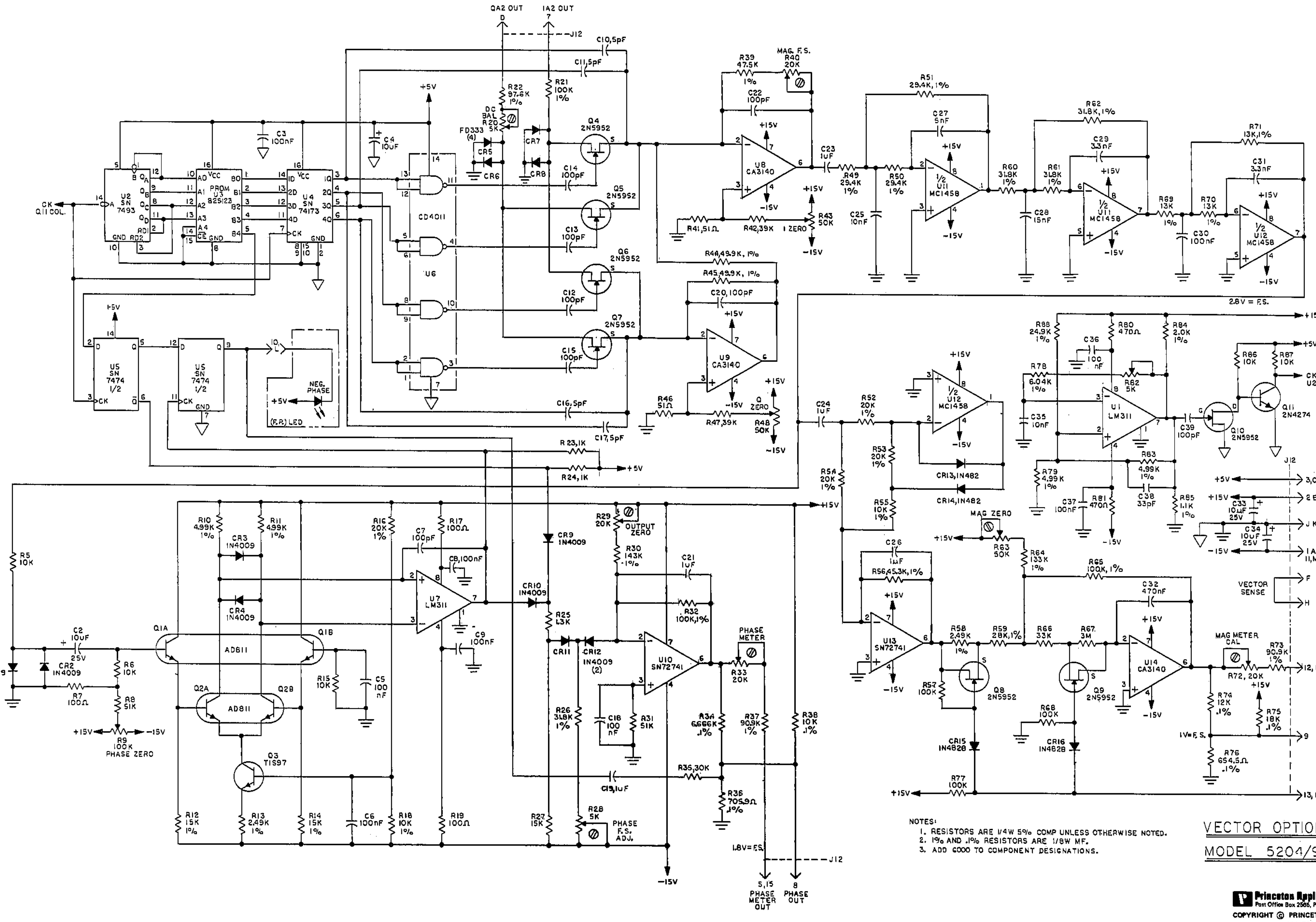
SHT. 1 OF 1
211750	D	SD	E



MODEL 5202/99
VECTOR BOARD



NOTES:
1. RESISTORS ARE 1/4W 5% COMP UNLESS OTHERWISE NOTED.
2. 1% AND .1% RESISTORS ARE 1/8W MF.
3. ADD 6000 TO COMPONENT DESIGNATIONS.

VECTOR OPTION BD

MODEL 5204/95,5202

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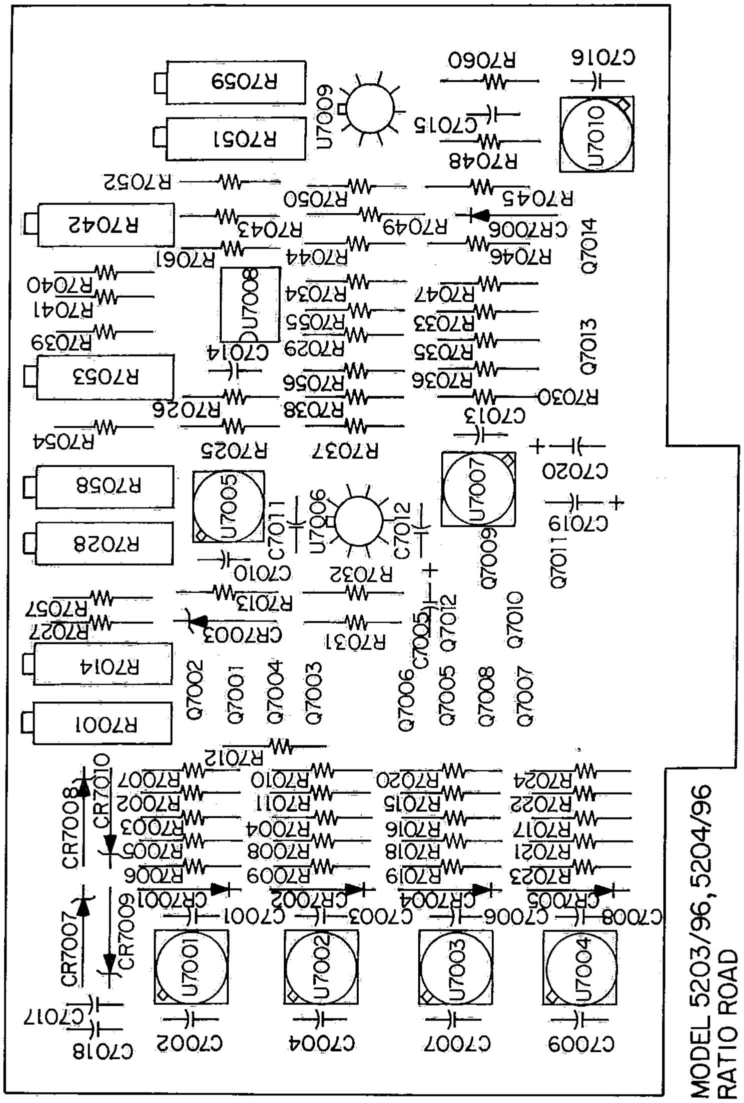
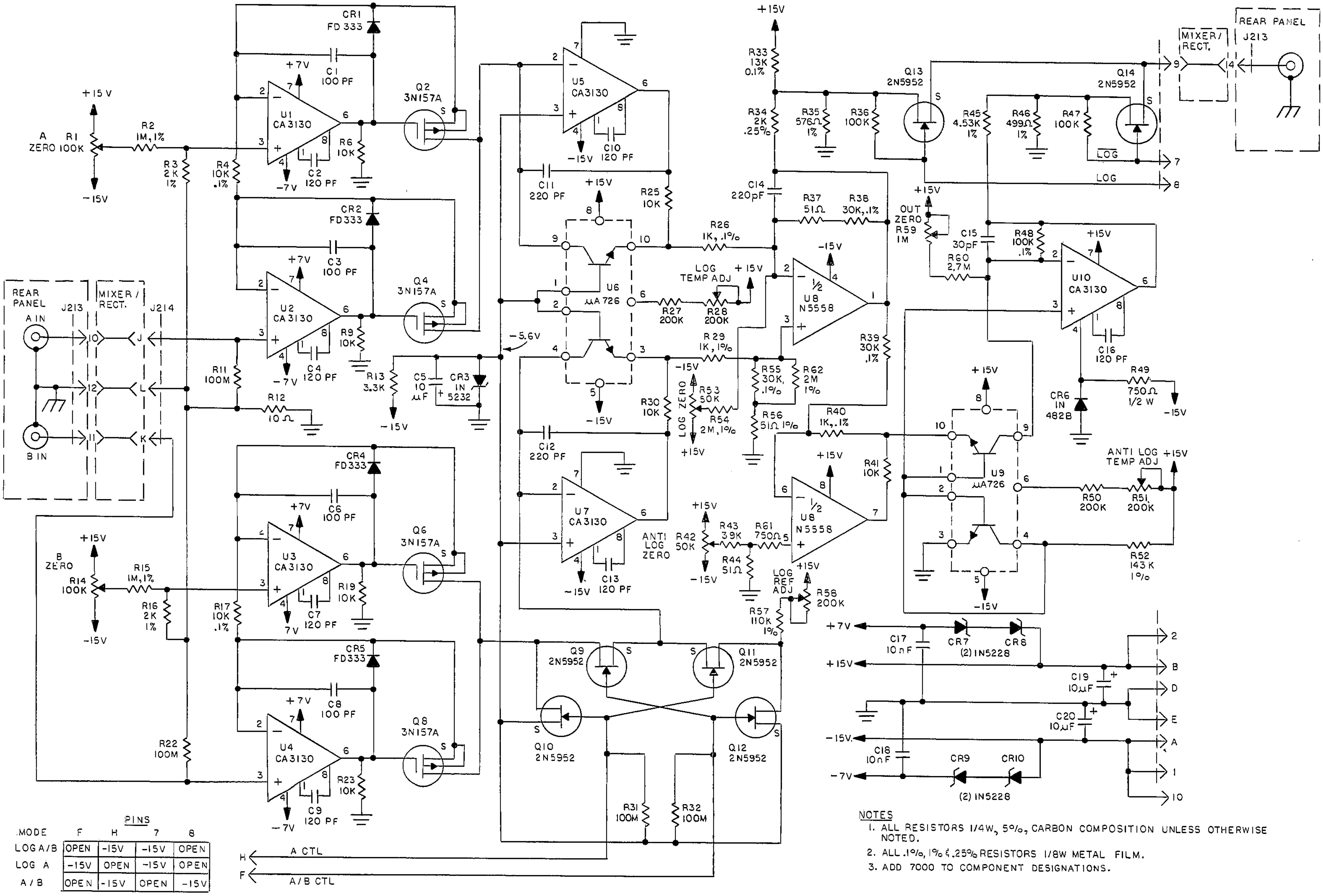
SHT. 1 OF 1 11252 D SD C



MODEL 5203/96, 5204/96
RATIO ROAD



.MODE	F	H	7	8
	PINS			
LOG A/B	OPEN	-15V	-15V	OPEN
LOG A	-15V	OPEN	-15V	OPEN
A / B	OPEN	-15V	OPEN	-15V

NOTES
1. ALL RESISTORS 1/4W, 5%, CARBON COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL .1%, 1% & .25% RESISTORS 1/8W METAL FILM.
3. ADD 7000 TO COMPONENT DESIGNATIONS.

RATIO BD

MODEL 5202/96 5204/96

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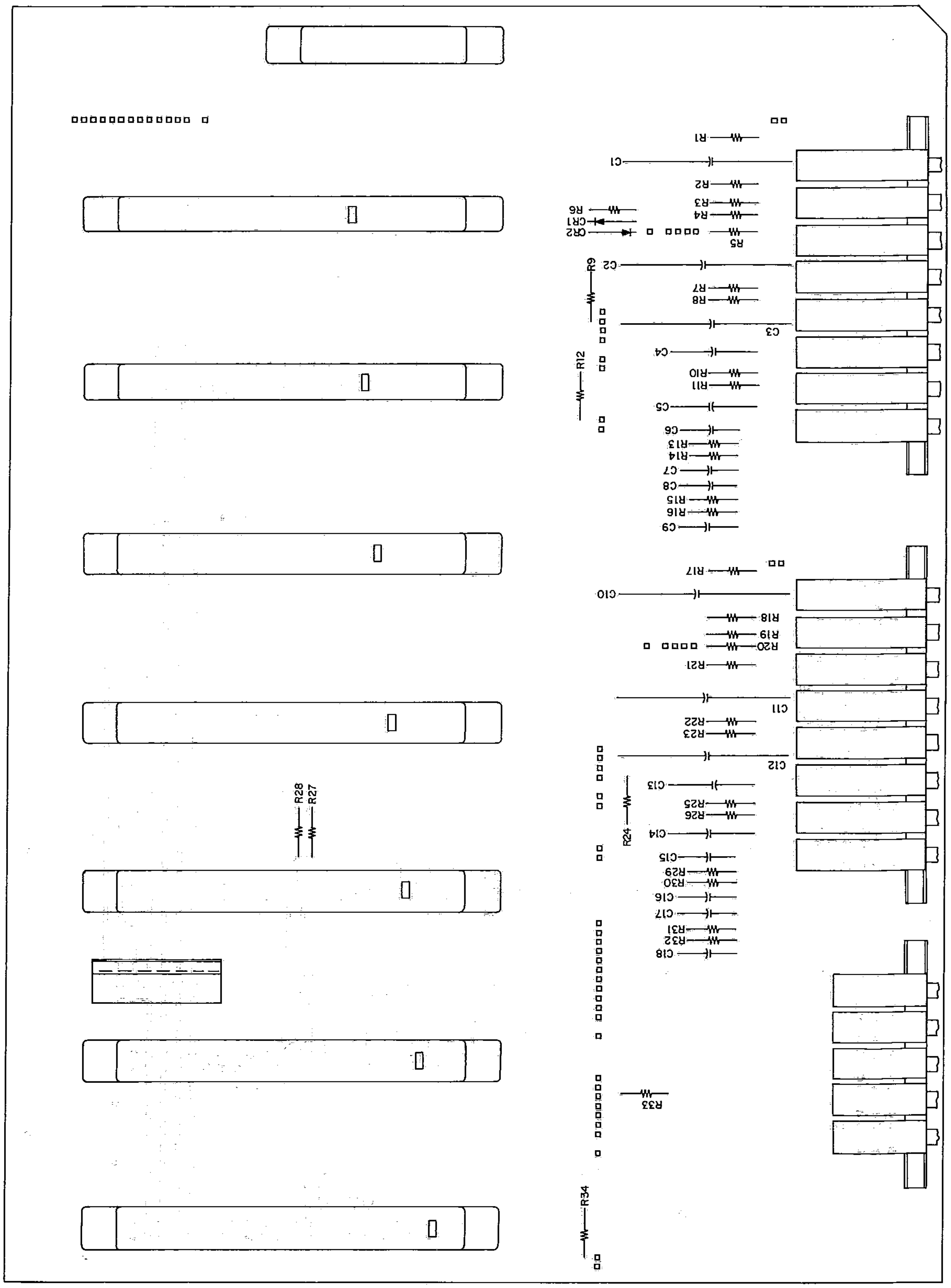
SHT. 1 OF 1 11323 C SD


R1
C1
R2
R3
R4
R5
R6
CR1
CR2
C2
R9
R7
R8
C3
R12
C4
R10
R11
C5
C6
R13
R14
C7
C8
R15
R16
C9
R17
C10
R18
R19
R20
R21
C11
R22
R23
C12
C13
R25
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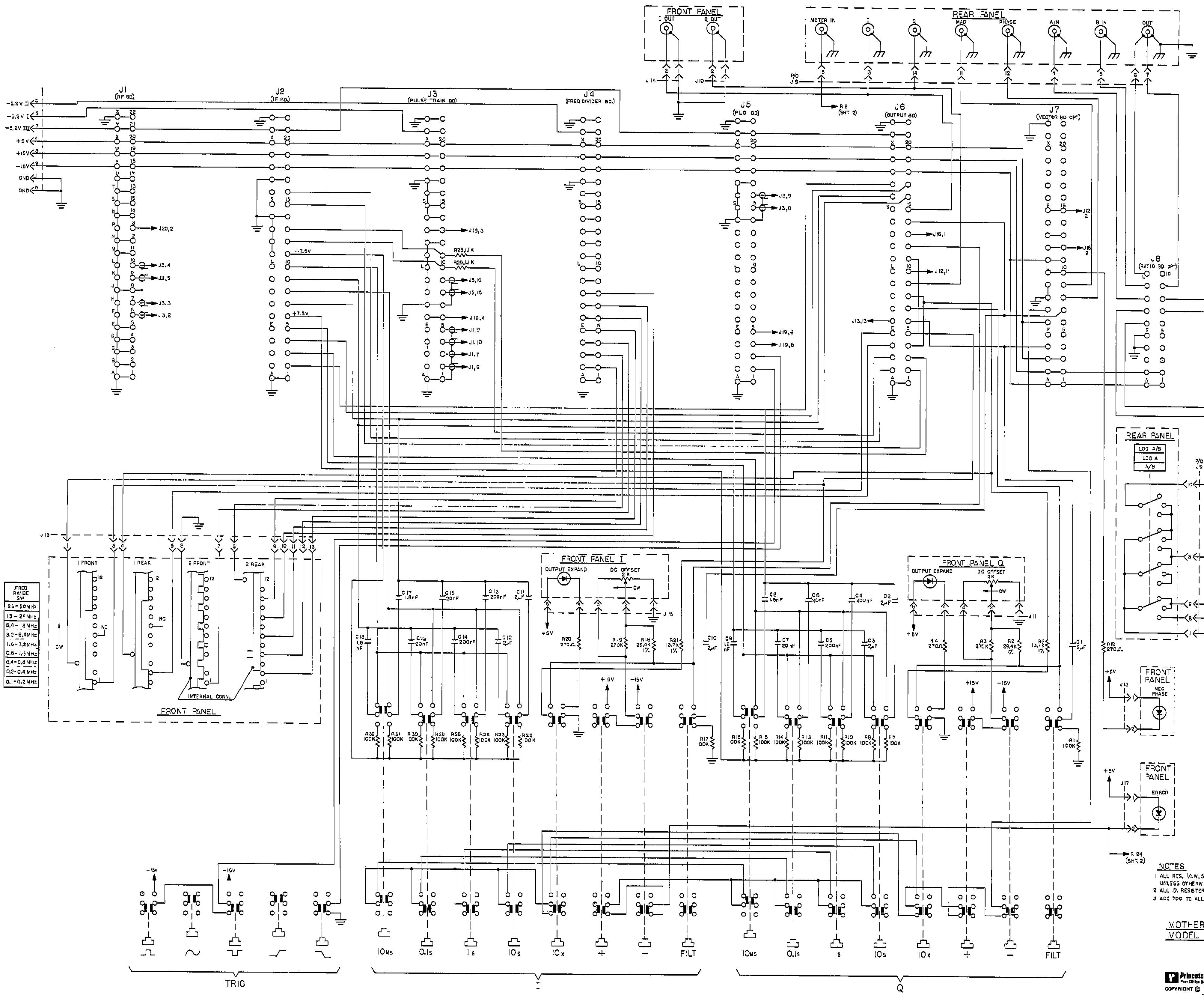
C18
R28
R27
R33
R34



FREQ RANGE SW
25–50MHz
13 – 2? MHz
6.4 – 13 MHz
3.2 – 6.4MHz
1.6 – 3.2MHz
0.8 – 1.6MHz
0.4 – 0.8 MHz
0.2 – 0.4 MHz
0.1 – 0.2 MHz

NOTES
1 ALL RES. 1/4W, 5% CARBON COMP. UNLESS OTHERWISE NOTED.
2 ALL 1% RESISTERS 1/8W. METAL FILM.
3 ADD 700 TO ALL COMP. PART NO.

MOTHER BD
MODEL 5202

Princeton Applied Research Corporation
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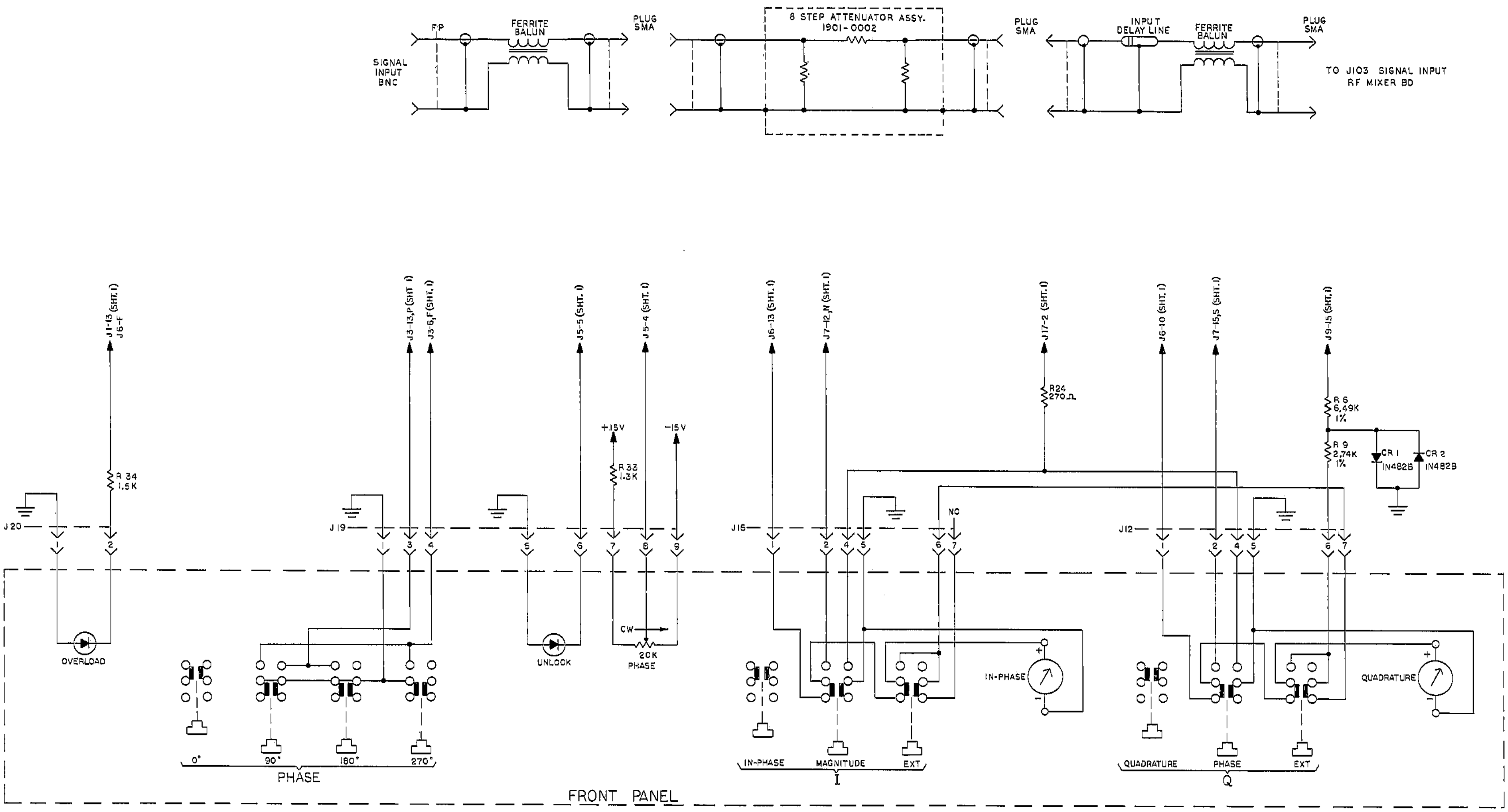
SHT. 1 OF 2 | 211719 | E | SD | D



NOTES
SEE SHT. 1.

MOTHER BOARD
MODEL-5202

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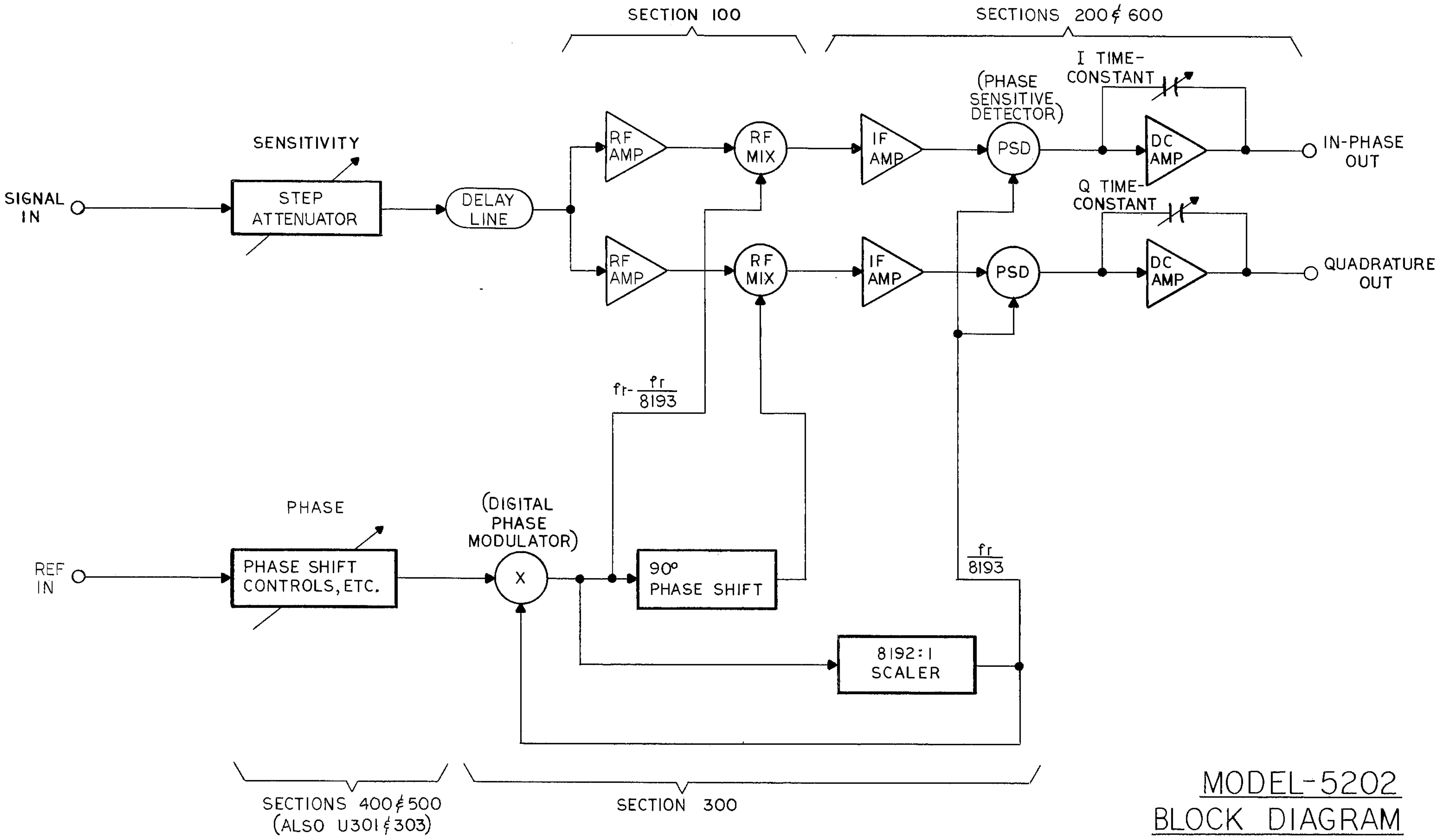
SHT. 2 OF 2 211719 D SD D



MODEL-5202
BLOCK DIAGRAM

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SHT. 1 OF 1 | 11911 | B | SD

APPENDIX A
FAST TIME-CONSTANT OPTION (5202/90)

This option consists of a replacement of the existing IF board and Output Amplifier board with modified boards. Relative to the schematic diagrams given in the Model 5202 manual, the changes are as follows.

(1) On the IF Board (schematic 11727-D-SD, page VII-13), R209, R210, R213, and R214 are changed from 5 MΩ to 499 kΩ.

(2) On the Output Board (schematic 11743-D-SD, page VII-13), the following changes have been made.

   (a) R607 and R608 are changed from 10 kΩ to 1 kΩ.

   (b) R628, R629, R632, and R633 are changed from 10 kΩ to 100 kΩ, 1%.

   (c) Potentiometers R626 and R627 are changed in value from 500 Ω to 5 kΩ.

When the new boards of Option /90 are installed, the time-constant values shown on the front panel will be ten times larger than the actual time constants.

The /90 Option yields a 75 μs minimum output time constant; the rise time (10% to 90%) will be less than 100 μs when all time-constant pushbuttons are released.

The increased output bandwidth will require that routine minor adjustment of the RF and AC BALANCE adjustments be made to minimize ripple in the output. Refer to Subsections 5.7 and 5.12 in the manual. Those adjustments should be performed with all time-constant pushbuttons in their released positions.

After making the adjustments detailed in Subsections 5.7 and 5.12, the following AC BALANCE adjustment will be required.

(1) Apply a 1 MHz signal to the Reference Input (no signal is to be applied to the Signal Input).

(2) Release all Time Constant and Filter pushbuttons.

(3) Adjust the "I" AC BALANCE (R250), and the "I" RF BALANCE (R146), as required to obtain less than 30 mV pk-pk at the "I" OUTPUT connector.

(4) Adjust the "Q" AC BALANCE (R249), and the "Q" RF BALANCE (R167), to obtain less than 30 mV pk-pk ac at the "Q" OUTPUT connector.

WARRANTY

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

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

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

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

SHOULD YOUR EQUIPMENT REQUIRE SERVICE

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

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

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

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

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

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

E. Address correspondence to:

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