INSTRUCTION AND MAINTENANCE MANUAL

ITHACO MODEL 3921

LOCK-IN AMPLIFIER

REV. 0 NOVEMBER, 1985

REV. 1 JULY, 1986

ITHACO, INC.
735 West Clinton Street
P O Box 6437
Ithaca, New York 14851-6437
Telephone 607-272-7640

ITHACO, Inc. warrants each Lock-In Amplifier to be free of defects in material and workmanship for a period of two years after shipment to the original purchaser; batteries are specifically excluded.

All other conditions remain as printed in the Warranty inserted at the end of this Instruction Manual

Rev. 1 July, 1986 JLS

Minor corrections to clarify autophase interference threshold (Pg. 26) and preamp power out (Pg. 11).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

GENERAL DESCRIPTION

1.1 DESCRIPTION

The Model 3921 Lock-In Amplifier represents a breakthrough in performance vs price. Built around a completely new phase sensitive detector circuit that eliminates harmonic responses, it achieves significant cost savings by eliminating all signal channel pre-detection filtering. The unit operates over the entire frequency range of 10 Hz to 15 kHz without decade or range switching, and will provide fundamental only response throughout the complete range.

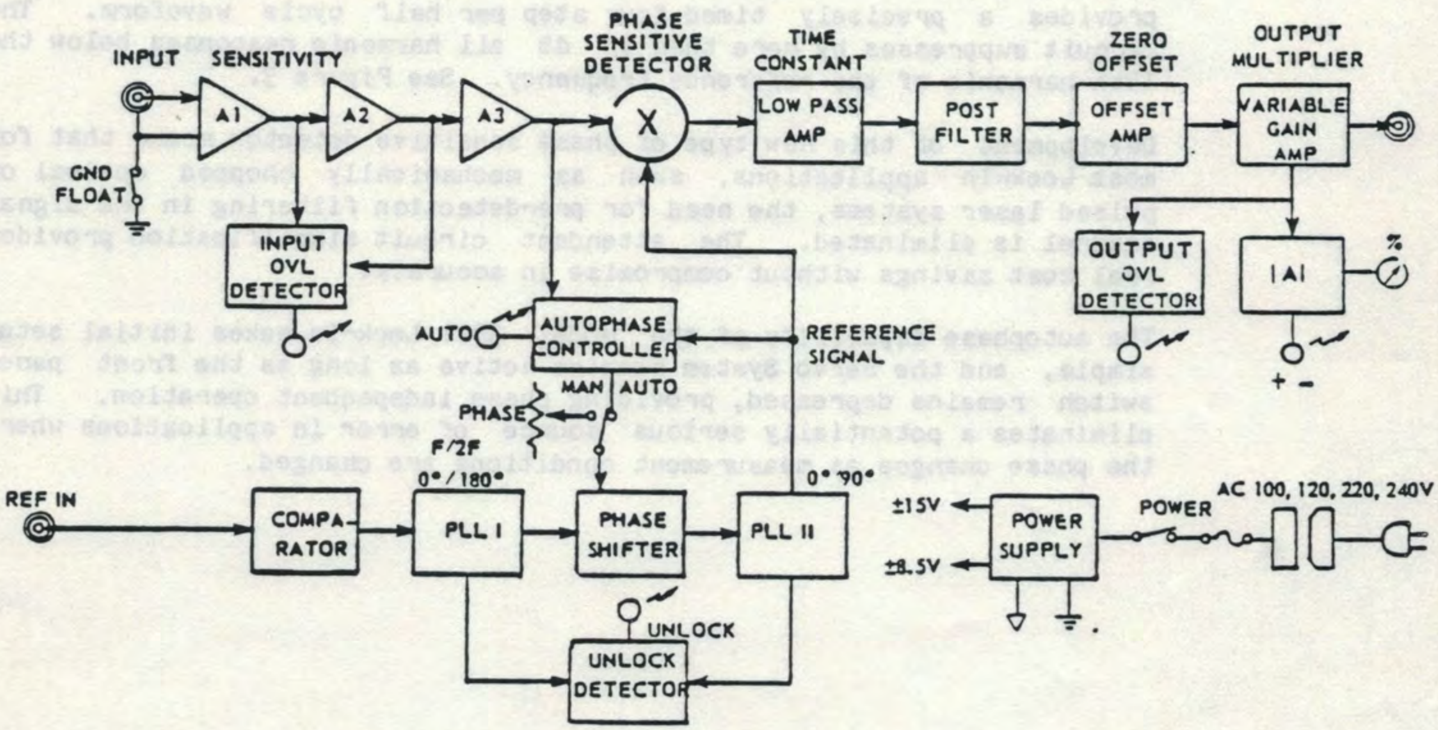


Figure 1.1

1.2 FEATURES

The instrument incorporates an electronic Autophase Servo System, accuated by a pushbutton, that eliminates the need for tedious manual phase adjustments. The System is operable over the full dynamic reserve of the instrument for random noise interference.

The input preamplifier can be used in either a floating (quasi-differential) or grounded mode similar to the inputs on more expensive ITHACO models. This configuration is usually more convenient for the user to deal with than a true differential input, which requires fabrication of special cables.

Other features include: continuous frequency tracking over the entire operating frequency range at 1 Hz/sec @ 10 Hz and 150 Hz/sec @ 1 kHz slew rate, time constants to 30 seconds plus 1 second post filter, continuous sensitivity setting, separate input overload and output overload detectors with separate overload lights, analog ratio option available, and a front panel switch for turning off all indicator lamps while making low level optical measurements. Its basic 10 µV to 1V sensitivity can be extended to 10 nV using ITHACO remote modular preamplifiers powered from the 3921. Current input preamplifiers are also available.

The ITHACO Model 3921 employs a new type of phase sensitive detector circuit (Patent Pending) which retains the advantages of a square wave mixing circuit but overcomes the major problem of harmonic responses. By approximating a sinusoid with incremental switching, the circuit provides the low phase jitter and switching precision possible with modern digital technology. Extensive use of logic integrated circuits provides a precisely timed four step per half cycle waveform. The circuit suppresses by more than 55 dB all harmonic responses below the 15th harmonic of the reference frequency. See Figure 3.

Development of this new type of phase sensitive detector means that for most Lock-In applications, such as mechanically chopped optical or pulsed laser systems, the need for pre-detection filtering in the signal channel is eliminated. The attendant circuit simplification provides real cost savings without compromise in accuracy.

The autophase capability of the Model 3921 Lock-In makes initial setup simple, and the Servo System remains active as long as the front panel switch remains depressed, providing phase independent operation. This eliminates a potentially serious source of error in applications where the phase changes as measurement conditions are changed.

SECTION 2

SPECIFICATIONS

2.1 SIGNAL CHANNEL

Frequency Range:	10 Hz to 15 kHz
Sensitivity:	10 µV to 1 V for full scale (10 V) output in 1-10-100 sequence. Continuously variable by 10 turn locking control (MULTiplier).
Sensitivity Accuracy:	Less than 3% error at full scale (10 Hz to 10 kHz), less than 5% @ 15 kHz.
Stability of Setting:	100 ppm/C° typ
Input:	Quasi-differential, may be floated or grounded either at the instrument or the signal source
Input Impedance:	10MΩ shunted by <80 pF
Maximum Input:	±200 V dc. ±15 V peak ac, non-coherent
Maximum Common Mode Voltage:	±10 V
Common Mode Rejection:	100 dB at 100 Hz
Noise:	25 nV per root Hertz (typical) at 1 kHz with shorted input. See Figure 2.3.
Overload:	Separate indicators for input overload and output overload conditions.

2.2 REFERENCE CHANNEL

Modes:	External F, 2F
Frequency Range:	10 Hz to 15 Hz (to 7.5 kHz at 2F)
Phase Adjustment:	±100° continuously variable (manual mode) plus 0°/90° and 0°/180° switches
Autophase:	Electronic Servo System for automatic phase adjustment
Autophase Lamp:	Goes on when the automatic phase adjustment process is completed

Autophase Lamp Noise Threshold:	Extinguishes when the rms signal level drops to less than one thirtieth of the random p-p input noise (10 Hz - 10 kHz broadband).*
Autophase Lamp Sinusoid Threshold:	Extinguishes when rms signal level drops to less than one eighth of the peak to peak amplitude of an incoherent discrete frequency interference.*
Reference Voltage Range:	300 mV to 30 V peak to peak (sinusoidal waveform)
Maximum Allowable Voltage:	200 V dc, ±50 V peak ac
Input Impedance:	100 kΩ Shunted by <100 pF
Tracking Rate:	
Manual Mode:	0.04 Hz/sec per Hz reference frequency with less than 10° phase error (e.g. 40 Hz @ 1 kHz)
Autophase Mode:	Typically ≥0.1 Hz/sec per Hz with ref lock maintained and <1% signal error (e.g. 150 Hz/sec at 1 kHz).

*Typically Autophase will continue to work very accurately for signal levels an order of magnitude or more below this threshold, but with very slow response time.

2.3 PHASE SENSITIVE DETECTOR:

Harmonic Rejection:	Typically greater than 55 dB through the 14th harmonic (See Figure 2.4)
Dynamic Reserve:	Greater than 60 dB pp noise/full scale rms signal voltage
Time Constants:	10 msec to 30 sec in a 1-3-10 sequence, 6 dB octave (25 Hz to 0.008 Hz equiv. noise bandwidth)
Post Filter:	1 sec time constant, 12 dB/octave

2.4 OUTPUT

Meter:	0 to ±110% scale, 2.5% accuracy
Output Voltage:	±10 V dc full scale
Output Impedance:	1000Ω
Zero Offset:	10 turn potentiometer and polarity switch

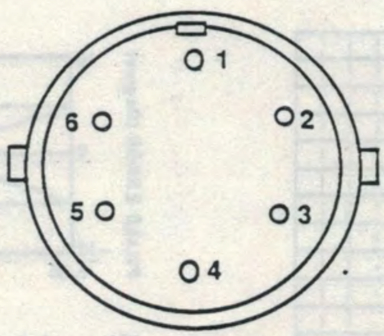
Output Stability:	50ppm/C° at X10 (0.5 mV offset/C°) 500ppm/C° at X1 (5 mV offset/C°) 50ppm/8 hours at X10 (0.5 mV offset/8 hr) 500ppm/8 hours at X1 (5 mV offset/8 hr)

2.5 OPTIONS

Option 02	Analog Ratio Option
3921RM	Rack Mount Kit
3921V1M7	Preamplifier Power Cable

2.6 MISCELLANEOUS SPECIFICATIONS

Lamps Off:	By front panel switch
Power:	100, 120, 220, 240 V ac ±10% 50/60 Hz at 12 VA
Environmental: Operation Storage:	 0° to 40°C, 10% to 90% RH -10° to 60°C; 10% to 80% RH
Dimensions:	18.9" (480mm)W x 3.46" (88mm)H x 13.8" (350mm)D. Fits standard rack mount
Weight:	15 lbs (7 kg) without options
Preamp dc Power Out	±20 Vdc via rear panel connector @ 30Ω (±50 mA max.).



MATING CABLE CONNECTOR
HIROSE RM12BRD-6S
P/N NF-314-03042-00

1	N.C.	4	-20V OUT
2	N.C.	5	+20 V OUT
3	N.C.	6	POWER GND

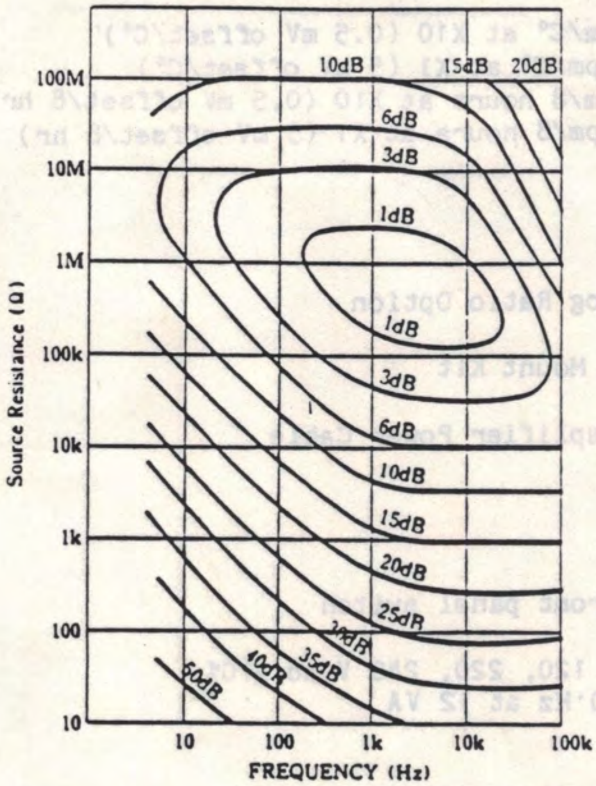


Figure 2.2 NOISE FIGURE CONTOURS AT 290°k

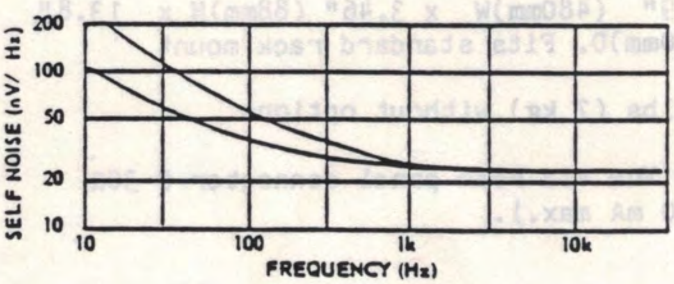


Figure 2.3 SELF NOISE VS FREQUENCY

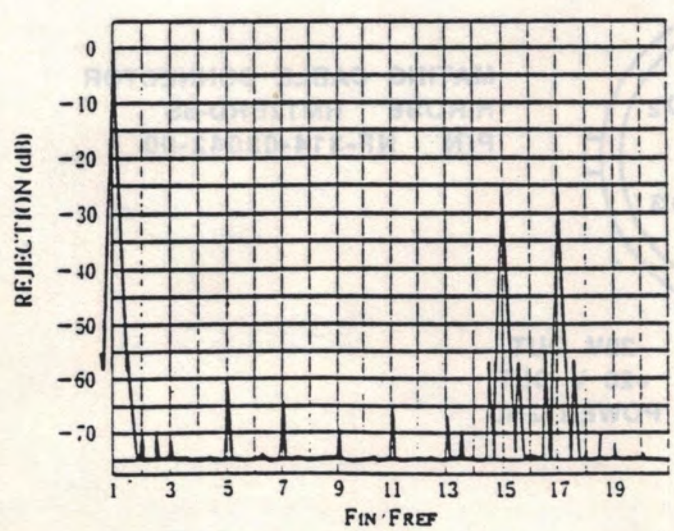


Figure 2.4 HARMONIC REJECTION

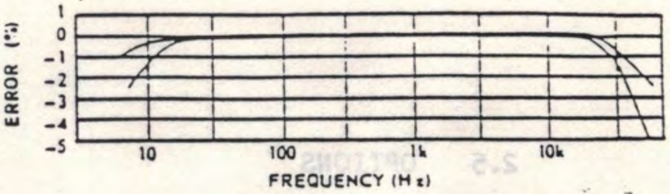


Figure 2.5 FREQUENCY RESPONSE

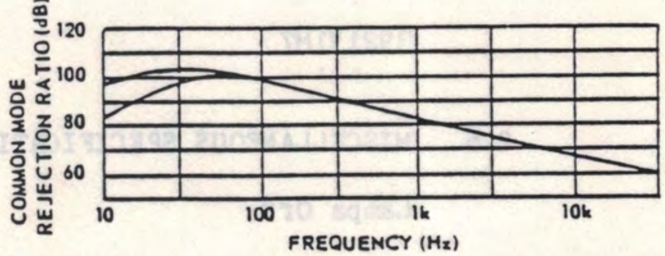


Figure 2.6 CMRR VS FREQUENCY

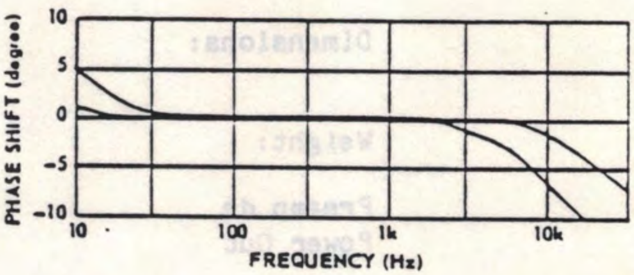


Figure 2.7 PHASE SHIFT VS FREQUENCY

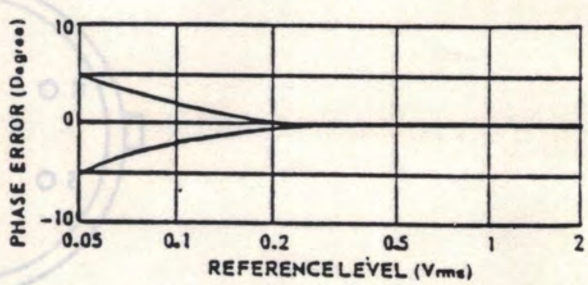
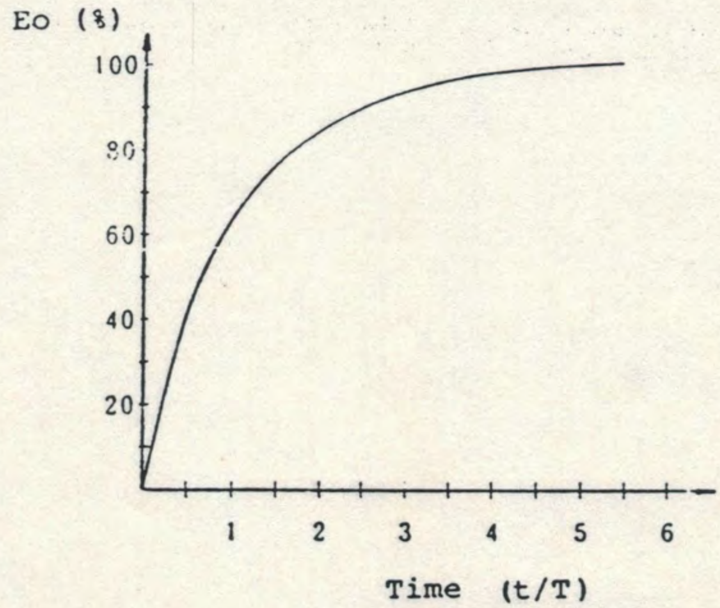
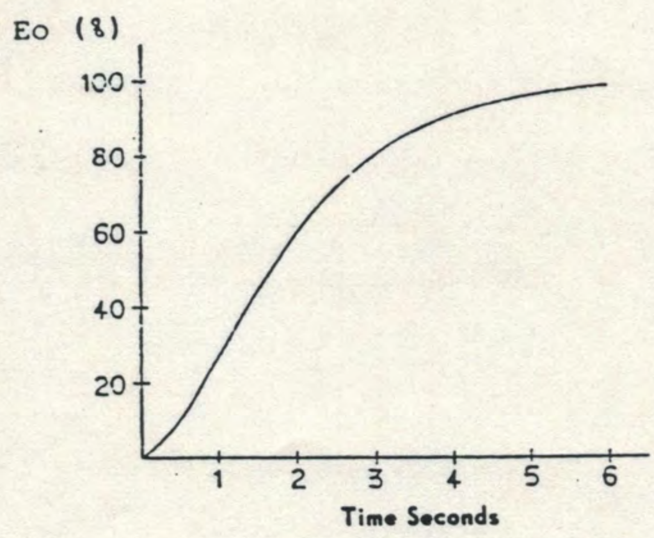


Figure 2.8 PHASE SHIFT VS REF LEVEL



t/T	Eo (%)
0.5	39.35
1.0	63.21
1.5	77.69
2.0	86.47
2.5	91.79
3.0	95.02
3.5	96.98
4.0	98.17
4.5	98.89
5.0	99.32
5.5	99.59
6.0	99.75

Figure 2-9 6dB/OCT LPF RESPONSE
(Post Filter Off or Time Constant > 1 sec)



SECONDS	Eo (%)
0.5	9.02
1.0	26.42
1.5	44.22
2.0	59.40
2.5	71.27
3.0	80.09
3.5	86.41
4.0	90.84
4.5	93.89
5.0	95.96
5.5	97.34
6.0	98.26

Figure 2-10 12dB OCT POST FILTER RESPONSE
(Time Constant < 1 sec)

SECTION 3

PREPARATION FOR USE

3.1 INSPECTION

Upon unpacking the instrument, inspect it for any damage that may have occurred in transit. Save all packing materials in case the unit must be returned. Visually check to confirm that there are no broken controls or connectors, and that the case and panel surfaces are free from dents and scratches. If any damage is detected, the customer must file a claim with the carrier and should also forward a copy to ITHACO. We will then give advice on the disposition of the equipment and will arrange for repair or replacement without waiting for a settlement of the claim against the carrier.

3.1.1 COMPONENTS SUPPLIED

3921 Lock-In Amplifier
Instruction Manual
Power Cable, 3 Conductor x 7 feet
Fuse + Spare (mounted in fuseholder, 0.5A for 100 or 120 Vac line power)
BNC Signal Cable
Hex Wrench (1.5 mm across flats) for turns counting knobs

3.1.2 ELECTRICAL CHECKOUT

The customer should operate the equipment to verify that it functions correctly. See Section 6.2, Operational Inspection.

3.2 ENCLOSURE AND MOUNTING

The instrument is housed in a bench top enclosure which includes a hinged front leg assembly for easy viewing of the front panel. The enclosure fits into a 3 1/2" high space in a standard 19" relay rack. For this purpose ITHACO makes available an optional Rack Mounting Kit, the 3921RM, which consists of two brackets and the necessary nuts and bolts for their installation on the front corners of the enclosure.

3.2.1 INSTALLATION OF RACK MOUNT EARS

Remove four screws from the two rear plastic moldings. Remove moldings and slide out side panels. Then remove the two screws on either side nearest the front of the instrument. Place sub bracket so that its holes line up with the removed screw holes. Place eared bracket so that its holes also line up, and secure with two flat head screws. Repeat on other side. Slide new shorter side panels in place and re-install rear molded pieces.

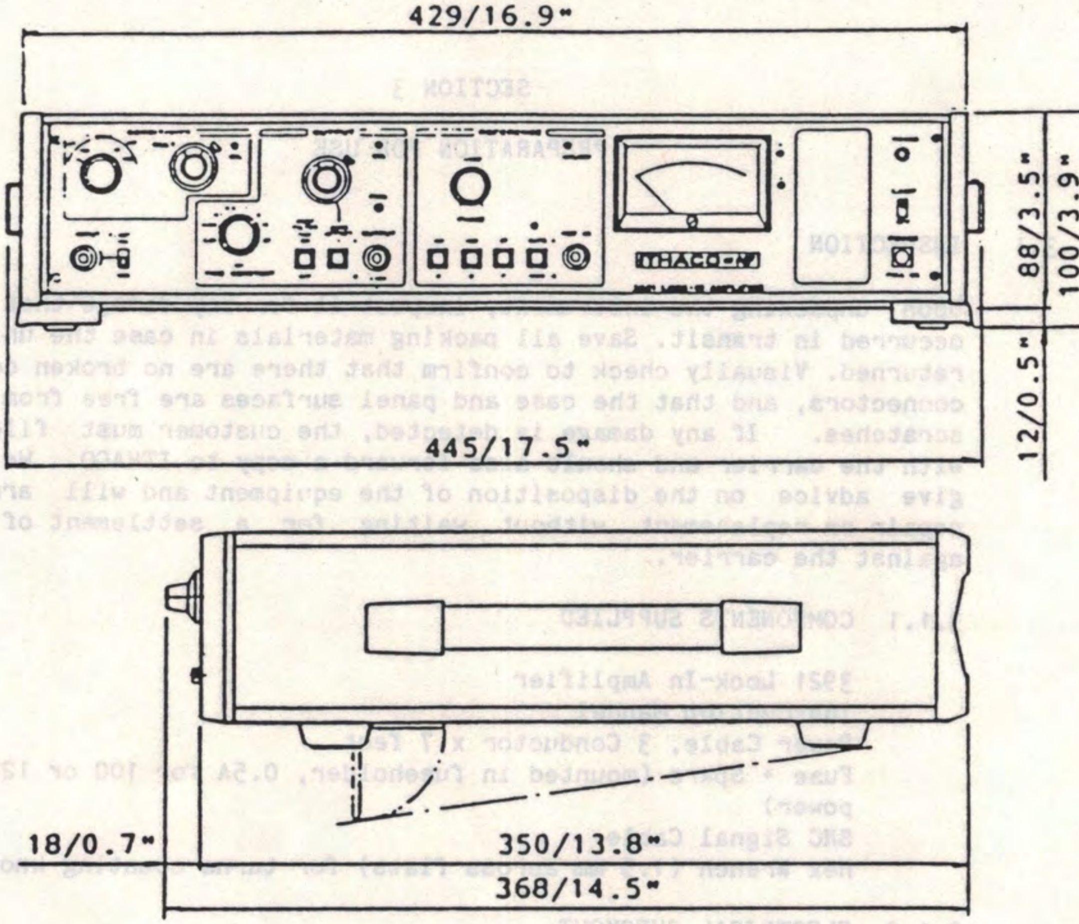


Figure 3.1

3.3 AC POWER AND GROUNDING

Before applying line power to the Lock-In, make sure that the rear panel voltage selector switches and fuse rating match the ac input. These switches should never be operated with the power cord plugged in. ITHACO ships the 3921 configured for 120 Vac operation. The 3-conductor power cord should plug into a power receptacle with an earth ground conductor.

AC LINE SWITCHES		VOLTAGE	FUSE 5x20mm
100-220	0-20	RANGE	FAST BLOW 250 V
100	0	90-110 Vac	0.5A
100	20	110-130 Vac	0.5A
220	0	200-240 Vac	0.5A
220	20	215-265 Vac	0.5A

Voltages outside the indicated ranges may cause damage to the equipment. Oversize fuses do not provide adequate safety in the event of equipment malfunction.

3.3.1 FUSES

The fuseholder is accessable when the power cord is removed from the rear panel. To remove it, insert a standard screwdriver in the slot and pull forward. The active fuse and a spare both fit in the holder, with the spare residing in the space closer to the exterior of the instrument.

3.3.2 GROUNDING

A rear panel terminal provides an alternative means for providing a ground to prevent electrical interference or shock hazards. It may be used to supplement a missing or untrustworthy power receptacle earth ground. It also may be used in place of power ground in instances where ground loop interference could cause measurement difficulties.

The instrument uses a line filter as shown below to prevent problems with electromagnetic interference. Leakage current does not exceed 0.5 mA rms at 250 Vac 60 Hz. The unit conforms to electronic measuring equipment safety standards detailed in IEC Publication 348.

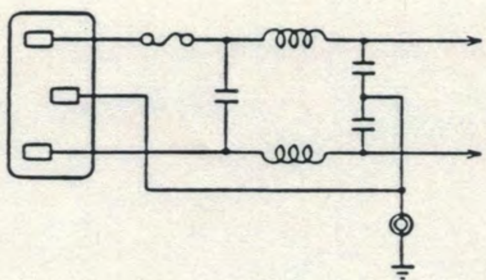


Figure 3.2 LINE FILTER CIRCUIT

SECTION 4

FUNCTIONS AND USE

4.1 CONTROLS, INDICATORS AND CONNECTORS

4.1.1 SIGNAL INPUT SECTION

(1) SENSITIVITY SWITCH (Input Voltage Range)

This sets the ac input gain in a 1-10-100 sequence. It is calibrated in volts and rms required to achieve a full scale output (100% on meter or 10 Vdc on output BNC) when the MULT control is set to 1.00.

(2) MULT (Sensitivity Multiplier Dial)

This 10 turn potentiometer controls the post-detector dc gain of the instrument, progressively reducing the gain as it is turned from its lower limit of 1.00 to its upper limit of 11.00, thereby reducing the overall sensitivity. The overall sensitivity equals the product of the MULT control and SENSITIVITY control settings.

Reading the absolute value of a changing input is facilitated by using MULT settings of 1, 2, 5 or 10.

For a steady signal, one can read the absolute value by setting the SENSITIVITY and MULT controls for a full scale output (100% on meter or 10 Vdc out). The product of the two settings equals the input level.

(3) OVL (Input Overload Lamp)

When on, it indicates that the ac input amplifier is being driven into distortion, either by the coherent signal or by its accompanying noise. The sensitivity control must be decreased.

(4) INPUT (Signal Input Connector)

The unknown signal input to be measured is applied here.

(5) FLOAT/GND (Input BNC Shell Grounding Switch)

Used to prevent ground loops due to doubly grounded input circuitry. Provides quasi-differential input in FLOAT position and single-ended input in GND position.

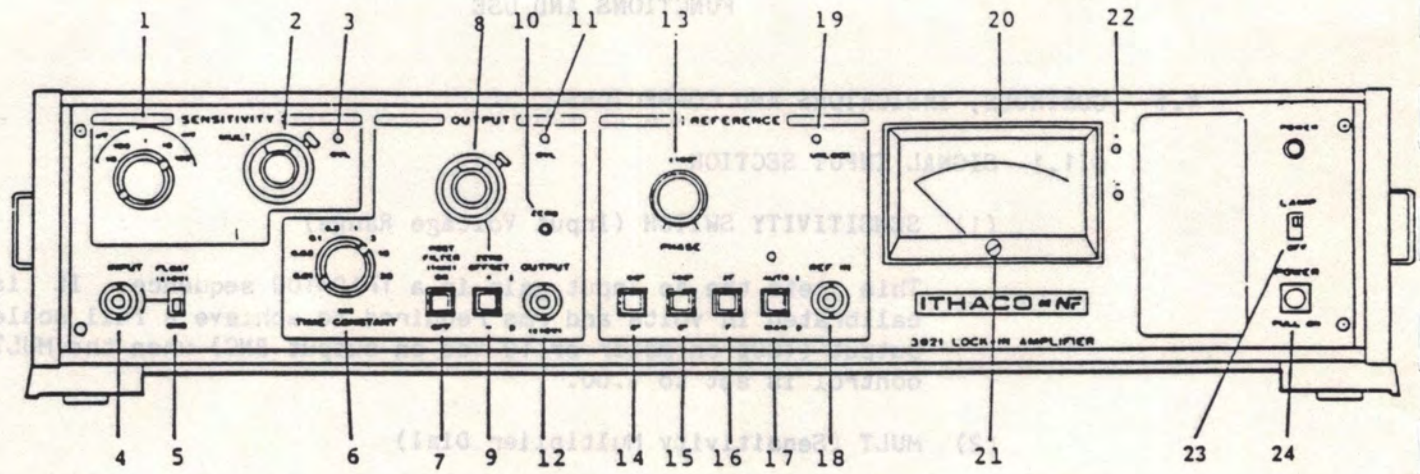


Figure 4.1 FRONT PANEL

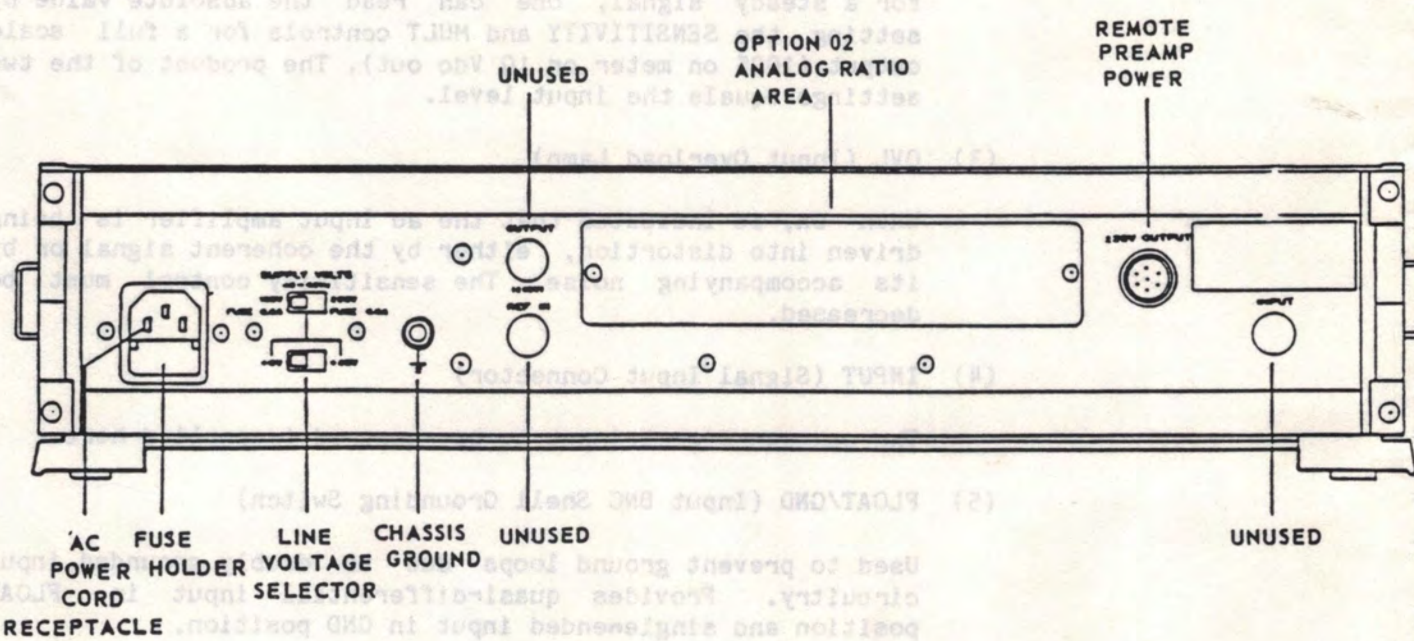


Figure 4.2 REAR PANEL

4.1.2 OUTPUT SECTION

(6) TIME CONSTANT (Output RC Filter Switch) (T_1)

Determines the cutoff frequency of the post-detector lowpass filter. The 6dB/octave rolloff smooths the dc output by attenuating ac interference components. The equivalent noise bandwidth (B) is calculated from the TIME CONSTANT (T_1) as follows, assuming the POST-FILTER is not turned on:

$$B = \frac{1}{4T_1} \text{ (Hz)}$$

The TIME CONSTANT should be set long enough to yield acceptable levels of output fluctuations on the meter or output BNC. The time required for the output to settle to its final value equals about four or five times the TIME CONSTANT setting.

(7) POST-FILTER (Additional Output Filtering Switch) (T_2)

Introduces a two section fixed 1 second time constant filter ($T_2 = 1$) in addition to T_1. Provides additional output smoothing with a 12dB/octave slope for cases of heavy interference mixed with the signal input. When active, the equivalent noise bandwidth is given by:

$$B = \frac{1}{4(T_1 + 2 - \frac{T_1}{2T_1 + 1})}$$

The cutoff frequency of the POST-FILTER is 0.125 Hz.

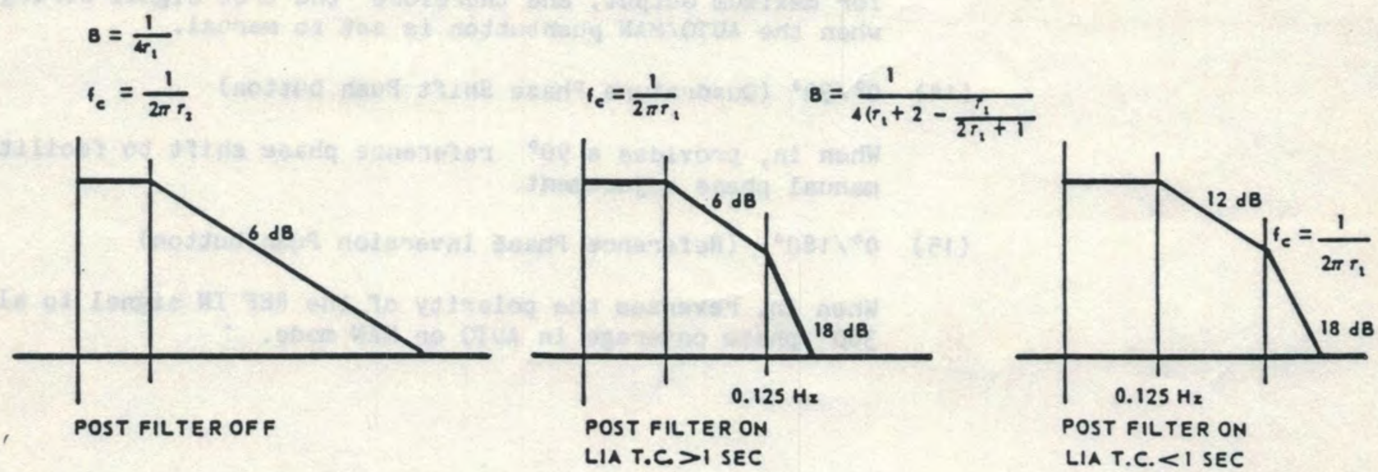


Figure 4.3 OUTPUT LOWPASS FILTER CHARACTERISTICS

(8) ZERO OFFSET (Signal Suppression Dial)

Adds a fixed dc voltage to the output. With MULT = 10.00, an offset of up to ±100% of full scale can be added. With MULT = 1.00, this increases to ±1000%. This feature allows one to observe small changes in signal level by suppressing coherent background level.

(9) +/- (Offset Polarity Push button)

Adds or subtracts value determined by ZERO OFFSET control. POSITIVE when in.

(10) ZERO (Baseline Offset Calibration)

This screwdriver adjustment sets the baseline output to 0 mV dc when the INPUT is shorted.

(11) OVL (Output Overload Lamp)

Indicates Post-detector dc output amplifier saturation if MULT is set too high. Will flicker if the TIME CONSTANT is not set high enough to suppress output fluctuations.

(12) OUTPUT (dc Output Connector)

Provides ±10 V dc full scale output for DVM, chart recorder or digitization by computer.

4.1.3 REFERENCE SECTION

(13) PHASE (Reference Phase Shifter Knob)

Allows for manual ±100° phase adjustment of the REF IN frequency relative to the SIGNAL input. Used in conjunction with the 0°/90° and 0°/180° push buttons to find the phase for maximum output, and therefore the true signal strength, when the AUTO/MAN pushbutton is set to manual.

(14) 0°/90° (Quadrature Phase Shift Push button)

When in, provides a 90° reference phase shift to facilitate manual phase adjustment.

(15) 0°/180° (Reference Phase Inversion Push button)

When in, reverses the polarity of the REF IN signal to allow 360° phase coverage in AUTO or MAN mode.

(16) 2F/F (Second Harmonic Push button)

Normally this is left in the out (F) position. When this control is in the (2F) position, the Lock-In doubles the REF INPUT frequency and responds to the signal INPUT frequency component at twice the reference frequency.

(17) AUTO/MAN (Autophase Function Push button)

When in, provides for automatic adjustment of phase ±100°. An electronic servo loop operates until an output maximum is found. For signals shifted by more than ±100° relative to the reference, the 0°/180° push button (14) must be depressed. The lamp above the push button goes on to indicate that the Autophase circuitry has detected successful automatic phasing of the reference input.

(18) REF IN (Reference Input Connector)

The Lock-In synchronizing signal is applied here.

(19) UNLOCK (Reference Non-synchronizing Indicator Lamp)

Goes on to warn that the internal reference oscillator phase-locked loop has not captured the external reference frequency.

4.1.4 METER AND POWER SECTION

(20) METER (Analog Output Indicator)

Moving coil galvanometer with 0-100% scale for absolute output readings. Also has a 0-1-2 scale for ratio measurements if Analog Ration Option 02 is installed.

(21) METER ZERO

Screwdriver adjustment mechanically nulls the meter with unit power turned off.

(22) +/- (Meter Polarity Lamps)

Since the Lock-In Output is proportional to Acosϕ and the reference phase ϕ may range from 0° to 360°, the dc OUTPUT may range from -A to +A. To achieve higher meter resolution, this output is rectified to an absolute value in the meter circuit. The polarity lamps indicate the sign of this output. See Figure 4.4.

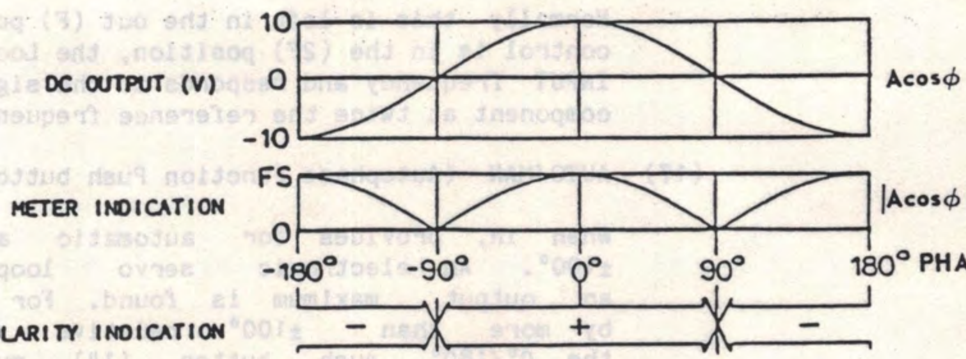


Figure 4.4 OUTPUT, METER AND POLARITY RELATIONSHIPS TO PHASE OF LOCK-IN

(23) LAMP OFF (Front Panel LED Defeat Switch)

When off, no indicator lamps will function. This prevents interference with detectors in low level optical work.

(24) POWER (ac Line Input Switch)

Pull out to turn on unit.

4.2 INPUT/OUTPUT CONNECTORS

4.2.1 SIGNAL INPUT

Due to the high impedance and sensitivity of the Lock-In input, one should always use co-axial cable. The grounding of the shield conductor should be made at <u>one point only</u> to prevent ground loop interference.

When the signal source has a ground return path, use the FLOAT position to break the BNC shell ground connection at the lock-in. The FLOAT position provides quasi-differential input amplification.

> CAUTION! To prevent damage when FLOATING the input, be sure that the common node ac voltage (between BNC shell and the cabinet) does not exceed ±10 volts peak. The center conductor may safely exhibit 200 V dc and ±15 V peak ac relative to the SIGNAL input BNC shell.

When the signal source does not have a ground reference, use the GND position. This shorts out one input of the differential amplifier and provides shield grounding for the input cable from the lock-in chassis.

One way to detect ground loop errors involves reducing the signal exactly 10 dB using a precision attenuator ahead of the lock-in input. The lock-in output should drop by a factor of 0.316. If the FLOAT/GND switch is incorrectly set, some other ratio will be observed. If both positions of the switch seem to give bad results, review and experiment with system grounds including source ground, power cord ground and chassis ground. See Section 3.3.2. Selection of the proper external preamp may solve the grounding problems in stubborn cases.

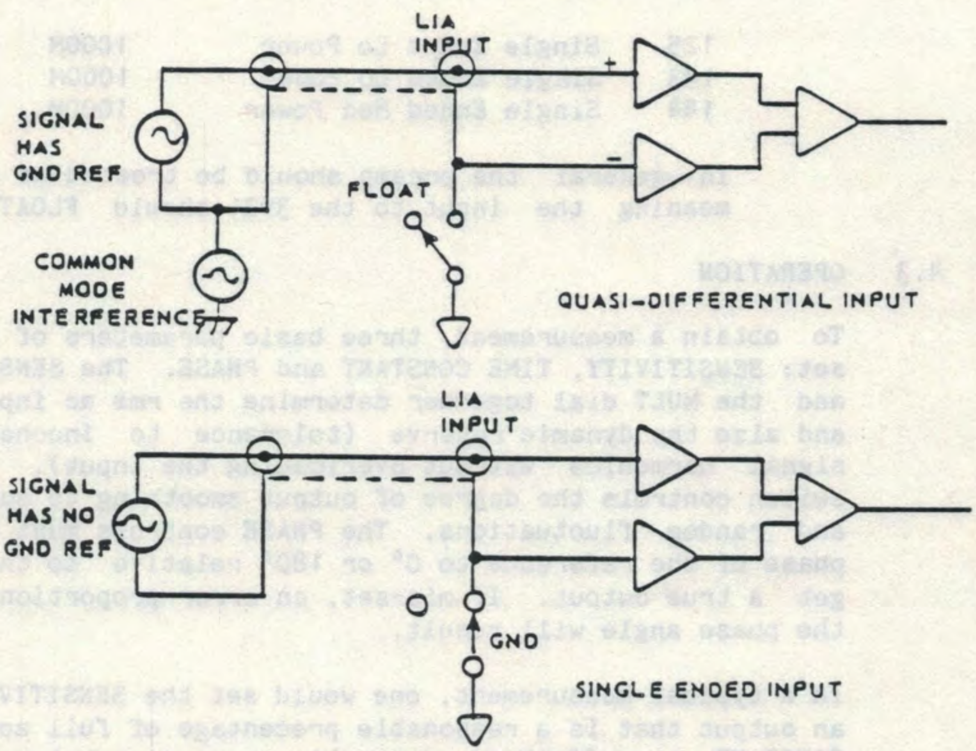


Figure 4.5 FLOATING AND GROUNDED LIA INPUTS

4.2.2 REFERENCE INPUT

The Model 3921 must have an external reference input to operate. For sinewaves, the level may range from 0.3 V p-p to 30 V p-p, however for levels below 1 V p-p the reference level must not fluctuate or else errors will occur due to reference phase variations. For rectangular wave input, the duty cycle must lie between 20:1 and 1:20.

The LIA will not operate if the UNLOCK lamp is lighted.

4.2.3 EXTERNAL PREAMPS

ITHACO remote preamplifiers may be powered from the rear panel ±20 V connector to achieve impedance matching, low noise performance, true differential input, current input, or greater sensitivity (e.g. 100 nV full scale).

ITHACO PREAMP MODEL	TYPE	INPUT IMPEDANCE	GAIN
1641	Current	0	$10^8/10^6/10^4$ V/A
1651	Differential Transformer	10K	60dB
	or Direct Single Ended	100M	20dB
1661	Lo Noise Single Ended	40K	40dB
1671	Lo Noise Single Ended	100M	20dB
1681	Differential	100M	20dB
125	Single Ended Lo Power	1000M	0dB
143	Single Ended Lo Power	1000M	20dB
144	Single Ended Med Power	1000M	40dB

In general the preamp should be treated as a grounded source, meaning the input to the 3921 should FLOAT.

4.3 OPERATION

To obtain a measurement, three basic parameters of the lock-in must be set: SENSITIVITY, TIME CONSTANT and PHASE. The SENSITIVITY range switch and the MULT dial together determine the rms ac input to dc output gain and also the dynamic reserve (tolerance to incoherent interference or signal harmonics without overloading the input). The TIME CONSTANT switch controls the degree of output smoothing to suppress output ripple and random fluctuations. The PHASE controls must be set to shift the phase of the reference to 0° or 180° relative to the signal in order to get a true output. If mis-set, an error proportional to the cosine of the phase angle will result.

In a typical measurement, one would set the SENSITIVITY controls to get an output that is a reasonable precentage of full scale, adjust the TIME CONSTANT to effect an acceptable compromise between settling time and output fluctuations due to noise, and operate the PHASE controls to achieve an output maximum. The settings normally would be made in the order given, with some repeated as the control parameters are refined. If the AUTO lamp goes on in the AUTO phase mode, then the manual phase adjustment will be unneccesary.

4.3.1 STARTING SETTINGS

Before beginning a measurement, the following initial control settings are suggested (see Fig. 4.1):

SENSITIVITY	100 mV
MULT	1.00
FLOAT/GND	GND
TIME CONSTANT	0.3 sec
ZERO OFFSET	0.00
POST FILTER	OFF
0°/90°	0°
0°/180°	0°
F/2F	F
AUTO/MAN	MAN
LAMP	ON

Mechanical zero of the meter (21) can be checked before power is turned on. Adjust if necessary. With power on, electrical ZERO (10) can be set with the input shorted using the above settings. If very accurate nulling via a DVM is desired, allow at least 1/2 hour warmup. Adjust if necessary.

4.3.2 REFERENCE INPUT

Connect REFerence INput signal. If the UNLOCK lamp fails to go off in several seconds, or if it does not remain off continuously, check to see that:

1. The frequency lies between 10 Hz and 15 kHz.
2. The level lies between 0.3 and 30 V pp (sinewave).
3. The duty cycle lies between 20:1 and 1:20 (pulsewave).
4. The waveform is relatively clean with regard to jitter noise and frequency instability.

4.3.3 SENSITIVITY AND MULT SETTING

Connect the signal to be measured to the INPUT BNC and set the FLOAT/GND switch as appropriate (see section 4.2.1, 4.2.3 and Figure 4.5).

Start with MULT = 10.00. This provides the greatest accuracy at the expense of the lowest dynamic reserve. This setting might be reduced later for several reasons:

1. To achieve maximum sensitivity if the signal is below 100 µV rms (10 µV sensitivity switch setting).
2. To achieve a larger full scale meter indication. In this case, it is advantage to use MULT control settings of 1.00, 2.00 or 5.00 to facilitate reading the meter.

3. To increase overload tolerance if the rms signal is more than 40 dB below the peak-to-peak input interference. The dynamic reserve increases to 60 dB at a setting of 1.00.

4. To set meter to a normalized reading such as 100% or 50% (1 on meter red scale) for a nominal signal level. Thus, for example, one could read the relative attenuation percentage directly off the meter and know that a 100% indication has an absolute value equal to the product of the SENSITIVITY switch setting and the MULT setting.

Increase the SENSITIVITY until a reading above 10% of full scale is obtained. If a flashing output overload lamp (11) occurs but the meter reading is not offscale, raise the TIME CONSTANT to increase the smoothing of the output.

If the meter indication is low but the input overload lamp (3) lights, the problem is due to interference that exceeds the dynamic reserve. Set MULT to 1.00 and try again.

4.3.3.1 DYNAMIC RESERVE

Table 4.1 defines the dynamic reserve limits for various settings of SENSITIVITY and MULT, where:

$$\text{Dynamic Reserve} = \frac{\text{Maximum Noise Voltage without overload (pp)}}{\text{Full Scale Voltage (rms)}}$$

SENSITIVITY	MULT	
	1.00	10.00
10μV	x1000	x100
100μV	x1000	x100
1mV	x1000	x100
10mV	x1000	x100
100mV	x200	x20

TABLE 4.1 DYNAMIC RESERVE

Figure 4.2 summarizes the tradeoff between lock-in output stability and dynamic reserve as a function of the MULT control setting. At 1.00, the unit will tolerate the most interference (1000:1) but, due to drift, noise and so forth, the out uncertainty will also be the greatest. At 10.00 the unit will be able to handle only one tenth as much interference, but the stability and measurement accuracy will increase tenfold.

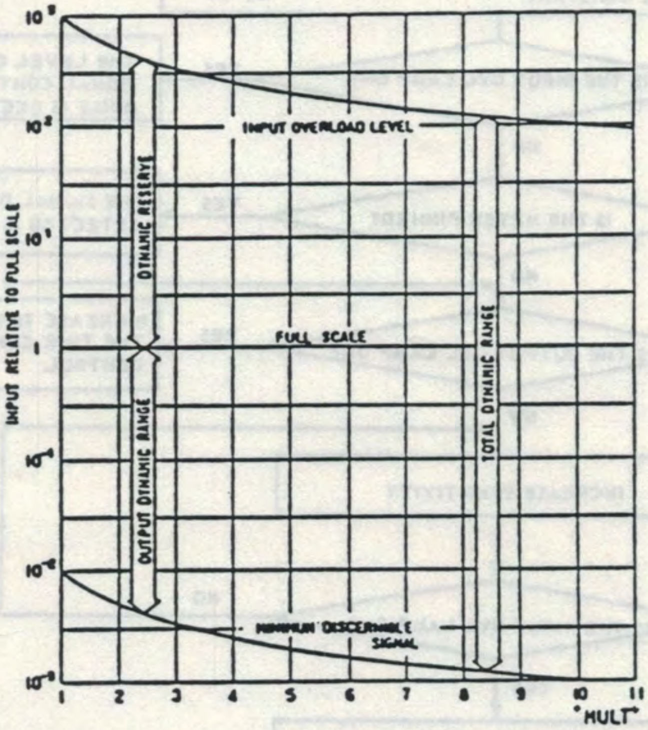


Figure 4.6 DYNAMIC RESERVE

4.3.4 TIME CONSTANT AND POST FILTER

These controls set the system bandwidth, thereby establishing the degree of interference rejection. Too high a bandwidth relative to the noise (overly low TIME CONSTANT setting) manifests itself as excessive output fluctuations. Increase the TIME CONSTANT setting, if necessary, to achieve an acceptably steady reading.

In low level work, line frequency harmonics near the signal frequency may cause a beat frequency in the output of the lock-in at 30 Hz or below. This can be observed by attaching an oscilloscope to the OUTPUT connector. If this ripple is large enough, it may interfere with readings or cause an output overload (11). Activating the POST FILTER will suppress the ripple by introducing a 12dB/octave (40dB/decade) rolloff starting at 0.125 Hz. This can be increased to 18dB/octave (60dB/decade) by also setting the TIME CONSTANT to one second. For best results, the operating frequency ought to be chosen to lie roughly centered between nearby harmonics of 60Hz. Typically one selects a frequency 25 Hz from one harmonic and 35 Hz from the other --e.g., 215 Hz which lies between the 3rd harmonic (180 Hz) and the 4th (240 Hz).

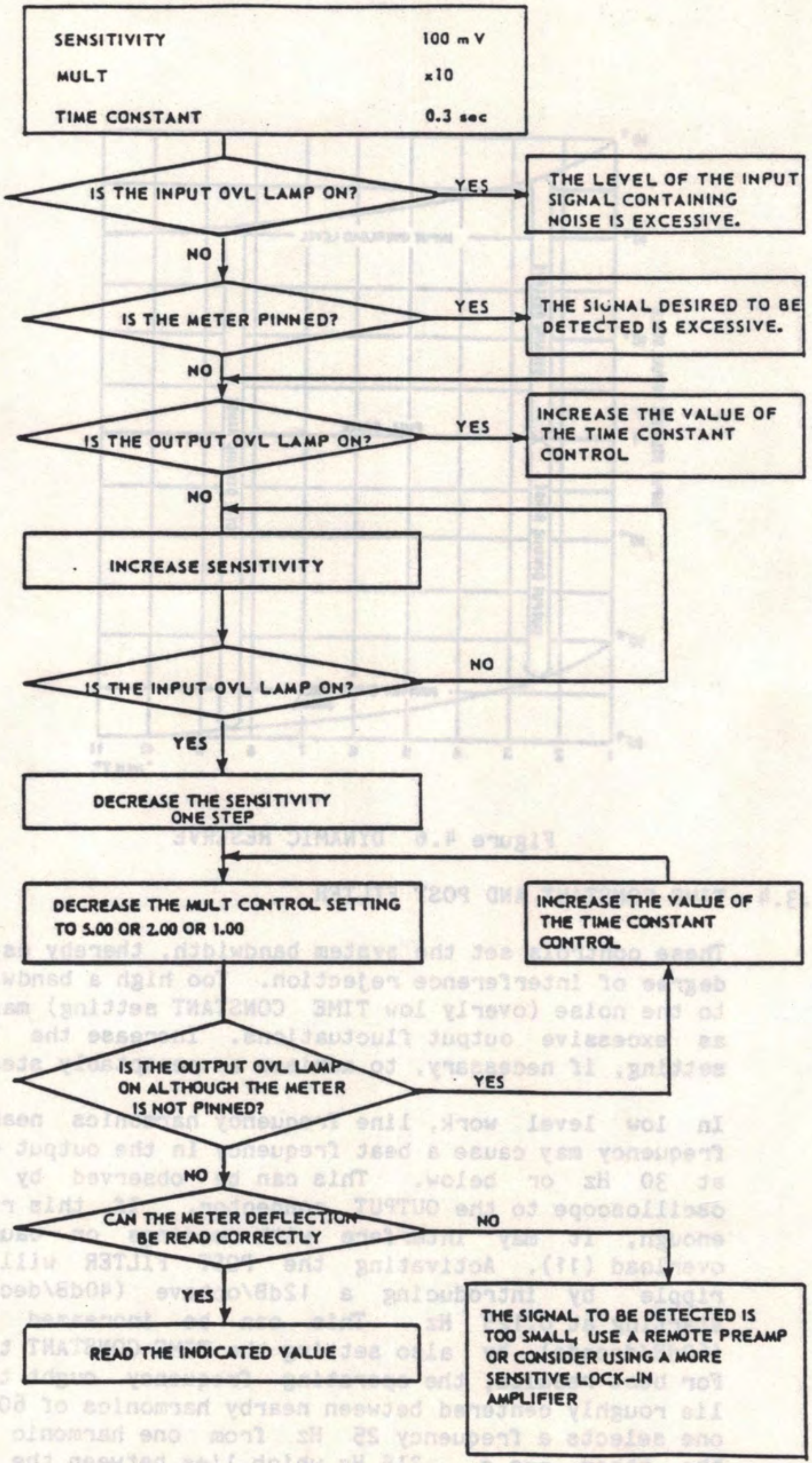


FIGURE 4.7 SUGGESTED SENSITIVITY SETTING PROCEDURE

4.3.5 PHASE SETTING

Since the output of the lock-in is proportional to Acosϕ, where ϕ equals the phase difference between the signal and reference inputs and A represents the signal magnitude, the phase must be properly adjusted to be a true reading. In general start out with Autophase active. If the Auto lamp will not come on, then MANual phasing ought to be investigated.

The Autophase circuit employs a separate phase sensitive detector. This technique is far superior to competitive techniques which electronically drive the phase to achieve an output null, then shift the phase 90°. First, the 3921 Autophase function is unaffected by the TIME CONSTANT setting. Second, it works very well in the presence of high noise levels.

4.3.5.1 AUTOPHASE

Set 0°/180° and 0°/90° Switches to 0° (out) and depress the AUTO switch. If the AUTO lamp does not come on with the SENSITIVITY switch set approximately correctly, reverse the 0°/180° switch. Failure of the lamp to go on within several seconds indicates that the input noise is large enough to impair functioning of the Autophase circuitry. This does not necessarily mean that the AUTO mode should not be used.

If the lamp is off due to poor SNR, there is a very good chance that the AUTO mode is still functioning to produce better results than the MAN mode. Typically this would happen when the input signal falls to a low level against a constant noise background. In this noisy environment, manual phase setting probably will be slower and less reliable than the automatic method. Be warned that below the lamp threshold the Autophase circuit is very slow (e.g., requires minutes to settle if the signal is 20 dB below threshold). However, if the signal drops without changing phase, this settling time constraint is removed. For both discrete frequency and random noise interference, accurate Autophase functioning is routinely observed until the signal falls 30 dB below the lamp threshold, at which point the signal is barely measurable anyway due to background noise.

4.3.5.2 MANUAL PHASE SETTING

In principle one could set phase manually by manipulating the PHASE control for a maximum meter reading, which would occur when the phase difference between the signal and the shifted reference input equalled 0° or 180° (180° would result in a negative output BNC voltage with an absolute value equal to the positive value which would be obtained if the 0°/180°

switch were reversed). This procedure is slow and prone to error, particularly if the input is noisy and/or a long TIME CONSTANT is in effect.

A much quicker and more accurate method is to adjust phase for a minimum output reading (near 0% on the meter), then reverse the 0°/90° switch to take measurements.

4.3.6 ZERO OFFSET

For normal measurements made via the front panel meter, this control should be set to 0.00. ZERO OFFSET is provided for two reasons. First, if observation of the OUTPUT is made on a chart recorder or DVM, the OUTPUT can be zero suppressed to facilitate measurement of small changes in a large background signal. The resolution increases in proportion to the additional gain provided by the external measurement device (e.g., 1 volt full scale on a chart recorder would yield a tenfold improvement). Second, if the MULT control is set to 1.00, then the SENSITIVITY switch can be increased one step (e.g., from 1 mv to 100 μV), with the meter indication being brought on scale using the ZERO OFFSET control. This increases the resolution of the 3921 tenfold.

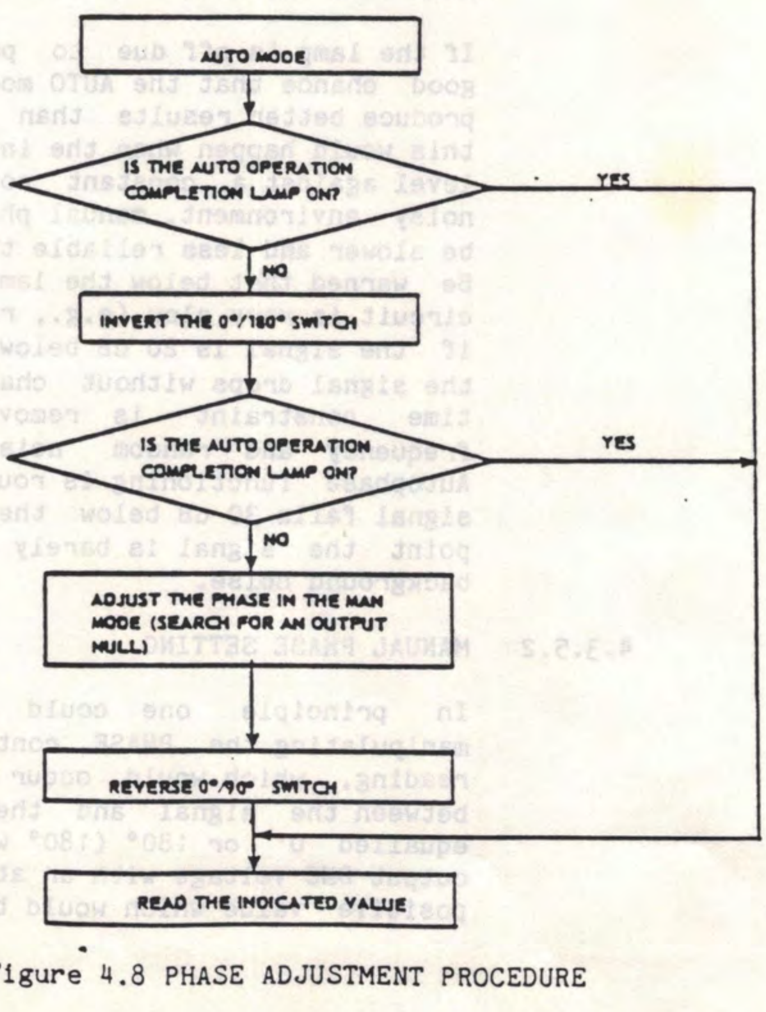


Figure 4.8 PHASE ADJUSTMENT PROCEDURE

When using ZERO OFFSET to increase meter resolution (MULT = 1.00), first set ZERO OFFSET = 0.00 and rotate the SENSITIVITY switch to get an on-scale reading. Next, increase the SENSITIVITY one step (ccw). Note polarity of meter on (+) (-) lamps (22). Switch to opposite polarity on ZERO OFFSET (+) (-) lamps (9) then increase ZERO OFFSET dial to null the meter. To obtain a precise null, adjust for equal brightness observing the (+) (-) polarity lamps.

The expression below gives the signal measurement in terms of panel control settings.

$$V_{in} = \text{SENSITIVITY} \left(\frac{\text{Meter \%}}{100} \times \text{MULT} - \text{OFFSET} \right)$$

If output ripple exists on the LIA output, it can interfere with zero suppression. As the meter approaches a null, the meter polarity circuit (Figure 4.5) will rectify the ripple, resulting in a residual meter reading that cannot be reduced using the ZERO OFFSET control alone. Both the (+) and (-) polarity lamps will be fully lighted. This effect can be eliminated by increasing the TIME CONSTANT or activating the POST FILTER switch, per Section 4.3.4. The ripple problem would not be apparent if an average responding ac voltmeter were reading the OUTPUT connector.

4.3.7 SWEEP SPEED

The Model 3921 reference frequency can be swept continuously over its full operating range: 10 Hz, to 15 kHz. In the MANual phase mode, reference lock will be maintained with less than 10% phase error (less than 3% amplitude error) as long as the sweep speed is not too fast relative to the reference frequency (0.04 Hz/sec per Hz).

In the AUTO phase mode faster tracking will prevail (0.1 Hz/sec per hz, typically) with lower signal error (1% or less).

FREQUENCY HZ	MAX MAN PHASE SPEED SPEED (3%ERROR) Hz/sec	MAX AUTO PHASE SWEEP SPEED (1%ERROR) Hz/sec
10	0.4	1
100	4	10
1000	40	150

TABLE 4.2 SWEEP SPEED

The values refer only to reference tracking effects. The measurement accuracy will also be dependent upon the output response time as set by the TIME CONSTANT control.

SECTION 5

PRINCIPLE OF OPERATION

5.1 THE BASIC LOCK-IN AMPLIFIER

The lock-in amplifier is an extremely selective ac voltmeter. It operates on the principle of narrowbanding to reject interference while passing the signal at the frequency of interest. In effect, the amplifier locks the center of its passband precisely onto a second input frequency, the reference input, which is coherent with the signal.

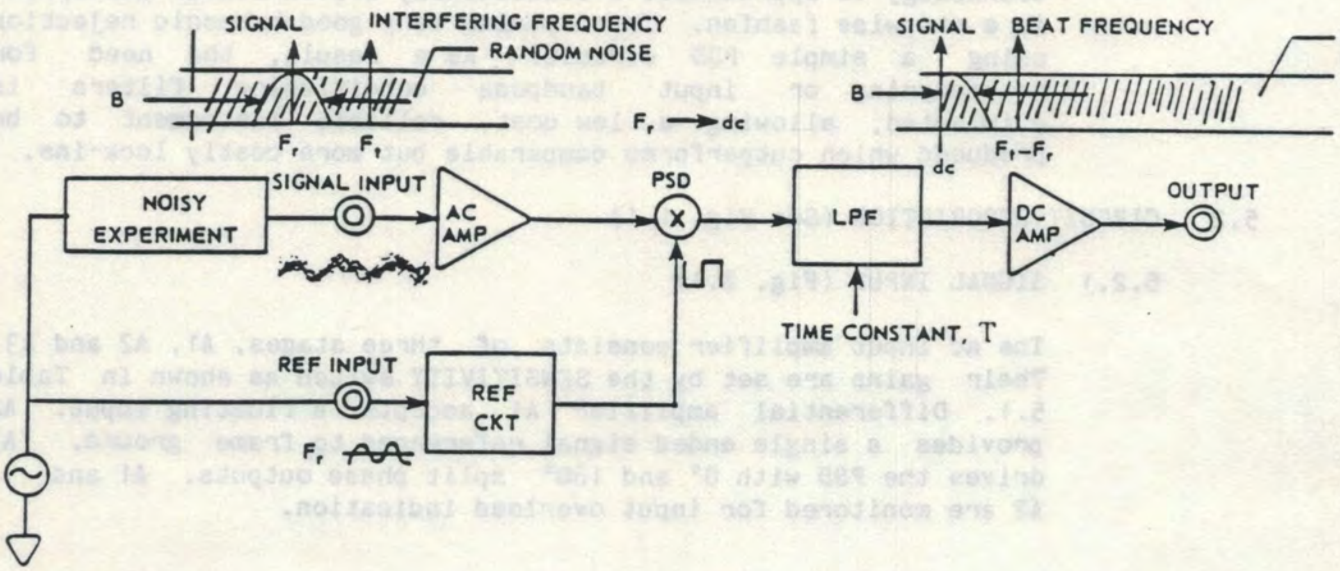


Figure 5:1 BASIC LOCK-IN AMPLIFIER BLOCK DIAGRAM

The phase sensitive detector (PSD) multiplies the input by the reference frequency, downshifting the spectrum so that the signal of interest appears as a pure dc level at its output. All other input components appear as beat frequencies or frequency shifted noise fluctuations. These can be removed by a simple, utterly stable RC (TIME CONSTANT) low pass filter (LPF) to provide practically arbitrarily narrow equivalent noise bandwidths (B). The effective Q referred to the reference frequency-approximately $F_r/(1/4T)$-can be set above 10^7 for the 3921.

The effectiveness of the filtering process varies as the square root of the bandwidth. This means that a 100-fold increase in TIME CONSTANT would be needed to achieve a 10-fold reduction in the output fluctuations being caused by random noise within the passband of the lock-in. The penalty would be 100-fold increase in meter response time.

5.1.1 THE 3921 PSD COMPARED TO OTHERS

Ideally the PSD should be a linear multiplier with a sinusoidal reference input. However no practical circuit exists which can operate over a wide dynamic range with sufficient accuracy and stability.

The classical lock-in amplifier employs a switching PSD which in effect multiplies the input by a square wave reference signal. While very accurate, it suffers from odd harmonic responses to signal input components that correspond to the overtones of the reference drive to the PSD. One common solution to this problem is to insert a tuned amplifier into the signal path to eliminate odd harmonics before they get to the PSD; an approach which has serious drawbacks of its own such as intolerance to reference frequency drift. Top-of-the-line ITHACO Dynatrac lock-ins circumvent these problems by a heterodyning technique, an approach not suitable for a low cost instrument.

The Model 3921 works on a hybrid principle using switching technology to approximate a sinusoidally driven linear multiplier in a stepwise fashion. This yields very good harmonic rejection using a simple PSD circuit. As a result, the need for heterodyning or input bandpass conditioning filters is eliminated, allowing a low cost, reliable instrument to be produced which outperforms comparable but more costly lock-ins.

5.2 CIRCUIT DESCRIPTION (See Fig. 1.1)

5.2.1 SIGNAL INPUT (Fig. 8.1)

The ac input amplifier consists of three stages, A1, A2 and A3. Their gains are set by the SENSITIVITY switch as shown in Table 5.1. Differential amplifier A1 accepts a floating input. A2 provides a single ended signal referenced to frame ground. A3 drives the PSD with 0° and 180° split phase outputs. A1 and A2 are monitored for input overload indication.

SENSITIVITY	STAGE GAINS			OVERALL GAIN
	A1	A2	A3	
10 µV	10.3	10	20	2060
100 µV	10.3	10	2	206
1 mV	10.3	1	2	20.6
10 mV	1.03	1	2	2.06
100 mV	1.03	1	.2	0.206

TABLE 5.1 AC AMPLIFIER GAINS

5.2.2 PSD (Fig. 8.2)

This is the heart of the lock-in. A pair of digital multplexers sequentially switch in a weighted portion of the signal to its output. The full scale drive to the PSD ranges from 20.6 mV rms (MULT = 1.00) to 206 mV rms (MULT = 10.00).

5.2.3 OUTPUT (Fig 8.3)

The PSD feeds the single pole lowpass filter-amplifier (Q106a) the corner frequency of which is controlled by the TIME CONSTANT switch.

The next amplifier stage (Q106b) incorporates the ZERO trim, the ZERO OFFSET dial and the two-pole, fixed frequency POST FILTER controls.

This is followed by the variable gain MULT dc amplifier (Q107b) which provides the OUTPUT BNC signal. It also feeds the rectifying meter amplifier (Q107A), and in turn the polarity indicating lamps (via Q108 c and d). Q108 a and b monitor for output overloads, lighting the OVL lamp whenever the output (including ripple) exceeds the range ±11.5 V.

5.2.4 REFERENCE SYSTEM

5.2.4.1 PLL-I (Fig. 8.4)

Input comparator Q201a waveshapes the reference input for the phase locked loop consisting of Q203 and associated components. Q204, 211, 212 a and b, and 1/2 Q213 form a sawtooth VCO within the loop. Q212c, 1/2 Q213 and Q214 form the feedback loop, which contains provision for 180° phase reversal and 2F operation. Q201b, c and d comprise an unlock lamp driver for PLL-I and PLL-II.

5.2.4.2 PLL-II AND PHASE SHIFTER (Fig. 8.5)

Q212d accomplishes a continuous ±100° PHASE shift by comparing the sawtooth output of PLL-I with a dc level. The PLL-II circuit, Q220, makes use of its on-chip VCO and filtering provisions. Q205, Q206 and Q210 generate the timing waveforms for the PSD. Feedback element Q238 allows for the 90° phase shift feature.

5.2.5 AUTOPHASE (Fig. 8.6)

A square wave PSD Q299 (separate from the main signal processing PSD) operates on the output of the A3 amplifier. In the AUTO mode, this is processed to a dc level and fed to the phase shifter, nulling the phase error in the main PSD. In the MAN mode, the dc level is provided by the PHASE knob. Q231a and Q233 extinquish the AUTO lamp if the input signal to noise ratio exceeds a preset threshold.

SECTION 6

MAINTENANCE

6.1 INTRODUCTION

This manual contains procedures for operational inspection and for user calibration adjustments. Schematic diagrams are provided to assist in trouble shooting. Problems which cannot be remedied in the field should be referred to the ITHACO Customer Service Department.

6.2 OPERATIONAL INSPECTION

These checks verify control functioning and whether or not the unit meets accuracy specifications.

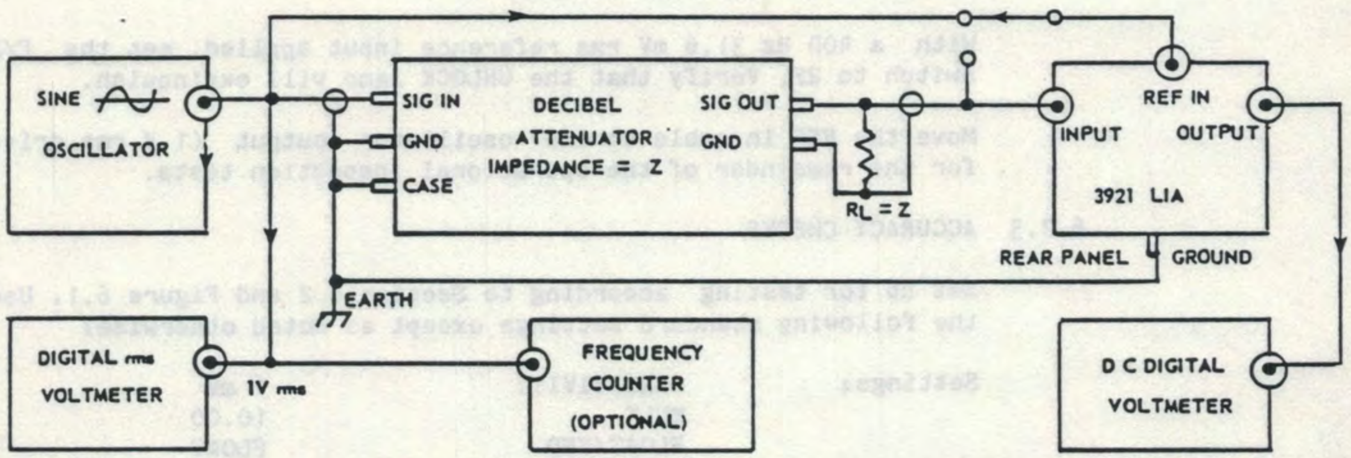


FIGURE 6.1 OPERATIONAL INSPECTION SETUP

Set the oscillator sinewave output to 1.000 V rms at 400 Hz and thereafter leave its level control alone (measure with a precision digital rms voltmeter such as a Hewlett Packard Model 34702A). Use a precision decade attenuator such as a General Radio Type 1450 - TA to deliver calibrated signal levels to the lock-in at 1.000 V, 100 mV, ..., 10 μV corresponding to attenuations of 0 dB, 20 dB, ..., 100 dB. Provide earth grounding as shown and be sure to load the attenuator output with a resistance equal to its internal impedance (e.g., 600 Ω 1% for the GR 1450 - TA). One should refrain from resetting the oscillator output level when changing from 400 Hz to other frequencies since rms meters generally tend to be inaccurate at the high and low ends of the 3921 frequency range. Use a high quality signal generator which you can trust not to change output amplitude when the frequency is changed such as a Wavetek Model 110 or Hewlett Packard Model 209A.

6.2.1 MECHANICAL ZERO CHECK

With power off, verify that the front panel METER reads zero. If not, adjust the screw (21).

6.2.2 REFERENCE LOCK CHECKS

Connect REF IN to output of attenuator and set attenuation to 0 dB (1 V rms sinusoidal reference input).

Settings:	F/2F	F
	Lamp Switch	On

The UNLOCK lamp should go off for the full frequency range of the instrument. Check at 10 Hz, 100 Hz, 1 kHz, 10 kHz and 15 kHz. Allow several seconds for re-locking when frequency is switched.

At 400 Hz, apply a 30 dB attenuation (31.6 mV rms reference input). The unlock lamp must remain off. The reference level at which lock is lost (typically below 10 mV rms) can be checked using the ac voltmeter if desired.

With a 400 Hz 31.6 mV rms reference input applied, set the F/2F switch to 2F. Verify that the UNLOCK lamp will extinquish.

Move the REF in cable to the oscillator output (1 V rms drive) for the remainder of the operational inspection tests.

6.2.3 ACCURACY CHECKS

Set up for testing according to Section 6.2 and Figure 6.1. Use the following standard settings except as noted otherwise:

Settings:	SENSITIVITY	1 mV
	MULT	10.00
	FLOAT/GND	FLOAT
	TIME CONSTANT	0.3 sec
	ZERO OFFSET	0.00
	POST FILTER	OFF
	AUTO/MAN	AUTO
	0°/180°	0°
	0°/90°	0°
	F/2F	F
	Input Signal	10.00 mV rms Sinewave (atten=40 dB) at 400 Hz
	Reference	1 V rms sinewave

With these settings the lock-in will display a full scale output.

6.2.3.1 OFFSET CHECKS

Settings:		
	MULT	1.00
	INPUT	Shorted
	FLOAT/GND	GND

With the frequency at 400 Hz observe the OUTPUT offset on the DVM. Assuming the unit has warmed up at least 30 minutes with the covers on, adjust the front panel baseline ZERO trimpot (10) for a 0.00 ±0.010 V dc reading. When MULT = 1.00, the baseline has a 5 mV/C° temperature coefficient specification (0.5 mV/C° when MULT = 10.00)

Increase the frequency to 10 kHz. Verify that the OUTPUT is less than 500 mV (5% on METER). An excessive baseline shift indicates a synchronous offset error.

6.2.3.2 GAIN ACCURACY CHECKS

Settings:		
	SENSITIVITY	1 mV
	MULT	1.00
	FLOAT/GND	FLOAT
	AUTO/MAN	MAN
	Input Signal	1.00 mV rms (ATTEN=60 dB)
	Frequency	400 Hz

<u>Absolute Accuracy</u>

Set 0°/90° to 90° and adjust PHASE for an output null ±100 mV. Reset 0°/90° to 0° (to get an output maximum reading of ACOS 0° = A). The METER should read 100% of full scale ±3% (10 V ±300 mV on DVM).

<u>MULTiplier Function and Accuracy</u>

Turn MULT control from 1.00 to 10.00. The METER should decrease continuously to about 10% of full scale.

Increase INPUT signal to 10.00 mV (40 dB atten) and verify a reading of 100% of full scale ±3% (10 V ±300 mV).

SENSITIVITY Switch Relative Accuracy

Settings:	SENSITIVITY	1 mV
	MULT	10.xx
	Input Signal	10.00 mV rms (40 dB Atten) @ 400 Hz

Adjust MULT control for a 100% METER reading (10.00 V OUTPUT). Using the precision attenuator in 20 dB steps from 0 dB (1 V rms) to 80 dB (100 μV rms), check each SENSITIVITY switch position from 100 mV to 10 μV for a full scale reading ±3% (10 V ±300 mV).

6.2.3.3 FREQUENCY RESPONSE AND AUTO FUNCTION CHECK

With setup given above, recheck for a 100% (10.00 V) reading with a 10.00 mV (40dB) input at 400 Hz (phased MAN mode).

Check for a 100% ±3% (10 V ±300 mV) reading for operating frequencies of 10 Hz, 100 Hz, 1 kHz and 10 kHz. Use a 3 second TIME CONSTANT for 10 Hz and 0.3 seconds for the other frequencies. Also check for 100% ±5% (10 V ±500 mV) at 15 kHz. For each frequency, momentarily turn on the AUTOphase function and verify that the AUTO lamp goes on and that the reading in AUTO mode is within the ±3% specifications (±5% at 15 kHz).

6.2.4 REFERENCE SIGNAL CHECKS

Settings:	SENSITIVITY	1 mV
	MULT	10.xx
	FLOAT/GND	FLOAT
	TIME CONSTANT	0.3 sec
	ZERO OFFSET	0.00
	POST FILTER	OFF
	AUTO/MAN	MAN
	0/180°	0°
	F/2F	F
	Input Signal	10 mV rms Sinewave (40 dB atten) @ 400 Hz
	Reference Input	1 V rms Sinewave

Phase the lock-in in the MAN mode by nulling the METER with the 0°/90° switch set to 90°, then reversing the 0°/90° switch to 0°. Then tweak MULT for a full scale output. The positive (+) (-) polarity lamp should be on.

Reverse the 0°/180° switch to 180°. The (+) lamp should go off and the (-) lamp should go on. The METER reading should be unchanged (DVM reading would change sign from plus to minus).

Switch to 2F mode. Verify that the unlock lamp goes back off. Assuming that the signal generator sinewave has less than 1% distortion, the METER reading should be nearly zero.

6.2.5 POST FILTER FUNCTION

Switch F/2F to F.
With the standard settings as given in Section 6.2.3 change the SENSITIVITY to 10 mV then back to 1 mV and observe the METER settling time. Switch in the POST FILTER function. Now the settling time should be several times slower when SENSITIVITY is switched.

6.2.6 ZERO OFFSET

Settings:	
MULT	10.00
INPUT	Shorted
FLOAT/GND	GND
ZERO OFFSET	0.00 (- polarity)
POST FILTER	OFF

Starting at 0.00, increase the ZERO OFFSET dial to 10.00. The METER reading should increase continuously (equal to the dial indication) with a full scale reading ±1% at a dial setting of 10.00. The (-) polarity lamp should be on. Reverse the ZERO OFFSET (+) (-) switch. The (-) lamp should go off and the (+) lamp should go on. Now the meter should read within ±5% of full scale.

With ZERO OFFSET = 10.00, reduce the MULT dial setting. The output OVL lamp should go on at a setting of roughly 8.70 (11.5 V on OUTPUT DVM). This checks the OUTPUT overload detector.

6.2.7 RATIO OPTION CHECK

See Section 9.6

6.3 CALIBRATION ADJUSTMENTS

The following screwdriver adjustments to trimpots and trim capacitors are to be used if the unit does not meet the specifications tested for in Section 6.2. Calibration should not be done until the internal temperature of the cabinet has stabilized (allow at least a 30 minute warmup).

To gain access to the adjustments, remove the two molded plastic pieces from the rear of the instrument by loosening the four retaining screws. The top will then slide rearward. Use care when handling the unit, as the side and bottom panels also are free to move when the rear moldings are removed.

Figure 6.3 shows the location of board components. Do not touch anywhere except at the indicated points. Keep the covers in place, sliding the top open only momentarily while making an adjustment.

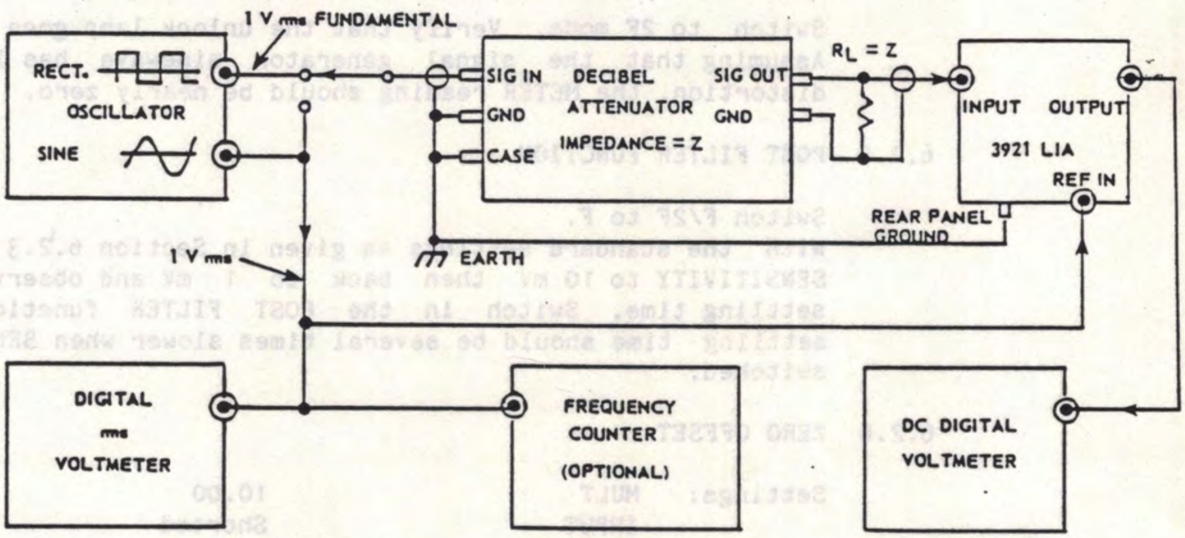


Figure 6.2 CALIBRATION SETUP

Use an oscillator with in-phase sine and square wave outputs. Initially route the sinewave to the reference input and the squarewave to the signal input. Later on both signal and reference will be sinewaves. Use a precision attenuator with an output load equal to its internal impedance in the signal path. Provide earth grounding as shown.

6.3.1 REFERENCE ADJUSTMENTS

6.3.1.1 MINIMUM REFERENCE LEVEL

Perform this procedure if the instrument won't lock with a 30 mV rms reference input per Section 6.2.2. This adjustment is made by minimizing the phase shift when the reference level is dropped 20 dB from a 1.00 V rms sinewave to a 100 mV rms sinewave.

Settings:	SENSITIVITY	1 mV
	MULT	10.00
	FLOAT/GND	FLOAT
	ZERO OFFSET	0.00
	POST FILTER	OFF
	TIME CONSTANT	0.3 sec
	0°/90°	90°
	0°/180°	0°
	F/2F	F
	AUTO/MAN	MAN
	Signal Input	400 Hz squarewave with 10 mV rms fundamental
	Reference Input	1 V rms sinewave

Apply a 1 V rms sinewave reference input. With attenuator set to 40 dB, adjust squarewave signal input for approximately a full scale output in the AUTO MODE. Switch to MAN mode and adjust PHASE to null the meter (± 100 mV dc on DVM).

Reduce the sinewave reference input to 100 mV rms. Adjust RV201 for DVM reading within ± 50 mV dc of the reading obtained at the 1.00 V rms reference input level.

6.3.1.2 MINIMUM LOCK FREQUENCY

Perform this step if the instrument won't lock at the lowest frequency (e.g., 10 Hz) per section 6.2.2. The procedure trims the free-running frequency of the PLL oscillator to roughly 1 Hz.

Settings:		
	F/2F	F
	Reference Input	1 V rms sinewave
	Scope Attachment	TP-12

With a reference applied, you should see a synchronous sawtooth wave at TP-12 with a 0.4 volt trough and 15 volt peak. Remove the reference signal. Adjust RV202 so that the sawtooth frequency equals approximately 1 cycle per second.

6.3.2 SIGNAL ACCURACY ADJUSTMENTS

6.3.2.1 OFFSET

Adjust the offset of the dc output amplifier (RV101) if the ZERO adjustment (10) won't null the output at 400 Hz per Section 6.2.3.1. Adjust the PSD trimmers (CV101/102) if the synchronous OFFSET error at 10 kHz is excessive per Section 6.2.3.1.

Settings:		
	SENSITIVITY	100 mV
	MULT	1.00
	INPUT	Shorted
	FLOAT/GND	GND
	TIME CONSTANT	0.3 sec
	POST FILTER	OFF
	ZERO OFFSET	0.00
	ZERO (10)	Centered
	F/2F	F
	AUTO/MAN	MAN
	Reference	1 v rms sinewave

Set the reference frequency to 400 Hz. Adjust RV101 for zero output (± 100 mV dc on DVM).

Set the reference frequency to 10 kHz. Adjust CV101 and /or CV102 as required to null the output (± 100 mV dc on DVM).

When done, null the offset to ±10 mV at 400 Hz using the ZERO adjustment (10).

6.3.2.2 GAIN CALIBRATIONS

Adjust RV103, 104 and 105 if inaccuracy is observed in Section 6.2.3.2. Some of these trims will affect the others, so if you do one you must do the others, and in the order given.

Settings:		
	SENSITIVITY	1 mV
	MULT	10.00
	FLOAT/GND	FLOAT
	TIME CONSTANT	0.3 sec
	POST FILTER	OFF
	ZERO OFFSET	0.00
	F/2F	F
	AUTO/MAN	AUTO
	Reference	400 Hz 1 V rms sinewave
	Input Signal	Calibrated 10 mV rms sinewave

Move the signal input cable feeding the attenuator from the square to the sinusoidal output of the signal generator. Use digital rms voltmeter for setting oscillator output to exactly 1.000 V rms at 400 Hz. Set attenuator to 40 dB to supply a calibrated 10.00 mV rms input to the 3921.

RV103: Adjust for a 10.00 V dc OUTPUT on DVM.
RV105: Adjust for full scale panel METER indication (100%).

Attenuate signal to 60 dB (1.000 mV rms input). Set MULT to 1.00.

RV104: Adjust for a 10.00 V dc OUTPUT on DVM.

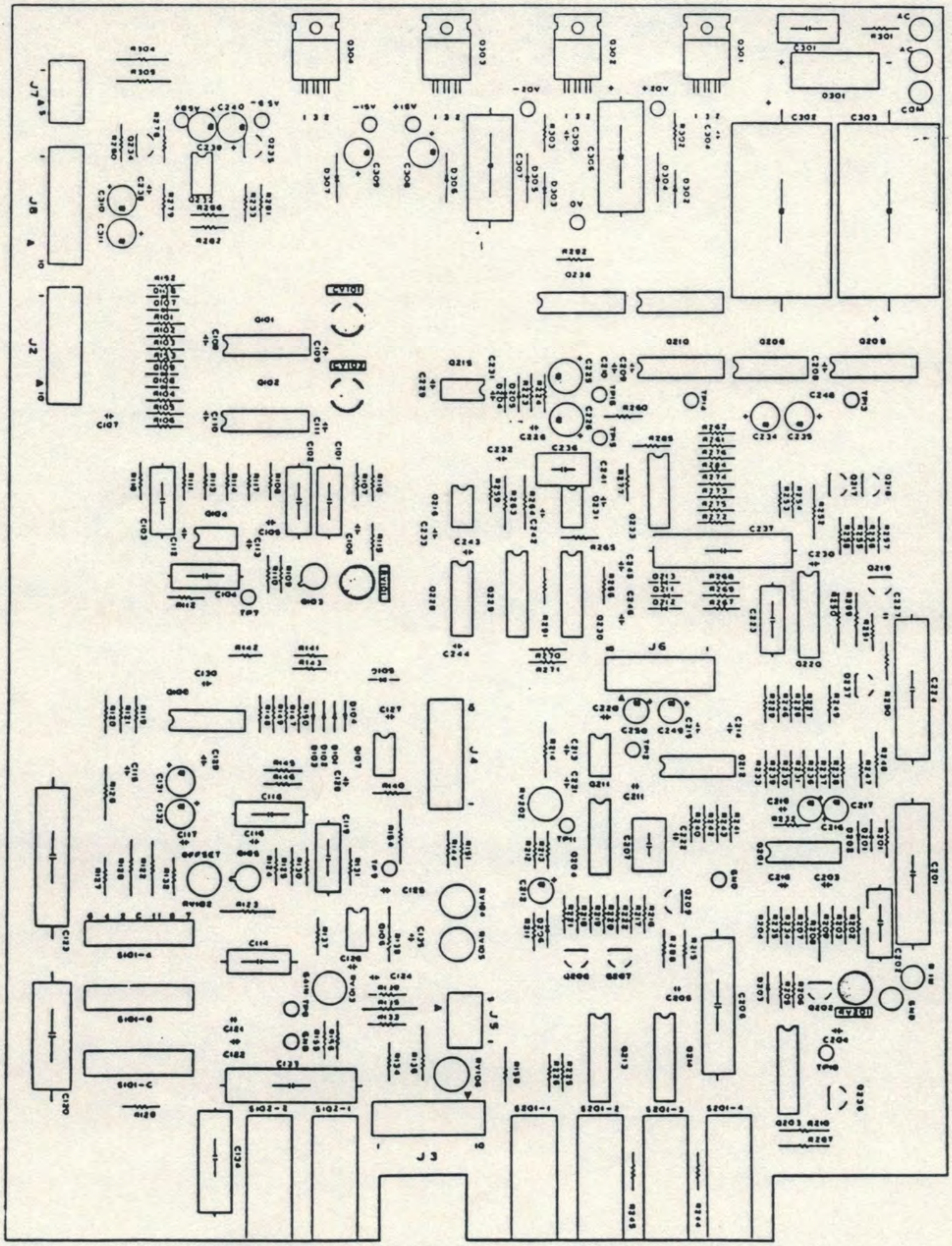


Figure 6.3 COMPONENT LOCATION

SECTION 7

PARTS LIST

7.1 INTRODUCTION

This section lists information concerning the electrical parts required to repair failures. Table 7-1 lists the abbreviations used in the parts list. Tables 7-2 thru 7-10 are the parts lists themselves, and Table 7-11 is a listing of the parts manufacturer's codes.

7.2 REPLACEABLE PARTS LIST

The parts lists of Tables 7-2 to 7-10 contain the following information.

CKT NO.

This is the part number within a particular circuit diagram. It is assigned per assembly.

ITHACO PART NO.

This is the ITHACO part code number. When ordering parts from ITHACO, specify this code number and part name.

NAME AND DESCRIPTION

This is the part name and a simple description or specifications.

MFR CODE

This is the code number for the part manufacturer. Table 7-11 lists the correspondence between code numbers and manufacturers.

MFR PART NUMBER

This is the manufacturer's individual part number. The OBD listed in this column indicates parts that had been manufactured to special ITHACO specifications (order by description).

QTY

This is the number of parts used.

7.3 ORDERING INFORMATION

In ordering parts from this parts list, the following information should be provided.

Model name (Ex.: 3961)

Instrument serial no. (Ex.: 4Q-27456)

ITHACO part no. (Ex.: 302-01241-00)

Name and description (Ex.: Fuse, Cartridge: 3A, 250V)

Quantity (Ex.: 2)

Parts specified as pairs must always be ordered as a pair.

TABLE 7-1 REFERENCE DESIGNATORS AND ABBREVIATIONS

REFERENCE DESIGNATORS

AS	Assembly	P	Plug
ATT	Attenuator	PB	Printed Circuit Board
B	Fan, Motor	PC	Photocell
BT	Battery	PJ	Printed Circuit Jack
C	Capacitor	PL	Pilot Lamp
CV	Capacitor, variable	Q	Transistor, IC
D	Diode	R	Resistor
DS	Display	RN	Resistor, network
F	Fuse, Fuse Holder	RV	Resistor, variable
FL	Filter	S	Switch
H	Timer	T	Transformer
J	Jack, Receptacle	TH	Thermistor
K	Relay	TM	Terminal
L	Inductor	V	Vacuum Tube
M	Meter	W	Wire
MP	Miscellaneous Parts	X	Crystal (oscillator)
NE	Neon Lamp	Z	Network

ABBREVIATIONS

ASSY	Assembly	PLSTC	Plastic
CAB	Carbon	POLY	Polyester, Polystyrene
CAP	Capacitor	PWR	Power
CER	Ceramic	RECPT	Receptacle
CONN	Connector	RECT	Rectifier
DIP	Dual in line	RES	Resistor
ELECT	Electrical, electrolytic	SEG	Segment
FXD	Fixed	SI	Silicon
LED	Light emitting diode	SIP	Single in line
MET	Metal (film)	SW	Switch
MF	Metalized film	TA	Tantalum
NUM	Numerical	VAR	Variable
PC	Printed Circuit	WW	Wirewound

(NOTE)

Components such as IC sockets, heat sings and fuse clips are sometimes indicated by a suffixed (') after the reference designator for the main part (i.e., the IC transistor or fuse).

(Example) Q9 Transistor
Q9' Heat sink

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
	352-02033-00	CABLE,PWR:	H022	UC-904-J11	1
	352-04532-00	FASTENER:PWR CABLE	K008	CB-3	1
	701-10026-00	HEX KEY WRENCH:(1.5)			1
R2	225-01005-00	RES.,FXD,MET:10.0M OHM,+/-1%,1/2W	S010	HRN1/2 10.0M OHM F	1
R3	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1

Table 7-2 ACCESSORIES

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
J4	314-03042-00	CONN,RCPT,METAL:6 CONTACT,FEMALE	H005	RM12BRD-6S	1
J5	240-03212-00	CONN,INLET,LINE FILTER:3A,250V	T017	ZUB 2203-00-F	1
MP2	330-10510-00	CONTACT,ELEC:FOR 18_24 AWG WIRE	N012	LDF-01T-1.3AS	7
P1	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P2	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P3	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P4	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P5	314-06530-00	CONN,BODY,PLUG:5 CONTACT	N007	163690-3	1
P6	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P7	314-06530-00	CONN,BODY,PLUG:5 CONTACT	N007	163690-3	1
P8	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P*	314-06815-00	CONTACT,ELEC:FOR 22_26AWG WIRE	N007	163691-1	46
PL1	304-00619-00	LED:RED	S014	GL2PR1	1
PL2	304-00619-00	LED:RED	S014	GL2PR1	1
PL3	304-00619-00	LED:RED	S014	GL2PR1	1
PL4	304-00619-00	LED:RED	S014	GL2PR1	1
PL5	304-00619-00	LED:RED	S014	GL2PR1	1
PL6	304-00619-00	LED:RED	S014	GL2PR1	1
RV1*	239-03511-00	DIAL:	N017	23M	1
RV2	239-08076-00	RES.,VAR,WW:10K OHM,5%	K010	M-22S1C 10K OHM	1
RV2*	239-03511-00	DIAL:	N017	23M	1
RV4	237-10071-00	RES.,VAR,CAB:5K OHM	T025	RV24YN15SB 5K OHM	1
S1	332-09511-00	SW,SLIDE:1A,125V	H013	MFS201N	1
S2	332-00238-00	SW,TOGGLE:3A,250V	H013	MTA206N	1
S3	332-09511-00	SW,SLIDE:1A,125V	H013	MFS201N	1
S4	332-50031-00	SW,VOLTAGE SELECTOR:D424401,424402	E001		1
S4'	314-08745-00	CONN,BODY,PLUG:8 CONTACT	M005	5239-08	1
S4"	314-08214-00	CONTACT,ELECT:FOR 18_24AWG WIRE	M005	5167TL	8
TM1	330-05346-00	BINDING POST,METAL	S009	Z-058	1

Table 7-3 CHASSIS WIRING

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
C101	207-06162-00	CAP.,FXD,POLY:220PF,+/-5%,150V	N004	C914SX2200J	1
C102	207-06162-00	CAP.,FXD,POLY:220PF,+/-5%,150V	N004	C914SX2200J	1
C103	207-06138-00	CAP.,FXD,POLY:160PF,+/-5%,150V	N004	C914SX1600J	1
C104	207-06138-00	CAP.,FXD,POLY:160PF,+/-5%,150V	N004	C914SX1600J	1
C105	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C106	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C107	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C108	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C109	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C110	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C111	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C112	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C113	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C114	207-06103-00	CAP.,FXD,POLY:120PF,+/-5%,150V	N004	C914SX1200J	1
C115	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C116	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C117	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C118	207-06201-00	CAP.,FXD,POLY:330PF,+/-5%,150V	N004	C914SX3300J	1
C119	207-06201-00	CAP.,FXD,POLY:330PF,+/-5%,150V	N004	C914SX3300J	1
C120	207-06308-00	CAP.,FXD,POLY:820PF,+/-5%,150V	N004	C914SX8200J	1
C121	206-00135-00	CAP.,FXD,MY:0.01UF,+/-10%,50V	S026	DEP-103K 50V	1
C122	206-00259-00	CAP.,FXD,MY:0.1UF,+/-10%,50V	S026	DEP-104K50V	1
C123	206-04114-00	CAP.,FXD,PLSTC:1UF,+/-10%,200V	S002	TME-105K200A	1
C124	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C125	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C126	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C127	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C128	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C129	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C130	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C131	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C132	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C133	206-06541-00	CAP.,FXD,MF:2.2UF,+/-10%,100V	M003	FNX-HS1003-225K	1
C134	206-06524-00	CAP.,FXD,MF:1UF,+/-10%,100V	M003	FNX-HS1003-105K	1
C135	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
CV101	219-01562-00	CAP.,VAR,PLSTC:1.4PF_5.5PF,250V	H002	2222 808 11558	1
CV102	219-01562-00	CAP.,VAR,PLSTC:1.4PF_5.5PF,250V	H002	2222 808 11558	1
D101	160-00137-00	DIODE:SI	T004	1S1588	1
D102	160-00137-00	DIODE:SI	T004	1S1588	1
D103	160-00137-00	DIODE:SI	T004	1S1588	1
D104	160-00137-00	DIODE:SI	T004	1S1588	1
D105	160-00137-00	DIODE:SI	T004	1S1588	1
D106	160-00137-00	DIODE:SI	T004	1S1588	1
D107	160-00137-00	DIODE:SI	T004	1S1588	1
D108	160-00137-00	DIODE:SI	T004	1S1588	1

Table 7-4 PSD, TC & OUTPUT CKT

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
D109	160-00137-00	DIODE:SI	T004	1S1588	1
J2	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
J3	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
J4	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
J5	314-03433-00	CONN,RCPT,TOP:5 CONTACT,FEMALE	N007	163680-3	1
PP	330-01049-00	TERMINAL,PIN:	E012	LC-2-G (YELLOW)	4
FB	340-10293-00	P.C.BOARD:NP-10293,D******	E005	0BD	1
Q101	134-10521-00	IC:C-MOS	H001	MB84052B	1
Q102	134-10521-00	IC:C-MOS	H001	MB84052B	1
Q103	110-04550-00	FET,DUAL:	N004	UPA70A	1
Q104	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q105	110-04550-00	FET,DUAL:	N004	UPA70A	1
Q106	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q107	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q108	122-02011-00	IC:QUAD,VOLTAGE COMPARATOR	S003	NJM2901N	1
R101	224-02371-00	RES.,FXD,MET:2.37K OHM,+/-1%,1/4W	H002	MR-25 2.37K OHM F	1
R102	224-07681-00	RES.,FXD,MET:7.68K OHM,+/-1%,1/4W	H002	MR-25 7.68K OHM F	1
R103	224-04222-00	RES.,FXD,MET:42.2K OHM,+/-1%,1/4W	H002	MR-25 42.2K OHM F	1
R104	224-02371-00	RES.,FXD,MET:2.37K OHM,+/-1%,1/4W	H002	MR-25 2.37K OHM F	1
R105	224-07681-00	RES.,FXD,MET:7.68K OHM,+/-1%,1/4W	H002	MR-25 7.68K OHM F	1
R106	224-04222-00	RES.,FXD,MET:42.2K OHM,+/-1%,1/4W	H002	MR-25 42.2K OHM F	1
R107	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R108	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R109	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R110	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R111	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R112	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R113	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R114	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R115	224-03742-00	RES.,FXD,MET:37.4K OHM,+/-1%,1/4W	H002	MR-25 37.4K OHM F	1
R116	224-01272-00	RES.,FXD,MET:12.7K OHM,+/-1%,1/4W	H002	MR-25 12.7K OHM F	1
R117	224-01272-00	RES.,FXD,MET:12.7K OHM,+/-1%,1/4W	H002	MR-25 12.7K OHM F	1
R118	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R119	224-01822-00	RES.,FXD,MET:18.2K OHM,+/-1%,1/4W	H002	MR-25 18.2K OHM F	1
R120	224-01822-00	RES.,FXD,MET:18.2K OHM,+/-1%,1/4W	H002	MR-25 18.2K OHM F	1
R121	224-01822-00	RES.,FXD,MET:18.2K OHM,+/-1%,1/4W	H002	MR-25 18.2K OHM F	1
R122	225-07873-00	RES.,FXD,MET:787K OHM,+/-1%,1/2W	K013	SN14K2H 787K OHM F	1
R123	225-06653-00	RES.,FXD,MET:665K OHM,+/-1%,1/2W	K013	SN14K2H 665K OHM F	1
R124	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R125	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R126	225-03323-00	RES.,FXD,MET:332K OHM,+/-1%,1/2W	K013	SN14K2H 332K OHM F	1
R127	224-06812-00	RES.,FXD,MET:68.1K OHM,+/-1%,1/4W	H002	MR-25 68.1K OHM F	1
R128	225-03653-00	RES.,FXD,MET:365K OHM,+/-1%,1/2W	K013	SN14K2H 365K OHM F	1
R129	224-02211-00	RES.,FXD,MET:2.21K OHM,+/-1%,1/4W	H002	MR-25 2.21K OHM F	1
R130	224-03400-00	RES.,FXD,MET:340 OHM,+/-1%,1/4W	H002	MR-25 340 OHM F	1

Table 7-4 PSD, TC & OUTPUT CKT (cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
R131	224-03400-00	RES.,FXD,MET:340 OHM,+/-1%,1/4W	H002	MR-25 340 OHM F	1
R132	224-03742-00	RES.,FXD,MET:37.4K OHM,+/-1%,1/4W	H002	MR-25 37.4K OHM F	1
R133	224-02741-00	RES.,FXD,MET:2.74K OHM,+/-1%,1/4W	H002	MR-25 2.74K OHM F	1
R134	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R135	225-08253-00	RES.,FXD,MET:825K OHM,+/-1%,1/2W	K013	SN14K2H 825K OHM F	1
R136	225-06983-00	RES.,FXD,MET:698K OHM,+/-1%,1/2W	K013	SN14K2H 698K OHM F	1
R137	224-02213-00	RES.,FXD,MET:221K OHM,+/-1%,1/4W	H002	MR-25 221K OHM F	1
R138	225-04533-00	RES.,FXD,MET:453K OHM,+/-1%,1/2W	K013	SN14K2H 453K OHM F	1
R139	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R140	224-01052-00	RES.,FXD,MET:10.5K OHM,+/-1%,1/4W	H002	MR-25 10.5K OHM F	1
R141	224-01821-00	RES.,FXD,MET:1.82K OHM,+/-1%,1/4W	H002	MR-25 1.82K OHM F	1
R142	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R143	224-01821-00	RES.,FXD,MET:1.82K OHM,+/-1%,1/4W	H002	MR-25 1.82K OHM F	1
R144	224-01821-00	RES.,FXD,MET:1.82K OHM,+/-1%,1/4W	H002	MR-25 1.82K OHM F	1
R145	224-03481-00	RES.,FXD,MET:3.48K OHM,+/-1%,,1/4W	H002	MR-25 3.48K OHM F	1
R146	224-01152-00	RES.,FXD,MET:11.5K OHM,+/-1%,1/4W	H002	MR-25 11.5K OHM F	1
R147	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R148	224-03481-00	RES.,FXD,MET:3.48K OHM,+/-1%,,1/4W	H002	MR-25 3.48K OHM F	1
R149	224-01152-00	RES.,FXD,MET:11.5K OHM,+/-1%,1/4W	H002	MR-25 11.5K OHM F	1
R150	224-01821-00	RES.,FXD,MET:1.82K OHM,+/-1%,1/4W	H002	MR-25 1.82K OHM F	1
R151	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R152	224-01302-00	RES.,FXD,MET:13.0K OHM,+/-1%,1/4W	H002	MR-25 13.0K OHM	1
R153	224-01302-00	RES.,FXD,MET:13.0K OHM,+/-1%,1/4W	H002	MR-25 13.0K OHM	1
R154	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R155	224-06651-00	RES.,FXD,MET:6.51K OHM,+/-1%,1/4W	H002	MR-25 6.51K OHM F	1
R156	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R158	225-06490-00	RES.,FXD,MET:649 OHM,+/-1%,1/2W	K013	SN14K2H 649 OHM F	1
RV101	238-10238-00	RES.,VAR,CERMET:50 OHM	K010	ET-6P 50 OHM	1
RV102	238-10238-00	RES.,VAR,CERMET:50 OHM	K010	ET-6P 50 OHM	1
RV103	238-10327-00	RES.,VAR,CERMET:50K OHM	K010	ET-6P 50K OHM	1
RV104	238-10262-00	RES.,VAR,CERMET:500 OHM	K010	ET-6P 500 OHM	1
RV105	238-10271-00	RES.,VAR,CERMET:1K OHM	K010	ET-6P 1K OHM	1
RV106	238-10335-00	RES.,VAR,CERMET:100K OHM	K010	ET-6P 100K OHM	1
S101	332-16851-00	SW,ROTARY:D421637-2	T027	OBD RP7X 3-3-8 BG	1
S102	332-18137-00	SW,PUSH:	I004	K2215L	1
S102'	359-03554-00	BUTTON,PUSH SW:GREY	I004	8951	2
S102"	359-06014-00	SPACER,PUSH SW:3 MILLI LONG	I004	3 MILLI-SPACER	4

Table 7-4 PSD, TC & OUTPUT CKT (cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
C201	206-04114-00	CAP.,FXD,PLSTC:1UF,+/-10%,200V	S002	TME-105K200A	1
C202	207-06150-00	CAP.,FXD,PLSTC:150PF,+/-5%,150V	N004	CQ14SX1500J	1
C203	203-00093-00	CAP.,FXD,CER:150PF,+/-10%,50V	M002	DD104B151K50V02	1
C204	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C205	206-00101-00	CAP.,FXD,MY:0.0056UF,+/-10%,50V	S026	DEP-562K 50V	1
C206	206-04114-00	CAP.,FXD,PLSTC:1UF,+/-10%,200V	S002	TME-105K200A	1
C207	206-00259-00	CAP.,FXD,MY:0.1UF,+/-10%,50V	S026	DEP-104K50V	1
C208	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C209	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C210	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C211	206-00135-00	CAP.,FXD,MY:0.01UF,+/-10%,50V	S026	DEP-103K 50V	1
C212	202-02032-00	CAP,FXD,TA:4.7UF,+/-20%,16V	N004	CS15E1C4R7M	1
C213	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C214	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C215	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C216	202-02032-00	CAP,FXD,TA:4.7UF,+/-20%,16V	N004	CS15E1C4R7M	1
C217	202-02032-00	CAP,FXD,TA:4.7UF,+/-20%,16V	N004	CS15E1C4R7M	1
C218	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C219	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C220	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C221	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C222	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C223	207-06286-00	CAP.,FXD,PLSTC:680PF,+/-5%,150V	N004	CQ14SX6800J	1
C224	206-04114-00	CAP.,FXD,PLSTC:1UF,+/-10%,200V	S002	TME-105K200A	1
C225	200-60271-00	CAP.,FXD,ELECT:100UF,+/-20%,16V	M001	CEUSM1C101	1
C226	200-60271-00	CAP.,FXD,ELECT:100UF,+/-20%,16V	M001	CEUSM1C101	1
C227	206-00151-00	CAP.,FXD,MY:0.015UF,+/-10%,50V	S026	DEP-153K 50V	1
C228	203-00093-00	CAP.,FXD,CER:150PF,+/-10%,50V	M002	DD104B151K50V02	1
C229	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C230	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C231	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C232	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C233	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C234	202-03055-00	CAP.,FXD,TA:4.7UF,+/-20%,25V	N004	CS15E1E4R7M	1
C235	202-03055-00	CAP.,FXD,TA:4.7UF,+/-20%,25V	N004	CS15E1E4R7M	1
C236	206-00259-00	CAP.,FXD,MY:0.1UF,+/-10%,50V	S026	DEP-104K50V	1
C237	206-04114-00	CAP.,FXD,PLSTC:1UF,+/-10%,200V	S002	TME-105K200A	1
C238	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C239	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C240	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C241	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C242	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C243	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C244	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C245	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1

Table 7-5 PLL-I & PLL-II CKT

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
C246	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C249	202-03055-00	CAP.,FXD,TA:4.7UF,+/-20%,25V	N004	CS15E1E4R7M	1
C250	202-03055-00	CAP.,FXD,TA:4.7UF,+/-20%,25V	N004	CS15E1E4R7M	1
D201	160-00137-00	DIODE:SI	T004	1S1588	1
D202	160-00137-00	DIODE:SI	T004	1S1588	1
D203	160-00137-00	DIODE:SI	T004	1S1588	1
D204	160-00137-00	DIODE:SI	T004	1S1588	1
D205	160-00137-00	DIODE:SI	T004	1S1588	1
D206	164-05412-00	DIODE,ZENER:SI,0.4W,9.41V_9.90V	N004	RD10EB2	1
D211	160-00137-00	DIODE:SI	T004	1S1588	1
D212	160-00137-00	DIODE:SI	T004	1S1588	1
D213	164-05170-00	DIODE,ZENER:SI,0.4W,4.55V_4.84V	N004	RD4.7EB2	1
J6	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
PP1	330-01049-00	TERMINAL,PIN:	E012	LC-2-G (YELLOW)	12
PP2	330-10013-00	TERMINAL,PIN:	N012	RT-03A-1.38	2
Q201	122-02011-00	IC:QUAD,VOLTAGE COMPARATOR	S003	NJM2901N	1
Q202	113-00388-00	TRANSISTOR:SI,NPN	M010	2SC828A-(Q)	1
Q203	134-00461-00	IC:C-MOS	H003	HD14046B	1
Q204	134-00070-00	IC:C-MOS	T004	TC4007UBP	1
Q205	134-05161-00	IC:C-MOS	T004	TC4516BP	1
Q206	134-00304-00	IC:C-MOS	T004	TC4030BP	1
Q207	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q208	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q209	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q210	134-00100-00	IC:C-MOS	T004	TC4010BP	1
Q211	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q212	122-02011-00	IC:QUAD,VOLTAGE COMPARATOR	S003	NJM2901N	1
Q213	134-00274-00	IC:C-MOS	T004	TC4027BP	1
Q214	134-00533-00	IC:C-MOS	T004	TC4053BP	1
Q215	120-04545-00	IC:OPERATIONAL AMPLIFIER	A007	LM318H	1
Q216	122-03513-00	IC:VOLTAGE COMPARATOR	N013	LM311H	1
Q217	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q218	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q219	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q220	134-00461-00	IC:C-MOS	H003	HD14046B	1
Q228	134-00118-00	IC:C-MOS	T004	TC4011BP	1
Q229	134-00533-00	IC:C-MOS	T004	TC4053BP	1
Q230	134-00533-00	IC:C-MOS	T004	TC4053BP	1
Q231	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q232	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q233	122-02011-00	IC:QUAD,VOLTAGE COMPARATOR	S003	NJM2901N	1
Q234	113-00388-00	TRANSISTOR:SI,NPN	M010	2SC828A-(Q)	1
Q235	112-00219-00	TRANSISTOR:SI,PNP	M010	2SA564-(Q)	1
Q236	110-00686-00	FET:	T004	2SK30ATM-Y	1
Q237	110-00686-00	FET:	T004	2SK30ATM-Y	1

Table 7-5 PLL-I & PLL-II CKT (cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
Q238	134-00533-00	IC:C-MOS	T004	TC4053BP	1
R201	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R202	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R203	224-02323-00	RES.,FXD,MET:232K OHM,+/-1%,1/4W	H002	MR-25 232K OHM F	1
R204	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R205	224-04991-00	RES.,FXD,MET:4.99K OHM,+/-1%,1/4W	H002	MR-25 4.99K OHM F	1
R206	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R207	224-02212-00	RES.,FXD,MET:22.1K OHM,+/-1%,1/4W	H002	MR-25 22.1K OHM F	1
R208	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R209	224-03010-00	RES.,FXD,MET:301 OHM,+/-1%,1/4W	H002	MR-25 301 OHM F	1
R210	225-06194-00	RES.,FXD,MET:6.19M OHM,+/-1%,1/2W	SC10	HRN1/2 6.19M OHM F	1
R211	224-03320-00	RES.,FXD,MET:332 OHM,+/-1%,1/4W	H002	MR-25 332 OHM F	1
R212	224-02491-00	RES.,FXD,MET:2.49K OHM,+/-1%,1/4W	H002	MR-25 2.49K OHM F	1
R213	224-02491-00	RES.,FXD,MET:2.49K OHM,+/-1%,1/4W	H002	MR-25 2.49K OHM F	1
R214	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R215	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R216	224-02003-00	RES.,FXD,MET:200K OHM,+/-1%,1/4W	H002	MR-25 200K OHM F	1
R217	224-02552-00	RES.,FXD,MET:25.5K OHM,+/-1%,1/4W	H002	MR-25 25.5K OHM F	1
R218	224-02001-00	RES.,FXD,MET:2.00K OHM,+/-1%,1/4W	H002	MR-25 2.00K OHM F	1
R219	224-01101-00	RES.,FXD,MET:1.10K OHM,+/-1%,1/4W	H002	MR-25 1.10K OHM F	1
R220	224-01101-00	RES.,FXD,MET:1.10K OHM,+/-1%,1/4W	H002	MR-25 1.10K OHM F	1
R221	224-01372-00	RES.,FXD,MET:13.7K OHM,+/-1%,1/4W	H002	MR-25 13.7K OHM F	1
R222	224-07501-00	RES.,FXD,MET:7.50K OHM,+/-1%,1/4W	H002	MR-25 7.50K OHM F	1
R223	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R224	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R225	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R226	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R227	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R228	224-04991-00	RES.,FXD,MET:4.99K OHM,+/-1%,1/4W	H002	MR-25 4.99K OHM F	1
R229	224-04320-00	RES.,FXD,MET:432 OHM,+/-1%,1/4W	H002	MR-25 432 OHM F	1
R230	224-01502-00	RES.,FXD,MET:15.0K OHM,+/-1%,1/4W	H002	MR-25 15.0K OHM F	1
R231	224-01101-00	RES.,FXD,MET:1.10K OHM,+/-1%,1/4W	H002	MR-25 1.10K OHM F	1
R232	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R233	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R234	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R235	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R236	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R237	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R238	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R239	224-01821-00	RES.,FXD,MET:1.82K OHM,+/-1%,1/4W	H002	MR-25 1.82K OHM F	1
R240	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R241	224-02492-00	RES.,FXD,MET:24.9K OHM,+/-1%,1/4W	H002	MR-25 24.9K OHM F	1
R242	224-02152-00	RES.,FXD,MET:21.5K OHM,+/-1%,1/4W	H002	MR-25 21.5K OHM F	1
R243	224-02671-00	RES.,FXD,MET:2.67K OHM,+/-1%,1/4W	H002	MR-25 2.67K OHM F	1
R244	224-01502-00	RES.,FXD,MET:15.0K OHM,+/-1%,1/4W	H002	MR-25 15.0K OHM F	1

Table 7-5 PLL-I & PLL-II CKT (cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
R245	224-01502-00	RES.,FXD,MET:15.0K OHM,+/-1%,1/4W	H002	MR-25 15.0K OHM F	1
R246	224-01502-00	RES.,FXD,MET:15.0K OHM,+/-1%,1/4W	H002	MR-25 15.0K OHM F	1
R247	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R248	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R249	224-01501-00	RES.,FXD,MET:1.50K OHM,+/-1%,1/4W	H002	MR-25 1.50K OHM F	1
R250	225-07504-00	RES.,FXD,MET:7.50M OHM,+/-1%,1/2W	S010	HRN1/2 7.50M OHM F	1
R251	224-01743-00	RES.,FXD,MET:174K OHM,+/-1%,1/4W	H002	MR-25 174K OHM F	1
R252	225-07323-00	RES.,FXD,MET:732K OHM,+/-1%,1/2W	K013	SN14K2H 732K OHM F	1
R253	224-04642-00	RES.,FXD,MET:46.4K OHM,+/-1%,1/4W	H002	MR-25 46.4K OHM F	1
R254	224-02491-00	RES.,FXD,MET:2.49K OHM,+/-1%,1/4W	H002	MR-25 2.49K OHM F	1
R255	224-02001-00	RES.,FXD,MET:2.00K OHM,+/-1%,1/4W	H002	MR-25 2.00K OHM F	1
R256	224-02001-00	RES.,FXD,MET:2.00K OHM,+/-1%,1/4W	H002	MR-25 2.00K OHM F	1
R257	224-07501-00	RES.,FXD,MET:7.50K OHM,+/-1%,1/4W	H002	MR-25 7.50K OHM F	1
R258	224-01052-00	RES.,FXD,MET:10.5K OHM,+/-1%,1/4W	H002	MR-25 10.5K OHM F	1
R259	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R260	224-03013-00	RES.,FXD,MET:301K OHM,+/-1%,1/4W	H002	MR-25 301K OHM F	1
R261	224-01402-00	RES.,FXD,MET:14.0K OHM,+/-1%,1/4W	H002	MR-25 14.0K OHM F	1
R262	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R263	226-27529-00	RES.,FXD,MET:3.3M OHM,+/-5%,1/2W	N015	RP-23H 3.3M OHM J	1
R264	226-27529-00	RES.,FXD,MET:3.3M OHM,+/-5%,1/2W	N015	RP-23H 3.3M OHM J	1
R265	224-02211-00	RES.,FXD,MET:2.21K OHM,+/-1%,1/4W	H002	MR-25 2.21K OHM F	1
R266	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R267	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R268	224-01211-00	RES.,FXD,MET:1.21K OHM,+/-1%,1/4W	H002	MR-25 1.21K OHM F	1
R269	224-07151-00	RES.,FXD,MET:7.15K OHM,+/-1%,1/4W	H002	MR-25 7.15K OHM F	1
R270	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R271	224-05112-00	RES.,FXD,MET:51.1K OHM,+/-1%,1/4W	H002	MR-25 51.1K OHM F	1
R272	224-01500-00	RES.,FXD,MET:150 OHM,+/-1%,1/4W	H002	MR-25 150 OHM F	1
R273	224-01500-00	RES.,FXD,MET:150 OHM,+/-1%,1/4W	H002	MR-25 150 OHM F	1
R274	224-01472-00	RES.,FXD,MET:14.7K OHM,+/-1%,1/4W	H002	MR-25 14.7K OHM F	1
R275	224-01472-00	RES.,FXD,MET:14.7K OHM,+/-1%,1/4W	H002	MR-25 14.7K OHM F	1
R276	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R277	224-01821-00	RES.,FXD,MET:1.82K OHM,+/-1%,1/4W	H002	MR-25 1.82K OHM F	1
R278	224-06491-00	RES.,FXD,MET:6.49K OHM,+/-1%,1/4W	H002	MR-25 6.49K OHM F	1
R279	224-08451-00	RES.,FXD,MET:8.45K OHM,+/-1%,1/4W	H002	MR-25 8.45K OHM F	1
R280	224-03019-00	RES.,FXD,MET:30.1 OHM,+/-1%,1/4W	H002	MR-25 30.1 OHM F	1
R281	224-03019-00	RES.,FXD,MET:30.1 OHM,+/-1%,1/4W	H002	MR-25 30.1 OHM F	1
R282	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R283	224-01003-00	RES.,FXD,MET:100K OHM,+/-1%,1/4W	H002	MR-25 100K OHM F	1
R284	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R285	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R286	224-03321-00	RES.,FXD,MET:3.32K OHM,+/-1%,1/4W	H002	MR-25 3.32K OHM F	1
R287	226-27570-00	RES.,FXD,MET:1.5M OHM,+/-5%,1/2W	N015	RP-23H 1.5M OHM J	1
R288	224-04641-00	RES.,FXD,MET:4.64K OHM,+/-1%,1/4W	H002	MR-25 4.64K OHM F	1
R289	226-27561-00	RES.,FXD,MET:2.7M OHM,+/-5%,1/2W	N015	RP-23H 2.7M OHM J	1

Table 7-5 PLL-I & PLL-II CKT (cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
R290	224-01872-00	RES.,FXD,MET:18.7K OHM,+/-1%,1/4W	H002	MR-25 18.7K OHM F	1
R291	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R292	224-01502-00	RES.,FXD,MET:15.0K OHM,+/-1%,1/4W	H002	MR-25 15.0K OHM F	1
RV201	238-10351-00	RES.,VAR,CERMET:500K OHM	K010	ET-6P 500K OHM	1
RV202	238-10351-00	RES.,VAR,CERMET:500K OHM	K010	ET-6P 500K OHM	1
S201	332-12242-00	SW,PUSH:	I004	K4215L	1
S201'	359-03554-00	BUTTON,PUSH SW:GREY	I004	8951	3
S201"	359-03520-00	BUTTON,PUSH SW:IVORY	I004	8201	1
S201*	359-06014-00	SPACER,PUSH SW:3 MILLI LONG	I004	3 MILLI-SPACER	4

Table 7-5 PLL-I & PLL-II CKT (cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
C301	206-04017-00	CAP.,FXD,PLSTC:0.1UF,+/-10%,200V	S002	TME-104K200A	1
C302	200-50828-00	CAP.,FXD,ELECT:470UF,+/-20%,50V	M001	CEUST1H471	1
C303	200-50828-00	CAP.,FXD,ELECT:470UF,+/-20%,50V	M001	CEUST1H471	1
C304	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C305	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C306	200-50445-00	CAP.,FXD,ELECT:220UF,+/-20%,25V	M001	CEUST1E221	1
C307	200-50445-00	CAP.,FXD,ELECT:220UF,+/-20%,25V	M001	CEUST1E221	1
C308	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C309	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C310	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C311	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
D301	162-00012-00	DIODE,PWR,RECT,BRIDGE:1A,100V	S005	S1RBA10 (1S-2371A)	1
D302	164-05200-00	DIODE,ZENER:SI,0.4W,4.94V_5.20V	N004	RD5.1EB2	1
D303	164-05200-00	DIODE,ZENER:SI,0.4W,4.94V_5.20V	N004	RD5.1EB2	1
D304	160-00170-00	DIODE,PWR RECT:1A,200V	T004	1S1886	1
D305	160-00170-00	DIODE,PWR RECT:1A,200V	T004	1S1886	1
D306	160-00170-00	DIODE,PWR RECT:1A,200V	T004	1S1886	1
D307	160-00170-00	DIODE,PWR RECT:1A,200V	T004	1S1886	1
J7	314-03433-00	CONN,RCPT,TOP:5 CONTACT,FEMALE	N007	163680-3	1
J8	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
FP1	330-01049-00	TERMINAL,PIN:	E012	LC-2-G (YELLOW)	5
FP2	330-10013-00	TERMINAL,PIN:	N012	RT-03A-1.3B	3
Q301	126-02434-00	IC:VOLTAGE REGULATOR	S003	NJM7815A	1
Q302	126-02442-00	IC:VOLTAGE REGULATOR	S003	NJM7915A	1
Q303	126-02434-00	IC:VOLTAGE REGULATOR	S003	NJM7815A	1
Q304	126-02442-00	IC:VOLTAGE REGULATOR	S003	NJM7915A	1
Q'	354-01028-00	SPEACER,TRSNSISTOR:	T004	AC316A	4
R301	224-04759-00	RES.,FXD,MET:47.5 OHM,+/-1%,1/4W	H002	MR-25 47.5 OHM F	1
R302	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R303	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R304	225-03019-00	RES.,FXD,MET:30.1 OHM,+/-1%,1/2W	K013	SN14K2H 30.1 OHM F	1
R305	225-03019-00	RES.,FXD,MET:30.1 OHM,+/-1%,1/2W	K013	SN14K2H 30.1 OHM F	1

Table 7-6 POWER SUPPLY CKT

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
C1	206-01212-00	CAP.,FXD,MF:0.2UF,+/-1%,200V	E003	2MFO 0.2UF F	1
C2	206-01212-00	CAP.,FXD,MF:0.2UF,+/-1%,200V	E003	2MFO 0.2UF F	1
C3	202-02075-00	CAP.,FXD,TA:22UF,+/-20%,16V	N004	CS15E1C220M	1
C4	202-02075-00	CAP.,FXD,TA:22UF,+/-20%,16V	N004	CS15E1C220M	1
C5	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C6	207-05603-00	CAP.,FXD,PCLY:47PF,+/-10%,150V	N004	CQ14SX0470K	1
C7	207-06243-00	CAP.,FXD,PLSTC:470PF,+/-5%,150V	N004	CQ14SX4700J	1
C8	202-02075-00	CAP.,FXD,TA:22UF,+/-20%,16V	N004	CS15E1C220M	1
C9	202-02075-00	CAP.,FXD,TA:22UF,+/-20%,16V	N004	CS15E1C220M	1
C10	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C11	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C12	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C13	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C14	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C15	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C16	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C17	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C18	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C19	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C20	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C21	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C22	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C23	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C24	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C25	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
C26	202-03071-00	CAP.,FXD,TA:10UF,+/-20%,25V	N004	CS15E1E100M	1
D1	164-05412-00	DIODE,ZENER:SI,0.4W,9.41V_9.90V	N004	RD10EB2	1
D2	164-05412-00	DIODE,ZENER:SI,0.4W,9.41V_9.90V	N004	RD10EB2	1
D3	160-00137-00	DIODE:SI	T004	1S1588	1
D4	160-00137-00	DIODE:SI	T004	1S1588	1
J1	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
MP1	330-10013-00	TERMINAL,PIN:	N012	RT-03A-1.38	2
MP2	330-01049-00	TERMINAL,PIN:	E012	LC-2-G (YELLOW)	10
PB1	340-20494-03	P.C.BOARD:NP20494C,038751	E005	OBD	1
Q1	110-00694-00	FET:	T004	2SK30ATM-GR	1
Q2	110-00694-00	FET:	T004	2SK30ATM-GR	1
Q3	110-00694-00	FET:	T004	2SK30ATM-GR	1
Q4	110-00694-00	FET:	T004	2SK30ATM-GR	1
Q5	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q6	120-20044-00	IC:OPERATIONAL AMPLIFIER	T022	TL072CP	1
Q7	120-06092-00	IC:OPERATIONAL AMPLIFIER	N013	LF412CN	1
Q8	122-02011-00	IC:QUAD,VOLTAGE COMPARATOR	S003	NJM2901N	1
Q9	126-02345-00	IC:VOLTAGE REGULATOR	S003	NJM78L15A	1
Q10	126-02337-00	IC:VOLTAGE REGULATOR	S003	NJM79L15A	1
R1	224-01820-00	RES.,FXD,MET:182 OHM,+/-1%,1/4W	H002	MR-25 182 OHM F	1

Table 7-7 SIGNAL AMPLIFIER CKT

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
R2	225-01005-00	RES.,FXD,MET:10.0M OHM,+/-1%,1/2W	S010	HRN1/2 10.0M OHM F	1
R3	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1
R4	224-03012-00	RES.,FXD,MET:30.1K OHM,+/-1%,1/4W	H002	MR-25 30.1K OHM F	1
R5	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1
R6	225-01005-00	RES.,FXD,MET:10.0M OHM,+/-1%,1/2W	S010	HRN1/2 10.0M OHM F	1
R7	224-01820-00	RES.,FXD,MET:182 OHM,+/-1%,1/4W	H002	MR-25 182 OHM F	1
R8	226-02496-00	RES.,FXD,MET:2K OHM,+/-0.5%,1/4W	H002	RP-42A 2K OHM D	1
R9	226-02925-00	RES.,FXD,MET:9.09K OHM,+/-0.5%,1/4W	N015	RP-42A 9.09K OHM D	1
R10	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R11	226-02925-00	RES.,FXD,MET:9.09K OHM,+/-0.5%,1/4W	N015	RP-42A 9.09K OHM D	1
R12	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R13	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R14	224-04321-00	RES.,FXD,MET:4.32K OHM,+/-1%,1/4W	H002	MR-25 4.32K OHM F	1
R15	224-05111-00	RES.,FXD,MET:5.11K OHM,+/-1%,1/4W	H002	MR-25 5.11K OHM F	1
R16	224-05111-00	RES.,FXD,MET:5.11K OHM,+/-1%,1/4W	H002	MR-25 5.11K OHM F	1
R17	224-04321-00	RES.,FXD,MET:4.32K OHM,+/-1%,1/4W	H002	MR-25 4.32K OHM F	1
R18	224-05111-00	RES.,FXD,MET:5.11K OHM,+/-1%,1/4W	H002	MR-25 5.11K OHM F	1
R19	224-05111-00	RES.,FXD,MET:5.11K OHM,+/-1%,1/4W	H002	MR-25 5.11K OHM F	1
R20	226-05037-00	RES.,FXD,MET:200K OHM,+/-0.5%,1/4W	N015	RP-42A 200K OHM D	1
R21	226-03182-00	RES.,FXD,MET:20K OHM,+/-0.5%,1/4W	N015	RP-42A 20K OHM D	1
R22	224-01963-00	RES.,FXD,MET:196K OHM,+/-1%,1/4W	H002	MR-25 196K OHM F	1
R23	224-01962-00	RES.,FXD,MET:19.6K OHM,+/-1%,1/4W	H002	MR-25 19.6K OHM F	1
R24	224-04322-00	RES.,FXD,MET:43.2K OHM,+/-1%,1/4W	H002	MR-25 43.2K OHM F	1
R25	226-07510-00	RES.,FXD,MET:432K OHM,+/-0.5%,1/2W	N015	RP-23A 432K OHM D	1
R26	226-05321-00	RES.,FXD,MET:43.2K OHM,+/-0.5%,1/4W	N015	RP-42A 43.2K OHM D	1
R27	226-02747-00	RES.,FXD,MET:4.32K OHM,+/-0.5%,1/4W	N015	RP-42A 4.32K OHM D	1
R28	224-04322-00	RES.,FXD,MET:43.2K OHM,+/-1%,1/4W	H002	MR-25 43.2K OHM F	1
R29	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R30	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R31	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R32	224-02002-00	RES.,FXD,MET:20.0K OHM,+/-1%,1/4W	H002	MR-25 20.0K OHM F	1
R33	224-04322-00	RES.,FXD,MET:43.2K OHM,+/-1%,1/4W	H002	MR-25 43.2K OHM F	1
R34	224-01001-00	RES.,FXD,MET:1.00K OHM,+/-1%,1/4W	H002	MR-25 1.00K OHM F	1
R35	224-08250-00	RES.,FXD,MET:825 OHM,+/-1%,1/4W	H002	MR-25 825 OHM F	1
R36	224-02430-00	RES.,FXD,MET:243 OHM,+/-1%,1/4W	H002	MR-25 243 OHM F	1
R37	224-02430-00	RES.,FXD,MET:243 OHM,+/-1%,1/4W	H002	MR-25 243 OHM F	1
R38	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1
R39	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1
R40	224-03013-00	RES.,FXD,MET:301K OHM,+/-1%,1/4W	H002	MR-25 301K OHM F	1
R41	224-03013-00	RES.,FXD,MET:301K OHM,+/-1%,1/4W	H002	MR-25 301K OHM F	1
RV1	238-10289-00	RES.,VAR,CERMET:2K OHM	K010	ET-6P 2K OHM	1
RV2	238-10301-00	RES.,VAR,CERMET:10K OHM	K010	ET-6P 10K OHM	1
RV3	238-10271-00	RES.,VAR,CERMET:1K OHM	K010	ET-6P 1K OHM	1
S1	332-16843-00	SW,ROTARY:0421636-2	T027	08D RP7X 2-4-5 BG	1

Table 7-7 SIGNAL AMPLIFIER CKT (Cont)

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
J1	310-00142-00	CONN,RCPT:BNC,FEMALE	S009	BNC-147	1
J2	310-00142-00	CONN,RCPT:BNC,FEMALE	S009	BNC-147	1
P1	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P1*	314-06815-00	CONTACT,ELEC:FOR 22-26AWG WIRE	N007	163691-1	5
P2	314-06581-00	CONN,BODY,PLUG:10 CONTACT	N007	163690-8	1
P2*	314-06815-00	CONTACT,ELEC:FOR 22-26AWG WIRE	N007	163691-1	4
P3	314-06530-00	CONN,BODY,PLUG:5 CONTACT	N007	163690-3	1
P3*	314-06815-00	CONTACT,ELEC:FOR 22-26AWG WIRE	N007	163691-1	3
RV1	239-08050-00	RES.,VAR,WW:2K OHM	K010	M-22S10 2K OHM	1
RV1*	239-03511-00	DIAL:	N017	23M	1
S1	332-00017-00	SW,TOGGLE:6A,125V	H013	8A1011	1

Table 7-8 OVERALL CKT

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
C1	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C2	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C3	203-00131-00	CAP.,FXD,CER:1000PF,+100%-0%,50V	M002	DD104E102P50V02	1
C4	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C5	203-00514-00	CAP.,FXD,CER:0,047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C6	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C7	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C8	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C9	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C10	203-00131-00	CAP.,FXD,CER:1000PF,+100%-0%,50V	M002	DD104E102P50V02	1
C11	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C12	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C13	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C14	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C15	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C16	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C17	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C18	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C19	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C20	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C21	203-00514-00	CAP.,FXD,CER:0.047UF,+80%-20%,25V	M010	ECK-F1E473ZV	1
C22	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
C23	203-00085-00	CAP.,FXD,CER:100PF,+/-10%,50V	M002	DD104B101K50V02	1
D1	160-00137-00	DIODE:SI	T004	1S1588	1
D2	160-00137-00	DIODE:SI	T004	1S1588	1
D3	160-00137-00	DIODE:SI	T004	1S1588	1
D4	160-00137-00	DIODE:SI	T004	1S1588	1
D5	160-00137-00	DIODE:SI	T004	1S1588	1
D6	160-00137-00	DIODE:SI	T004	1S1588	1
D7	164-05200-00	DIODE,ZENER:SI,0.4W,4.94V_5.20V	N004	RD5.1EB2	1
J1	314-03484-00	CONN,RCPT,TOP:10 CONTACT,FEMALE	N007	163680-8	1
MP2	330-01049-00	TERMINAL,PIN:	E012	LC-2-G (YELLOW)	5
PB	340-30397-01	P.C.BOARD:NP-30397A,0312069	E005	OBD	1
Q1	120-20516-00	IC:OPERATIONAL AMPLIFIER	P004	OP-16FJ	1
Q2	120-04529-00	IC:OPERATIONAL AMPLIFIER	N013	LM308H	1
Q3	110-00694-00	FET:	T004	2SK30ATM-GR	1
Q4	110-00694-00	FET:	T004	2SK30ATM-GR	1
Q5	120-04529-00	IC:OPERATIONAL AMPLIFIER	N013	LM308H	1
Q6	120-20516-00	IC:OPERATIONAL AMPLIFIER	P004	OP-16FJ	1
Q7	115-95019-00	TRANSISTOR,TWIN:D424011	I003	ITS-1276	1
Q8	115-95019-00	TRANSISTOR,TWIN:D424011	I003	ITS-1276	1
Q9	120-20028-00	IC:OPERATIONAL AMPLIFIER	T022	TL082CP	1
R1	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R2	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R3	224-03929-00	RES.,FXD,MET:39.2 OHM,+/-1%,1/4W	H002	MR-25 39.2 OHM F	1

Table 7-9 MAIN BOARD CKT

CKT NO.	NF PART NO.	NAME AND DESCRIPTION	MFR CODE	MFR PART NUMBER	QTY
R4	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R5	224-03831-00	RES.,FXD,MET:3.83K OHM,+/-1%,1/4W	H002	MR-25 3.83K OHM F	1
R6	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R7	224-02001-00	RES.,FXD,MET:2.00K OHM,+/-1%,1/4W	H002	MR-25 2.00K OHM F	1
R8	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R9	224-01002-00	RES.,FXD,MET:10.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R10	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R11	224-01002-00	RES.,FXD,ME|:.0.0K OHM,+/-1%,1/4W	H002	MR-25 10.0K OHM F	1
R12	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1
R13	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R14	224-02492-00	RES.,FXD,MET:24.9K OHM,+/-1%,,1/4W	H002	MR-25 24.9K OHM F	1
R15	224-02009-00	RES.,FXD,MET:20.0 OHM,+/-1%,1/4W	H002	MR-25 20.0 OHM F	1
R16	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R17	224-04992-00	RES.,FXD,MET:49.9K OHM,+/-1%,1/4W	H002	MR-25 49.9K OHM F	1
R18	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R19	225-04993-00	RES.,FXD,MET:499K OHM,+/-1%,1/2W	K013	SN14K2H 499K OHM F	1
R20	225-03323-00	RES.,FXD,MET:332K OHM,+/-1%,1/2W	K013	SN14K2H 332K OHM F	1
R21	224-03929-00	RES.,FXD,MET:39.2 OHM,+/-1%,1/4W	H002	MR-25 39.2 OHM F	1
R22	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R23	224-03831-00	RES.,FXD,MET:3.83K OHM,+/-1%,1/4W	H002	MR-25 3.83K OHM F	1
R24	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R25	224-03010-00	RES.,FXD,MET:301 OHM,+/-1%,1/4W	H002	MR-25 301 OHM F	1
R26	224-01503-00	RES.,FXD,MET:150K OHM,+/-1%,1/4W	H002	MR-25 150K OHM F	1
R27	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R28	224-04991-00	RES.,FXD,MET:4.99K OHM,+/-1%,1/4W	H002	MR-25 4.99K OHM F	1
R29	224-01000-00	RES.,FXD,MET:100 OHM,+/-1%,1/4W	H002	MR-25 100 OHM F	1
R30	224-05622-00	RES.,FXD,MET:56.2K OHM,+/-1%,1/4W	H002	MR-25 56.2K OHM F	1
R31	224-04222-00	RES.,FXD,MET:42.2K OHM,+/-1%,1/4W	H002	MR-25 42.2K OHM F	1
R32	224-03831-00	RES.,FXD,MET:3.83K OHM,+/-1%,1/4W	H002	MR-25 3.83K OHM F	1
R33	225-09093-00	RES.,FXD,MET:909K OHM,+/-1%,1/2W	K013	SN14K2H 909K OHM F	1
R34	225-01004-00	RES.,FXD,MET:1.00M OHM,+/-1%,1/2W	K013	SN14K2H 1.00M OHM F	1
R35	225-04990-00	RES.,FXD,MET:499 OHM,+/-1%,1/2W	K013	SN14K2H 499 OHM F	1
R36	224-09099-00	RES.,FXD,MET:90.9 OHM,+/-1%,1/4W	H002	MR-25 90.9 OHM F	1
RV1	238-10122-00	RES.,VAR,CERMET:50K OHM	K010	RJ-6P 50K OHM	1
RV2	238-10122-00	RES.,VAR,CERMET:50K OHM	K010	RJ-6P 50K OHM	1
RV3	238-10076-00	RES.,VAR,CERMET:1K OHM	K010	RJ-6P 1K OHM	1
RV4	238-10122-00	RES.,VAR,CERMET:50K OHM	K010	RJ-6P 50K OHM	1
RV5	238-10122-00	RES.,VAR,CERMET:50K OHM	K010	RJ-6P 50K OHM	1
RV6	238-10122-00	RES.,VAR,CERMET:50K OHM	K010	RJ-6P 50K OHM	1
RV7	238-10149-00	RES.,VAR,CERMET:200KOHM	K010	RJ-6P 200K OHM	1
RV8	238-10025-00	RES.,VAR,CERMET:20 OHM	K010	RJ-6P 20 OHM	1

Table 7-9 MAIN BOARD CKT (cont)

ITHACO MFR. CODE	MANUFACTURER
A001	Alps Electric Co., Ltd
A007	Advanced Micro Devices Inc.
B001	Burr-Brown Corporation
D003	Dai-Ichi Denshi Kogyo K.K.
E001	NF Circuit Design Block Co., Ltd.
E005	Eight Kogyo Co., Ltd.
E012	MC Eight Co., Ltd.
H001	Fujitsu Ltd.
H002	Philips Electronic Components and Materials Division
H003	Hitachi Ltd.
H005	Hirose Electric Co., Ltd.
H014	Harris Semiconductor Inc.
H022	Hanai Electric Wire Co., Ltd.
H026	Fuji Ceramics Co., Ltd.
I003	Intersil Corporation
K006	Kawasaki Densen K.K.
K008	Kitagawa Ind Co., Ltd.
K010	Copal Electronics Co., Ltd.
K013	Kowa Denko Co., Ltd.
M001	Marconi Electronics Co., Ltd.
M002	Murata Mfg. Co., Ltd.
M004	Mitsumi Electric Co., Ltd.
M005	Molex-Japan Co., Ltd.
M007	Morimatsu Denshi Kogyo Co., Ltd.
M010	Matsushita Electronics Corp.
M014	Motorola Semiconductor Products
M019	Matsukyu Co., Ltd.
N001	Japan Servo Co. Ltd.
N003	Nippon Chemical condenser Co., Ltd.
N004	Nippon Electric Co., Ltd.
N013	National Semiconductor Corp.
N015	Nikkohm Co., Ltd.
N016	Japan Fine Chemical Company, Inc.
N018	Nihon Kaiheiki Ind. Co., Ltd.
O002	Okita Works Co., Ltd.
R001	Ryosan Denki Co., Ltd.
S001	Soshin Electric Co. Ltd.

Table 7-10 CODE LIST OF MANUFACTURERS

S002	Shizuki Electric Company Inc.
S003	New Japan Radio Co. Ltd.
S006	Sanken Electric Co., Ltd.
S007	Sato Parts Co., Ltd.
S009	Stack Electric Co., Ltd.
S010	Seidensha Electric Works Ltd.
S018	Signetics Corporation
S026	Shinyei Kaisha
T004	Toshiba Corporation
T005	Toyo Fuse Co., Ltd.
T009	Omron Electric Co., Ltd.
T017	TDK Electronics Co., Ltd.
T022	Texas Instruments Inc.
T025	Tokyo Cosmos Electric Co., Ltd.
W004	Wako Term Blk Mfg. Co., Ltd.
Y001	Yuasa Battery Co., Ltd.
Y003	Yamaichi Electric Mfg., Co., Ltd.
Y006	Yamagishi Musen Denki K.K.
Y007	Yagumo Tsushin Kogyo Co., Ltd.
Y008	Yokogawa-Hewlett-Packard Co., Ltd.

Table 7-10 CODE LIST OF MANUFACTURERS (Cont)

SECTION 8

CIRCUIT DIAGRAMS

8.1 INTRODUCTION

This section includes schematics. Refer to Section 7 for information on reference designators used in these drawings.

8.2 DRAWINGS

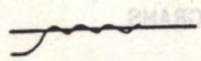
The drawing name is assigned as shown below.

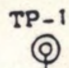
SIGNAL CONDITIONER BOARD CKT 1/2

Drawing name

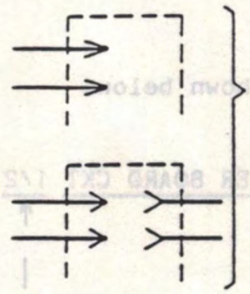
This indicates that this sheet is the first of two comprising this drawing.

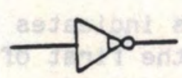
8.2.1 SPECIAL SYMBOLS

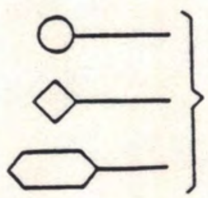

Twisted pair line

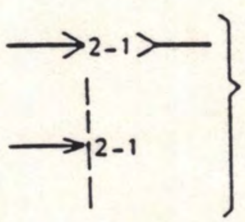


Test point


Multi-pin connector

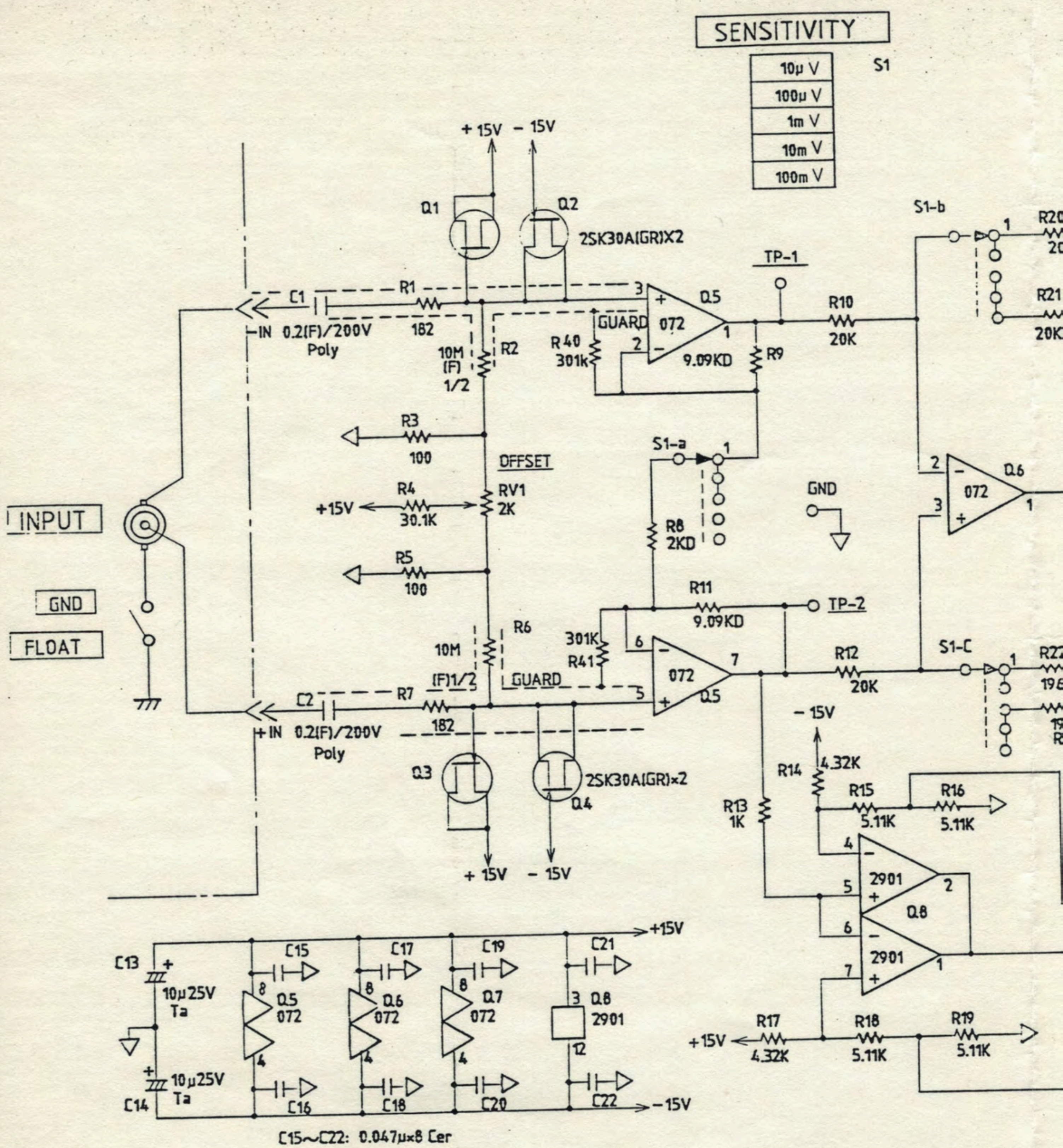

Open collector (inverter)


Indicates connections within the same PC board.
Connections are made to parts having the same symbol within or near these symbols.

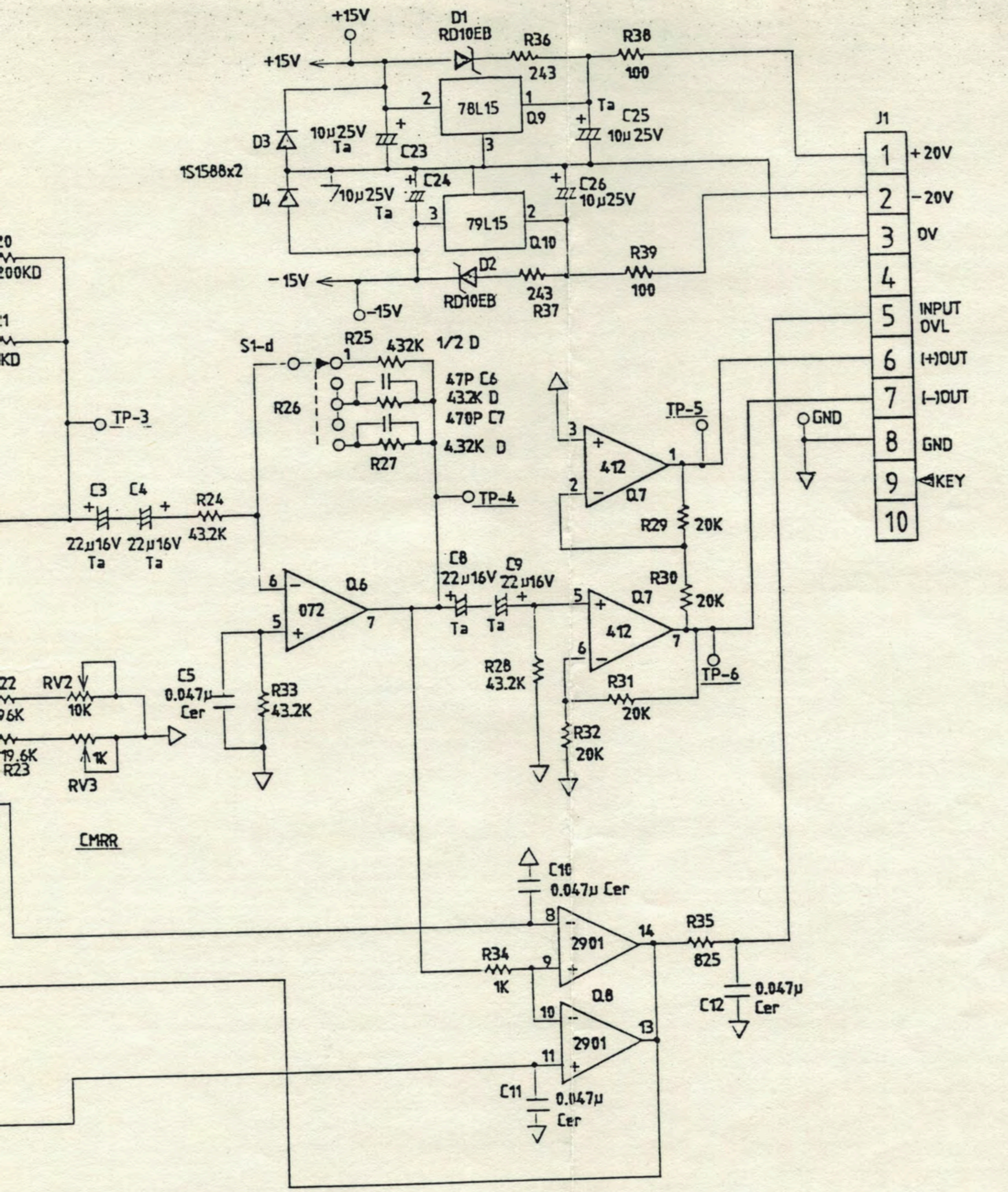


Indicates connections to a PC board edge connector.

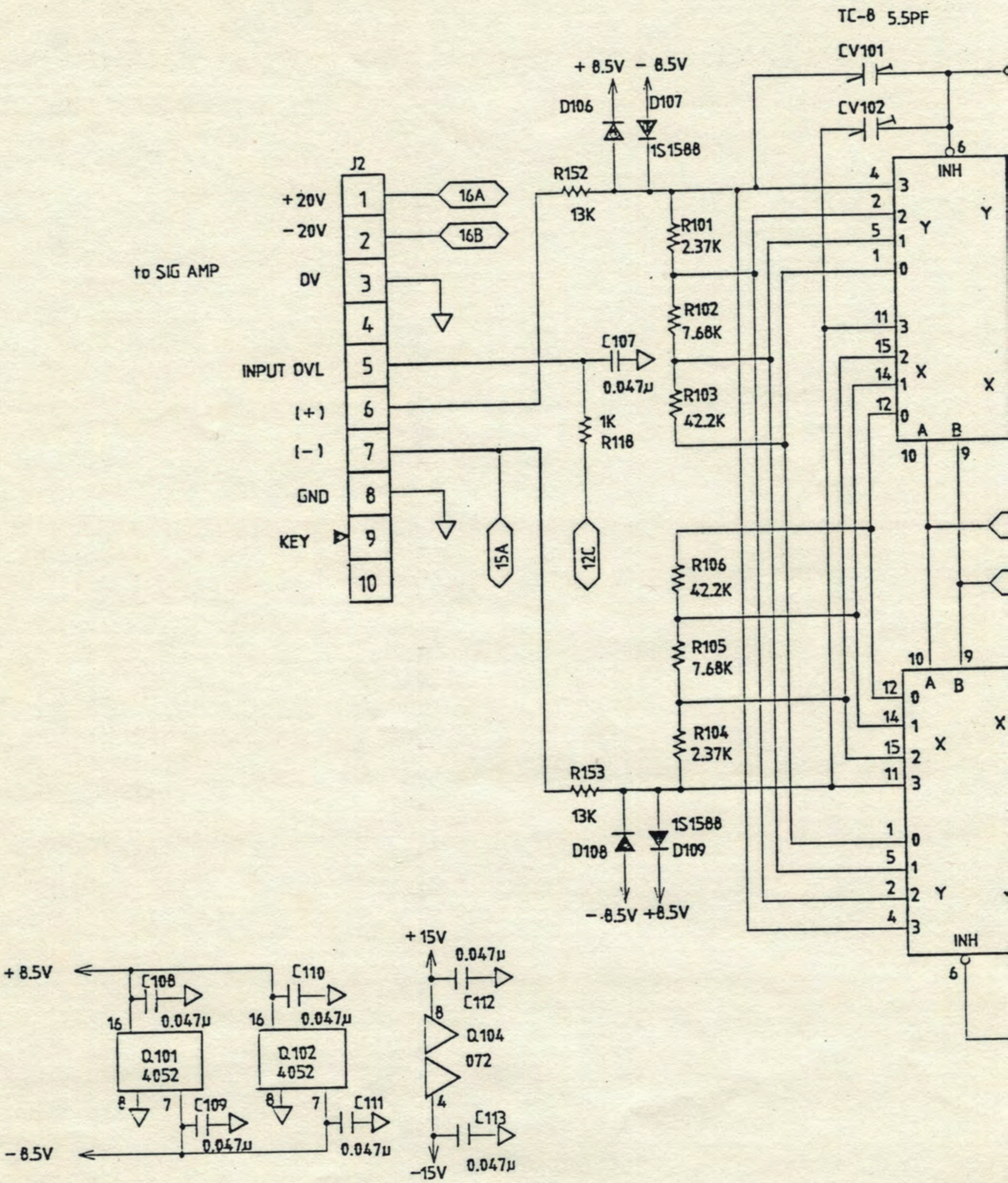
8.3 CIRCUIT DIAGRAMS LIST



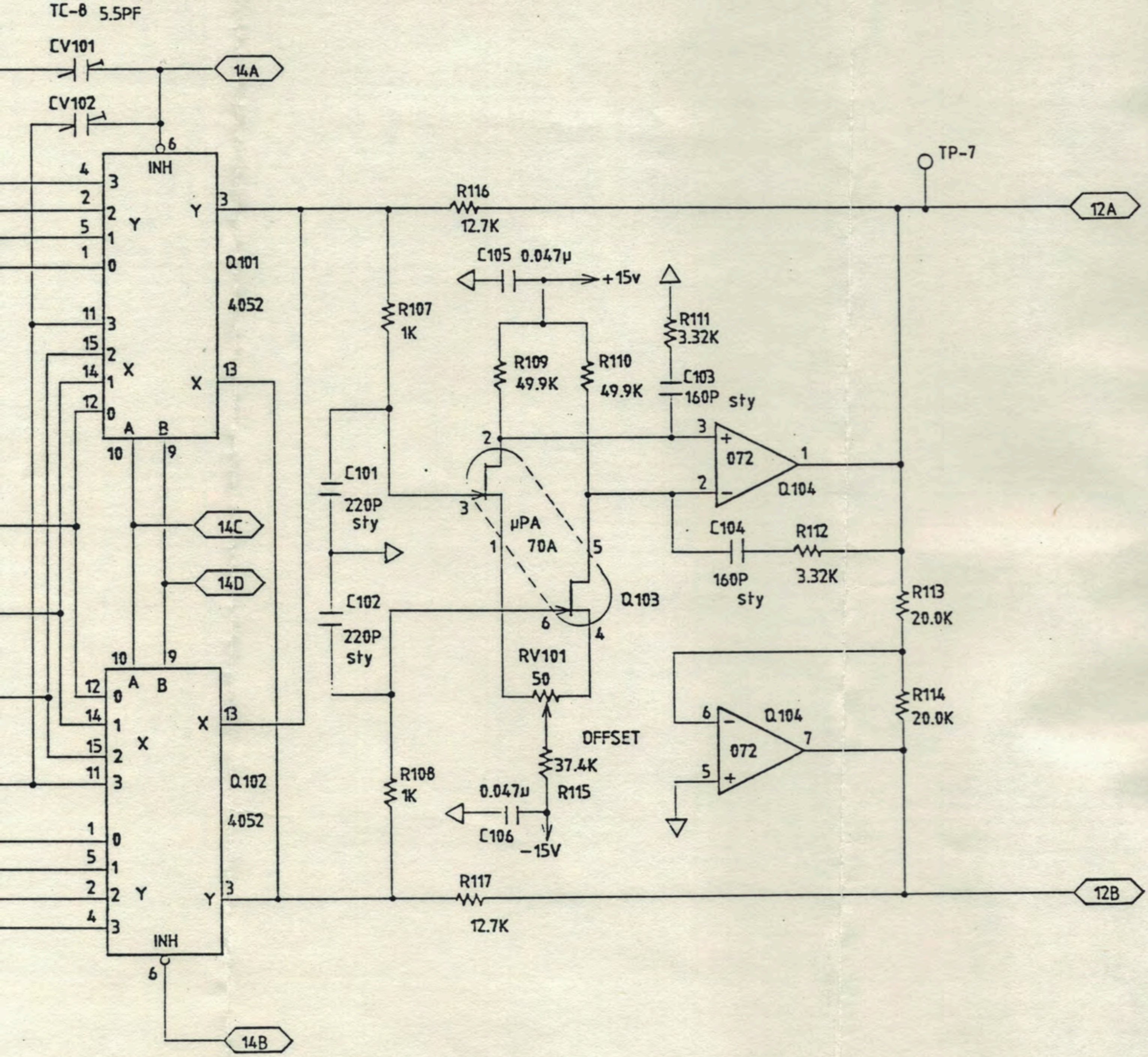
SENSITIVITY
10μ V
100μ V
1m V
10m V
100m V
S1
+15V
-15V
Q1
Q2
2SK30A(GR)X2
TP-1
C1
R1
-IN 0.2(F)/200V
Poly
182
GUARD
072
Q5
R10
20K
R40
301k
9.09KD
R9
10M
(F)
1/2
R2
R3
100
OFFSET
S1-a
R4
+15V
30.1K
RV1
2K
R8
2KD
GND
R5
100
R11
9.09KD
TP-2
INPUT
GND
FLOAT
10M
R6
(F)1/2
301K
R41
GUARD
R12
20K
S1-C
C2
R7
+IN 0.2(F)/200V
Poly
182
Q3
2SK30A(GR)×2
Q4
R14
4.32K
R15
5.11K
R16
5.11K
R13
1K
2901
Q8
S1-b
R20
R21
20K
Q6
C13
10μ25V
Ta
C14
10μ25V
Ta
C15
C16
C17
C18
C19
C20
C21
C22
072
Q7
2901
R17
4.32K
R18
5.11K
R19
5.11K
C15~C22: 0.047μ×8 Cer



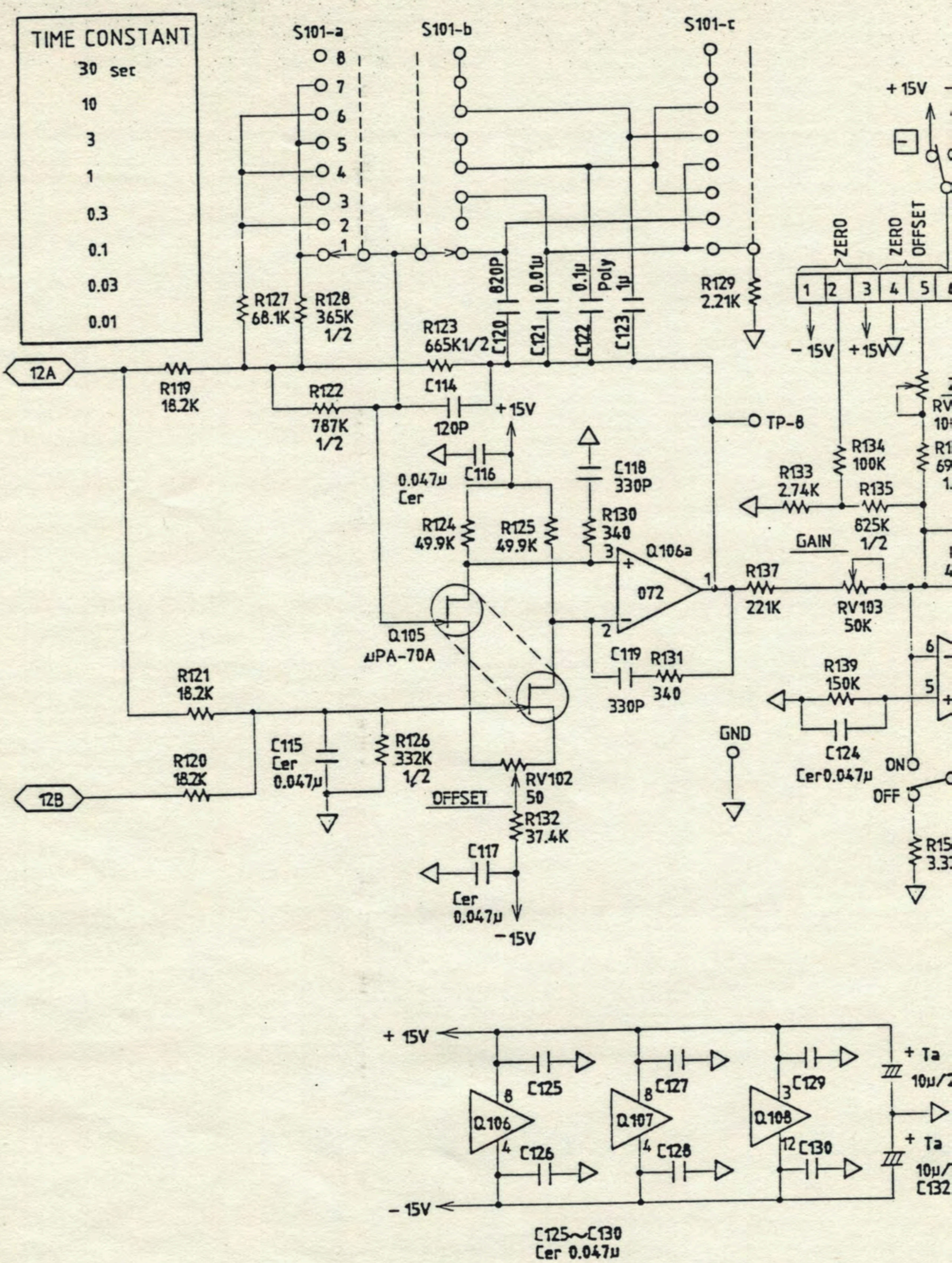
8-4 SIG AMP CKT



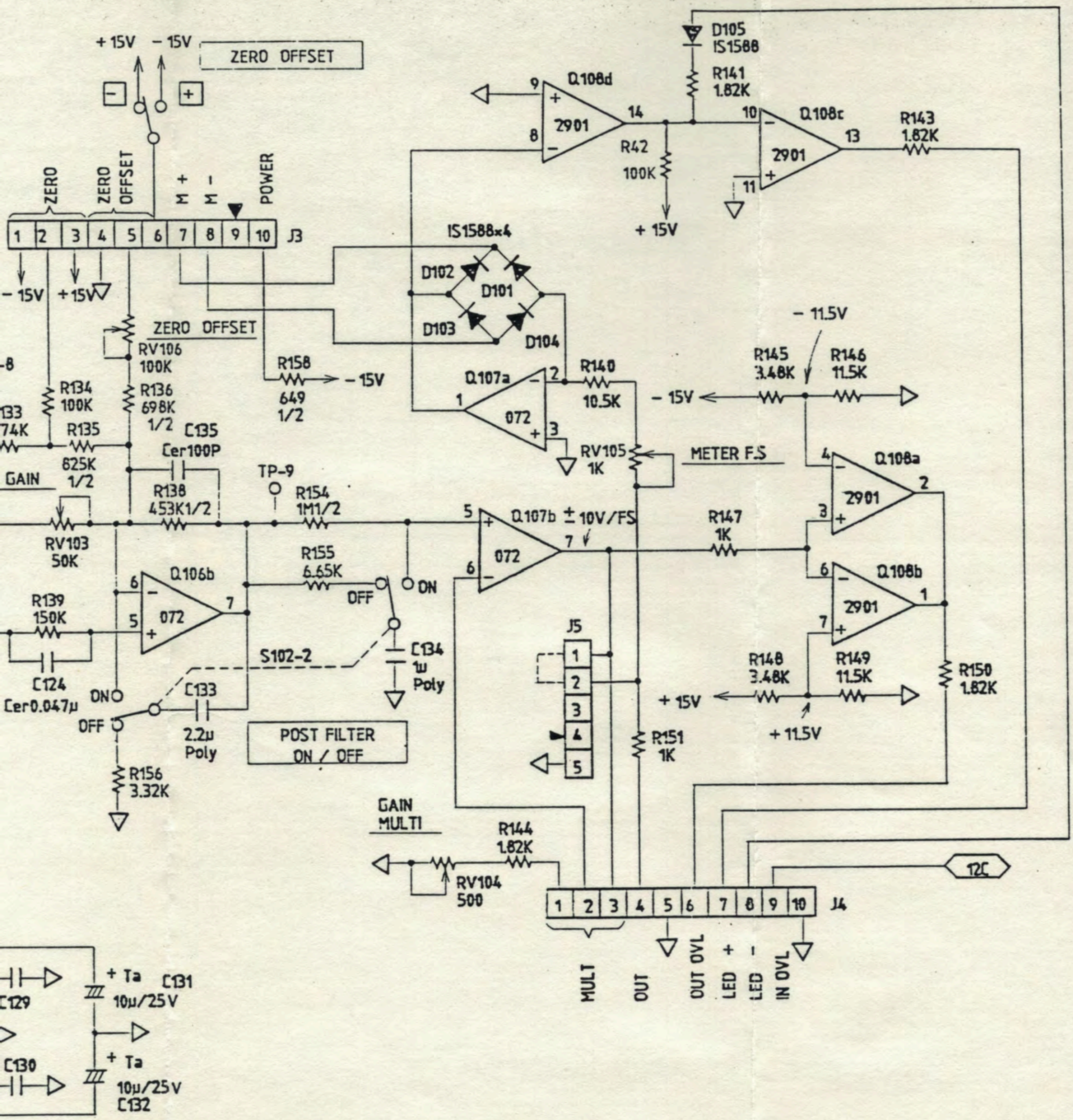
TC-8 5.5PF
CV101
CV102
+ 8.5V
- 8.5V
D106
D107
1S1588
J2
R152
13K
+20V
-20V
16A
16B
to SIG AMP
0V
INPUT OVL
(+)
(-)
GND
KEY
C107
0.047μ
1K
R118
15A
12C
R101
2.37K
R102
7.68K
R103
42.2K
R106
42.2K
R105
7.68K
R104
2.37K
R153
13K
D108
D109
-8.5V
+8.5V
INH
Y
X
A
B
+8.5V
-8.5V
C108
C109
C110
C111
C112
C113
Q101
4052
Q102
4052
+15V
-15V
Q104
072


TC-8 5.5PF
CV101
CV102
14A
INH
Q101
4052
R116
12.7K
TP-7
12A
C105 0.047μ
+15v
R107
1K
R111
3.32K
R109
49.9K
R110
49.9K
C103
160P sty
072
Q104
C101
220P
sty
μPA
70A
14C
14D
C104
160P
sty
R112
3.32K
R113
20.0K
Q103
C102
220P
sty
RV101
50
R114
20.0K
Q104
072
OFFSET
37.4K
R115
Q102
4052
R108
1K
0.047μ
C106
−15V
R117
12.7K
12B
14B

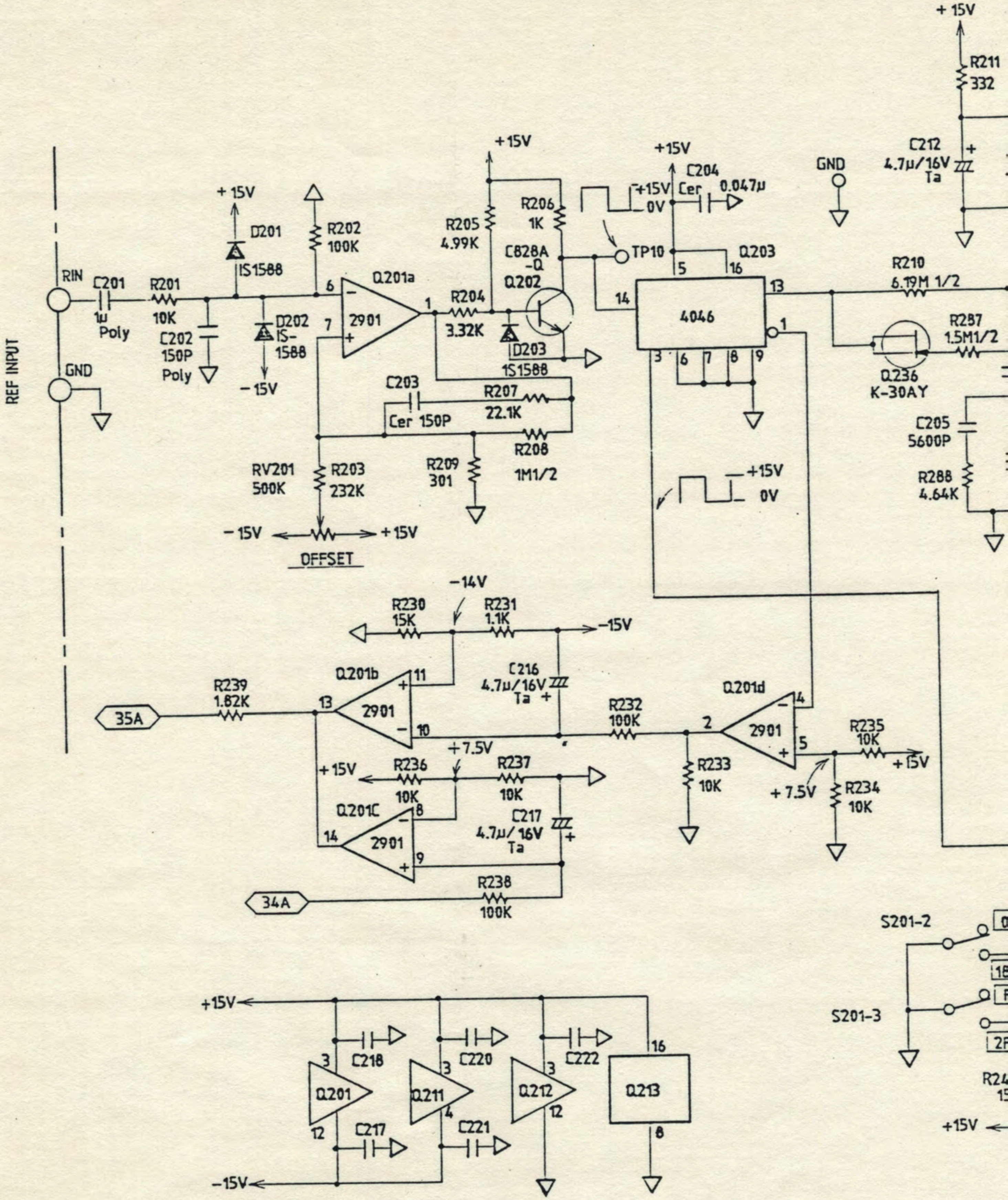
8-5 PSD CKT



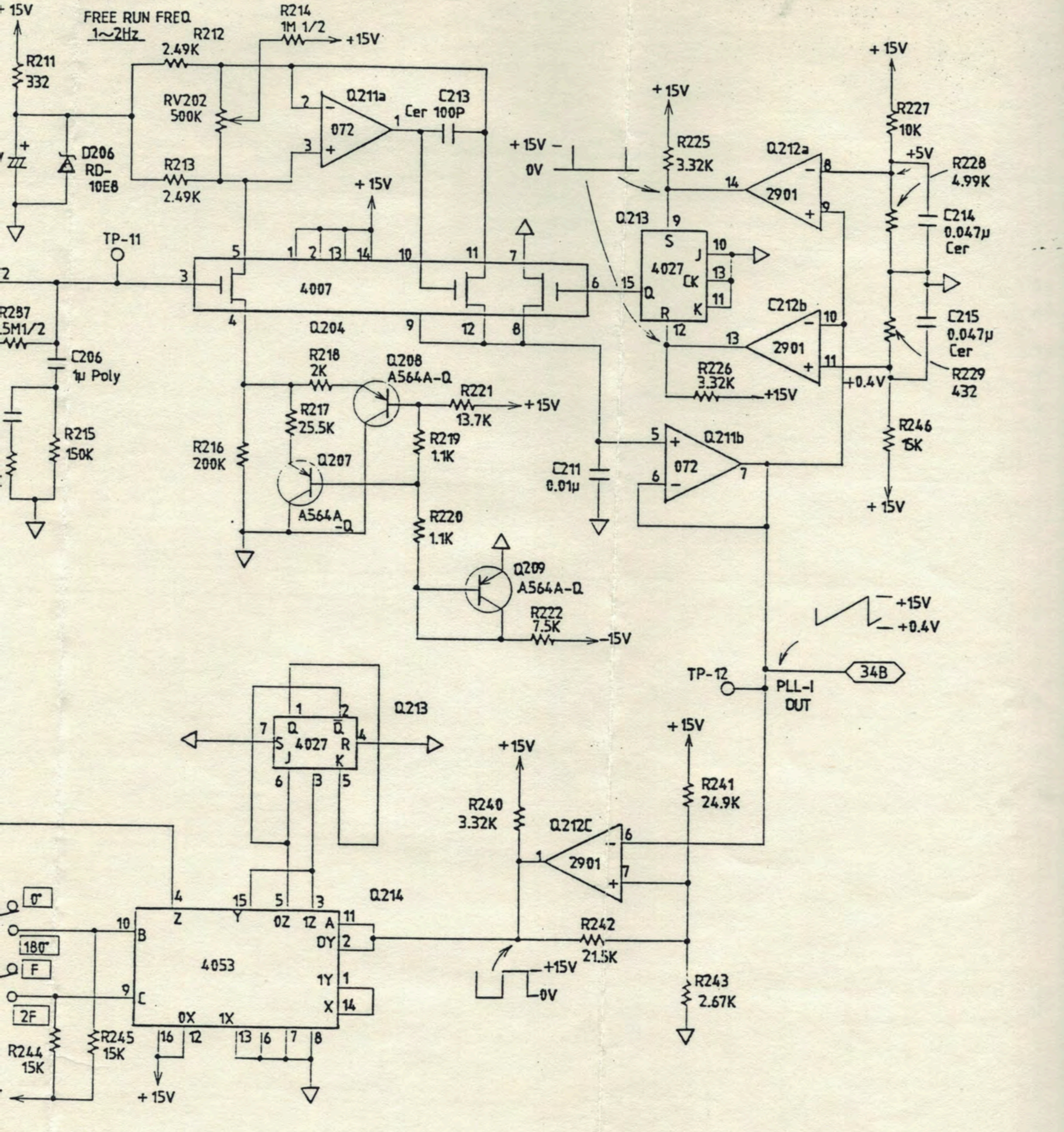
TIME CONSTANT
30 sec
10
3
1
0.3
0.1
0.03
0.01
S101-a
S101-b
S101-c
12A
12B
R119 18.2K
R127 68.1K
R128 365K 1/2
R123 665K1/2
R122 787K 1/2
C114 120P
820P C120
0.01µ C121
0.1µ C122
Poly 1µ C123
R129 2.21K
TP-8
+15V
-15V
C116 0.047µ Cer
C118 330P
R124 49.9K
R125 49.9K
R130 340
Q106a
072
Q105 µPA-70A
C119 330P
R131 340
R121 18.2K
R120 18.2K
C115 Cer 0.047µ
R126 332K 1/2
RV102 50
OFFSET
R132 37.4K
C117 Cer 0.047µ
GND
R137 221K
GAIN
RV103 50K
R133 2.74K
R134 100K
R135 825K 1/2
R139 150K
C124 Cer0.047µ
ON
OFF
ZERO
ZERO OFFSET
Q106
Q107
Q108
C125
C126
C127
C128
C129
C130
+ Ta 10µ/
C132
C125~C130 Cer 0.047µ



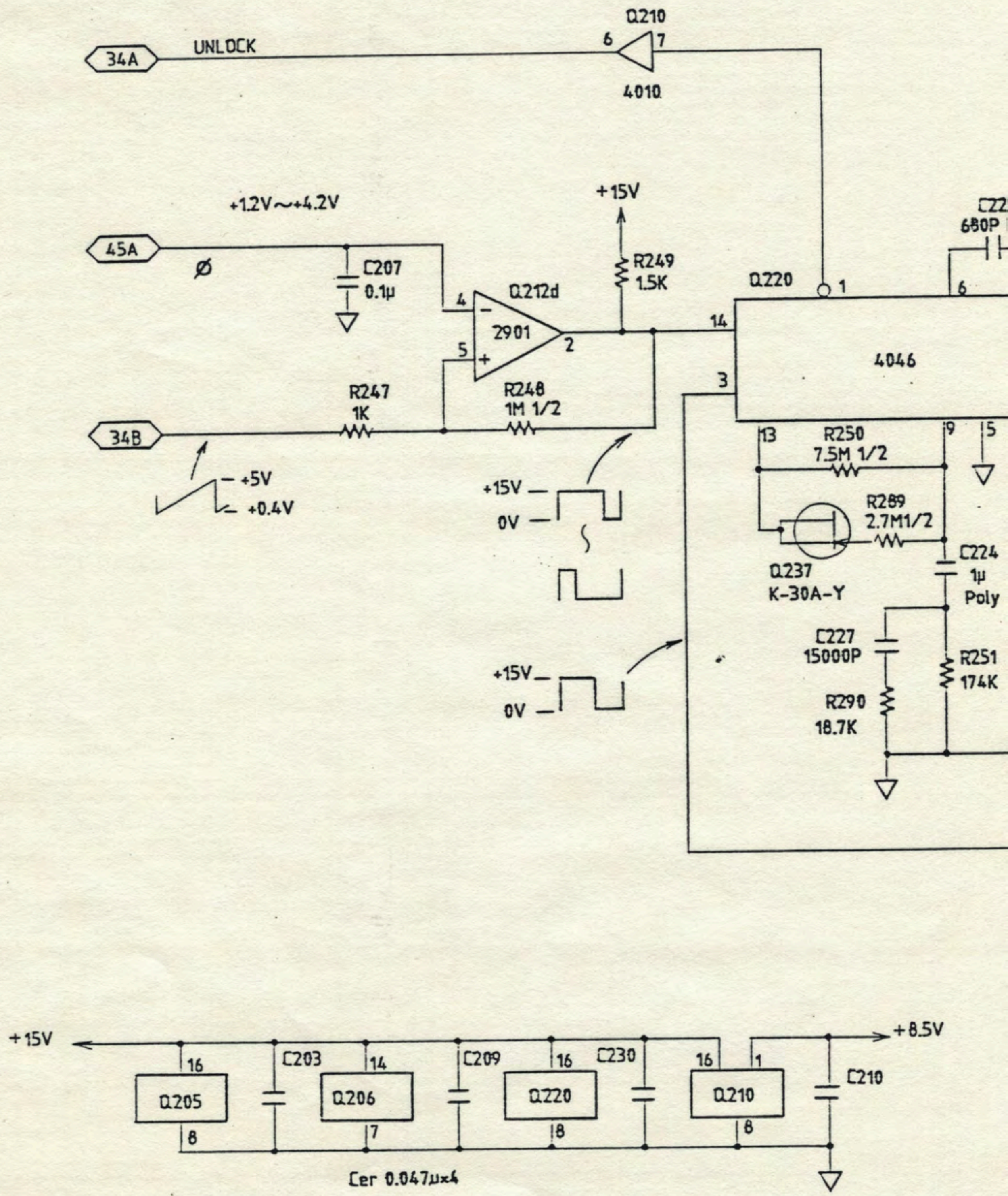
8−6 TC & OUTPUT CKT



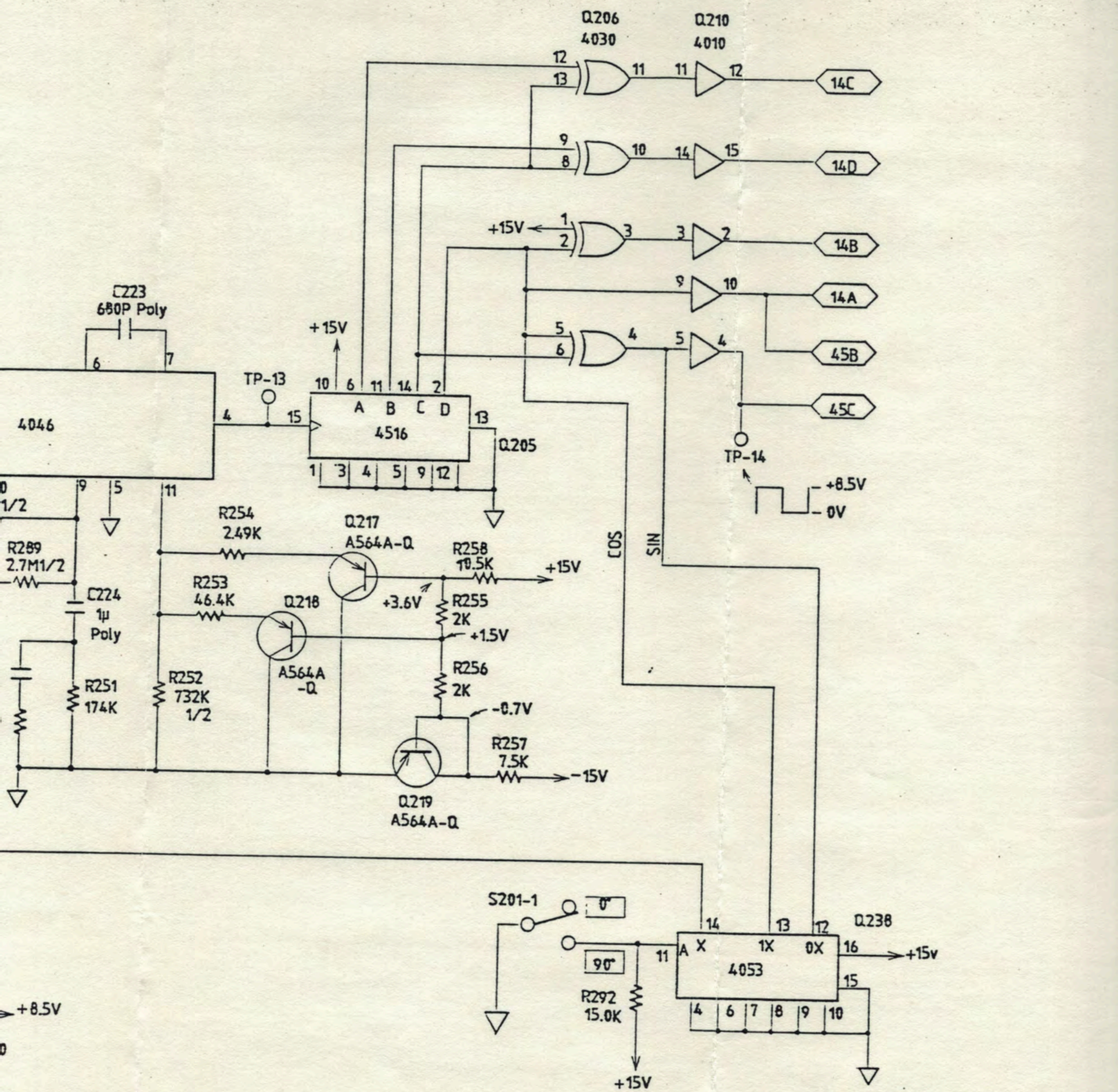
REF INPUT
RIN
GND
C201 1µ Poly
R201 10K
C202 150P Poly
+15V
D201 1S1588
D202 IS-1588
-15V
R202 100K
Q201a 2901
6
7
1
R204 3.32K
+15V
R205 4.99K
R206 1K
C828A -Q
Q202
D203 1S1588
C203 Cer 150P
R207 22.1K
R208 1M1/2
R209 301
RV201 500K
R203 232K
-15V
+15V
OFFSET
+15V
0V
C204 Cer 0.047µ
TP10
Q203
4046
5
16
14
13
1
3
6
7
8
9
GND
+15V
R211 332
C212 4.7µ/16V Ta
R210 6.19M 1/2
R287 1.5M1/2
Q236 K-30AY
C205 5600P
R288 4.64K
-14V
R230 15K
R231 1.1K
-15V
Q201b 2901
11
13
10
C216 4.7µ/16V Ta
R239 1.82K
35A
R232 100K
Q201d 2901
4
2
5
R233 10K
R235 10K
+15V
+7.5V
R234 10K
+7.5V
+15V
R236 10K
R237 10K
Q201C 2901
8
14
9
C217 4.7µ/16V Ta
R238 100K
34A
S201-2
S201-3
+15V
C218
C220
C222
Q201
Q211
Q212
Q213
3
12
4
16
8
C217
C221
-15V


+15V
FREE RUN FREQ
1~2Hz
R211
332
D206
RD-
10E8
R212
2.49K
RV202
500K
R213
2.49K
R214
1M 1/2
Q211a
072
C213
Cer 100P
TP-11
4007
Q204
R287
.5M1/2
C206
1μ Poly
R215
150K
R216
200K
R218
2K
R217
25.5K
Q208
A564A-Q
Q207
A564A-Q
R221
13.7K
R219
1.1K
R220
1.1K
Q209
A564A-Q
R222
7.5K
-15V
+15V
0V
R225
3.32K
Q212a
2901
Q213
4027
Q212b
R226
3.32K
C211
0.01μ
Q211b
R227
10K
+5V
R228
4.99K
C214
0.047μ
Cer
C215
0.047μ
Cer
R229
432
+0.4V
R246
15K
TP-12
PLL-I
OUT
34B
Q213
4027
Q214
4053
R240
3.32K
Q212C
2901
R241
24.9K
R242
21.5K
R243
2.67K
0°
180°
F
2F
R244
15K
R245
15K

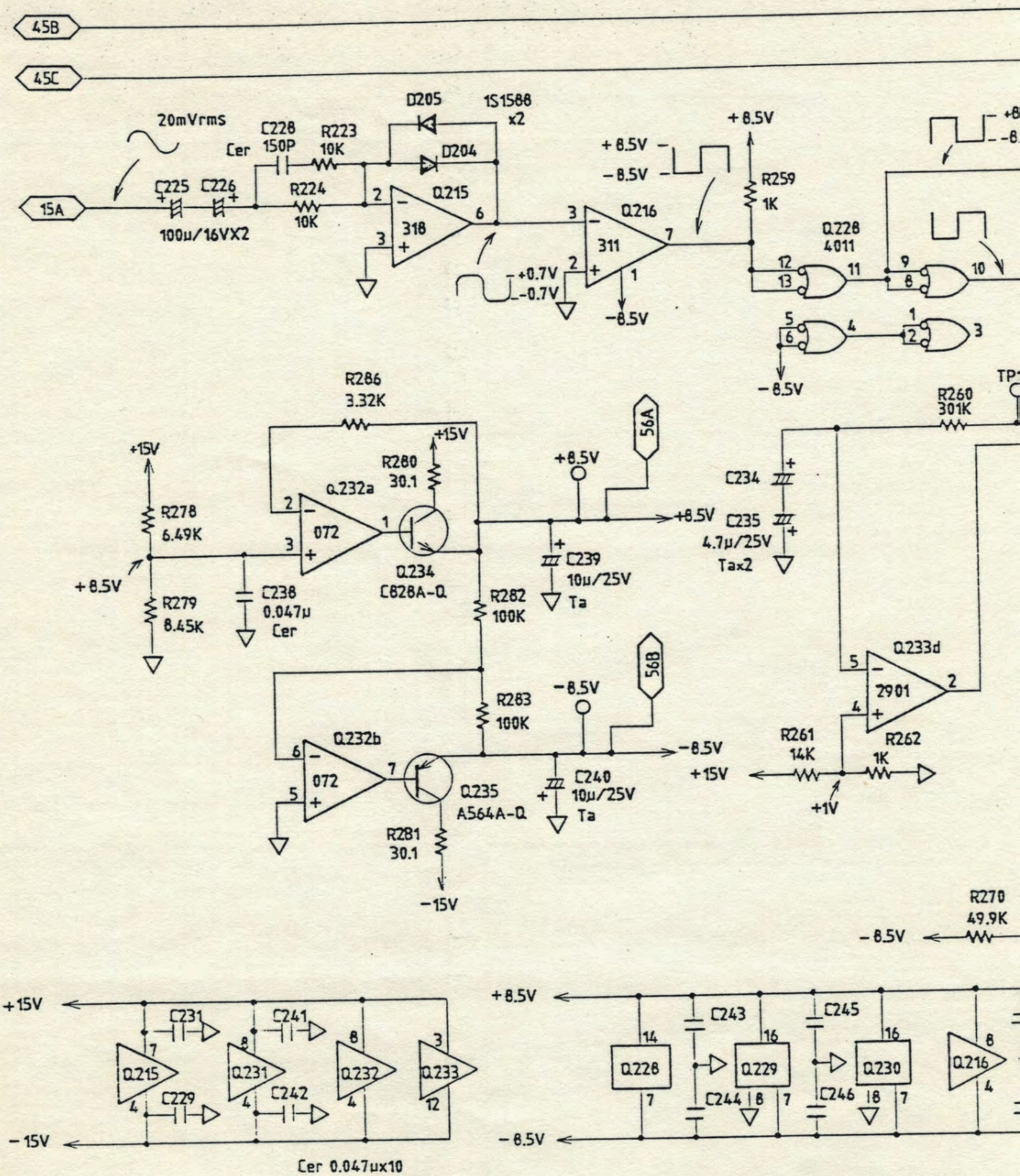
8-7 PLL-I CKT



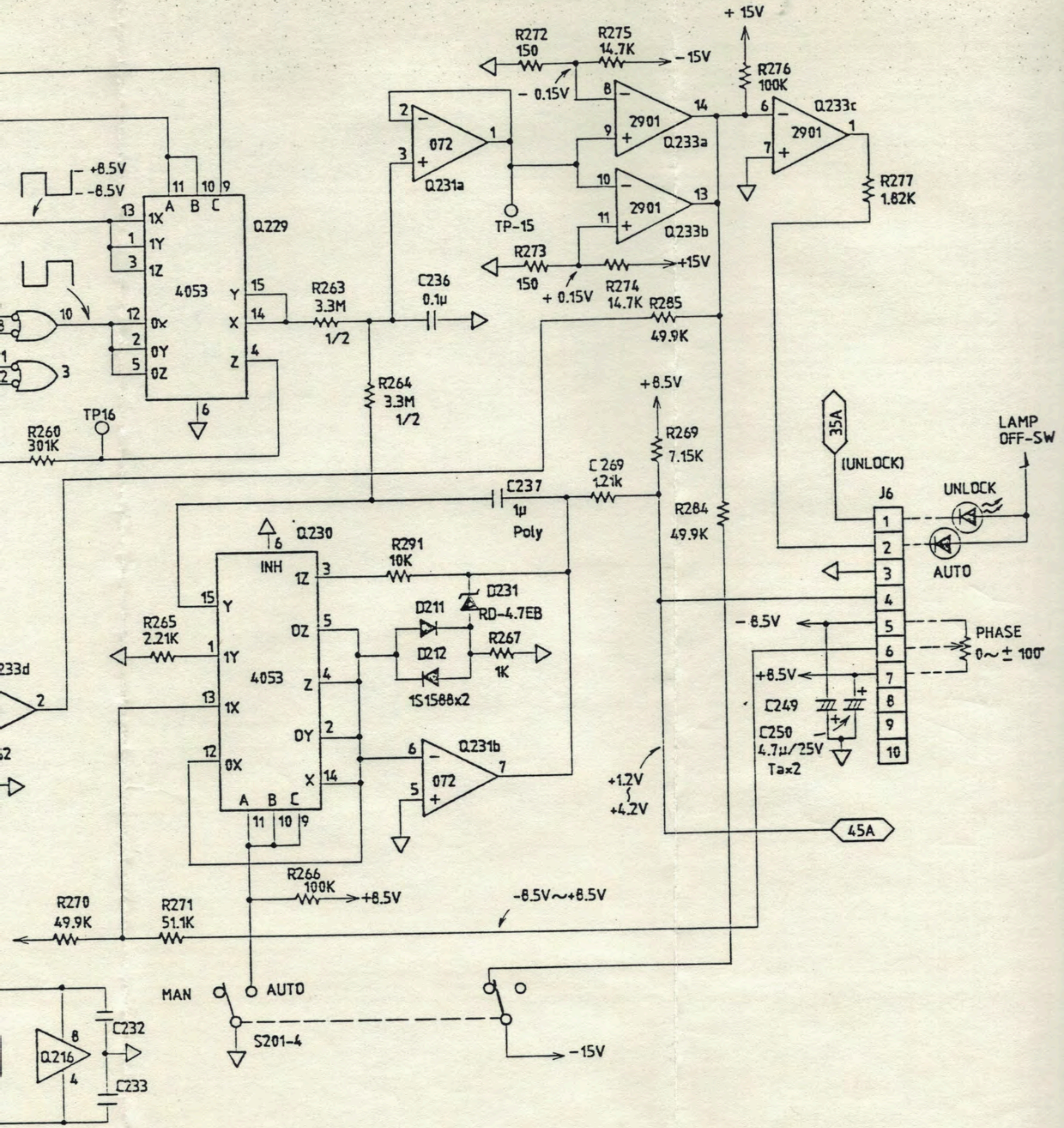
Q210
4010
34A
UNLOCK
+1.2V~+4.2V
45A
Ø
C207
0.1μ
Q212d
2901
+15V
R249
1.5K
Q220
4046
C22
680P
34B
R247
1K
R248
1M 1/2
+5V
+0.4V
+15V
0V
R250
7.5M 1/2
R289
2.7M1/2
Q237
K-30A-Y
C224
1μ
Poly
C227
15000P
R290
18.7K
R251
174K
+15V
Q205
C203
Q206
C209
Q220
C230
Q210
C210
+8.5V
Cer 0.047μ×4


Q206
4030
Q210
4010
14C
14D
14B
14A
45B
45C
+15V
TP-13
TP-14
+8.5V
0V
C223
680P Poly
4046
4516
A B C D
Q205
R254
2.49K
Q217
A564A-Q
R258
10.5K
R253
46.4K
Q218
A564A
-Q
R255
2K
+3.6V
+1.5V
R256
2K
-0.7V
R257
7.5K
-15V
Q219
A564A-Q
R289
2.7M1/2
C224
1μ
Poly
R251
174K
R252
732K
1/2
COS
SIN
S201-1
0°
90°
R292
15.0K
Q238
4053
X
1X
0X
+15v

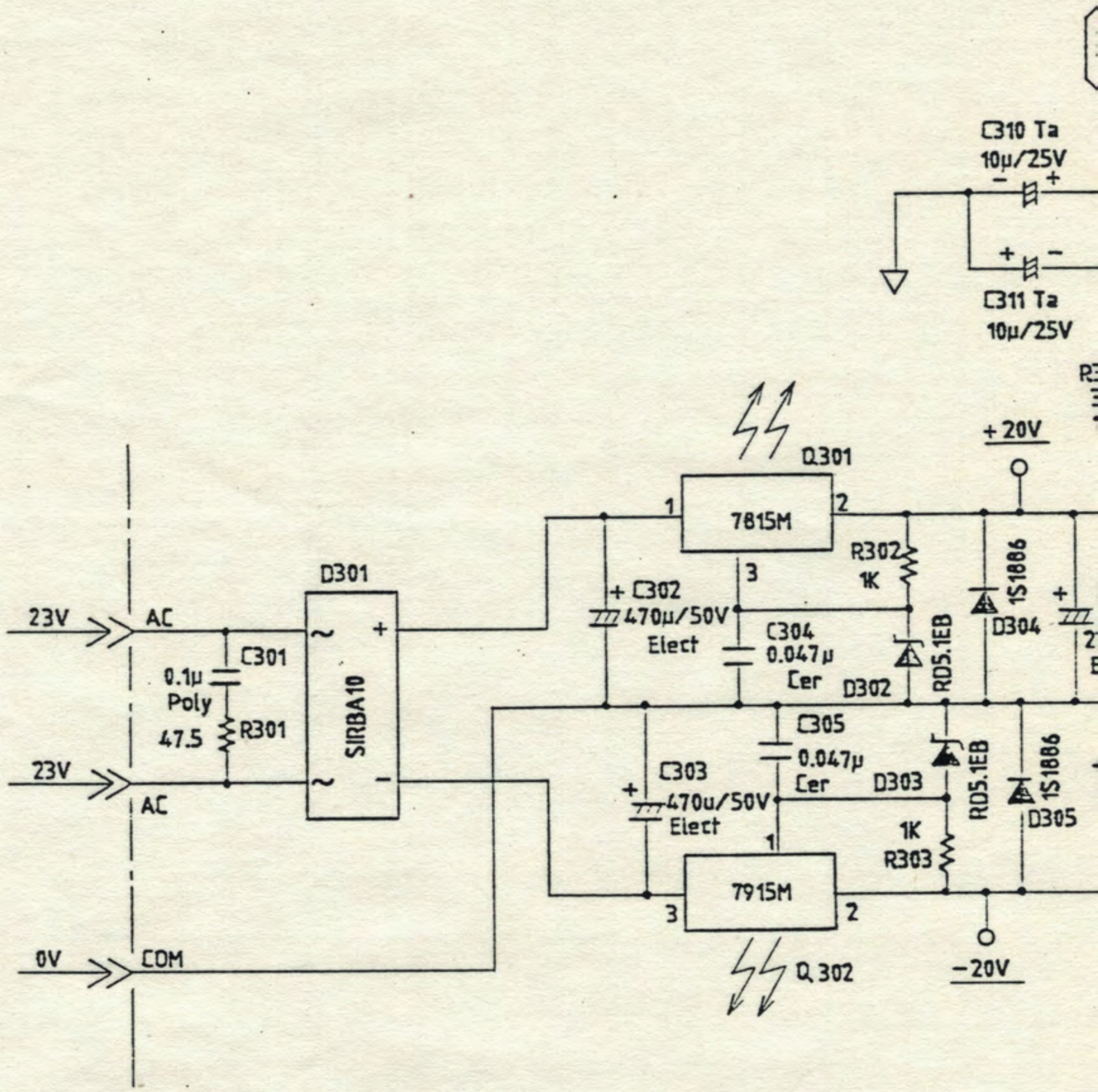
8-8 PLL-II CKT

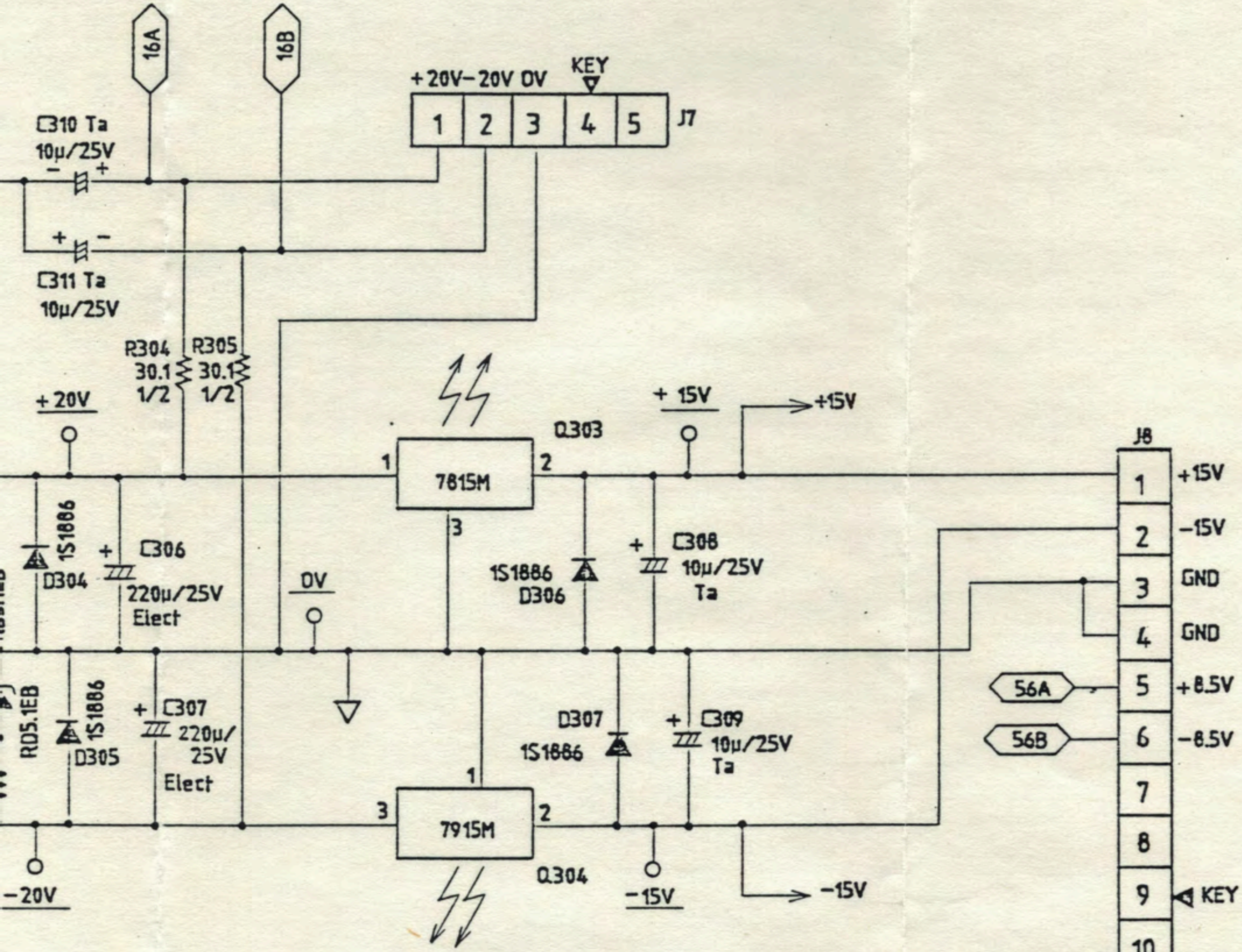


45B
45C
15A
20mVrms
C225
C226
100μ/16VX2
Cer
C228
150P
R223
10K
R224
10K
D205
D204
1S1588
x2
Q215
318
+0.7V
-0.7V
Q216
311
+8.5V
-8.5V
R259
1K
Q228
4011
TP
R260
301K
C234
C235
4.7μ/25V
Tax2
R286
3.32K
+15V
R280
30.1
Q232a
072
Q234
C828A-Q
56A
C239
10μ/25V
Ta
R278
6.49K
R279
8.45K
C238
0.047μ
Cer
R282
100K
R283
100K
56B
Q232b
Q235
A564A-Q
C240
R281
30.1
-15V
Q233d
2901
R261
14K
R262
1K
+1V
R270
49.9K
C231
C241
C229
C242
Q231
Q233
Cer 0.047μx10
C243
C244
C245
C246
Q229
Q230

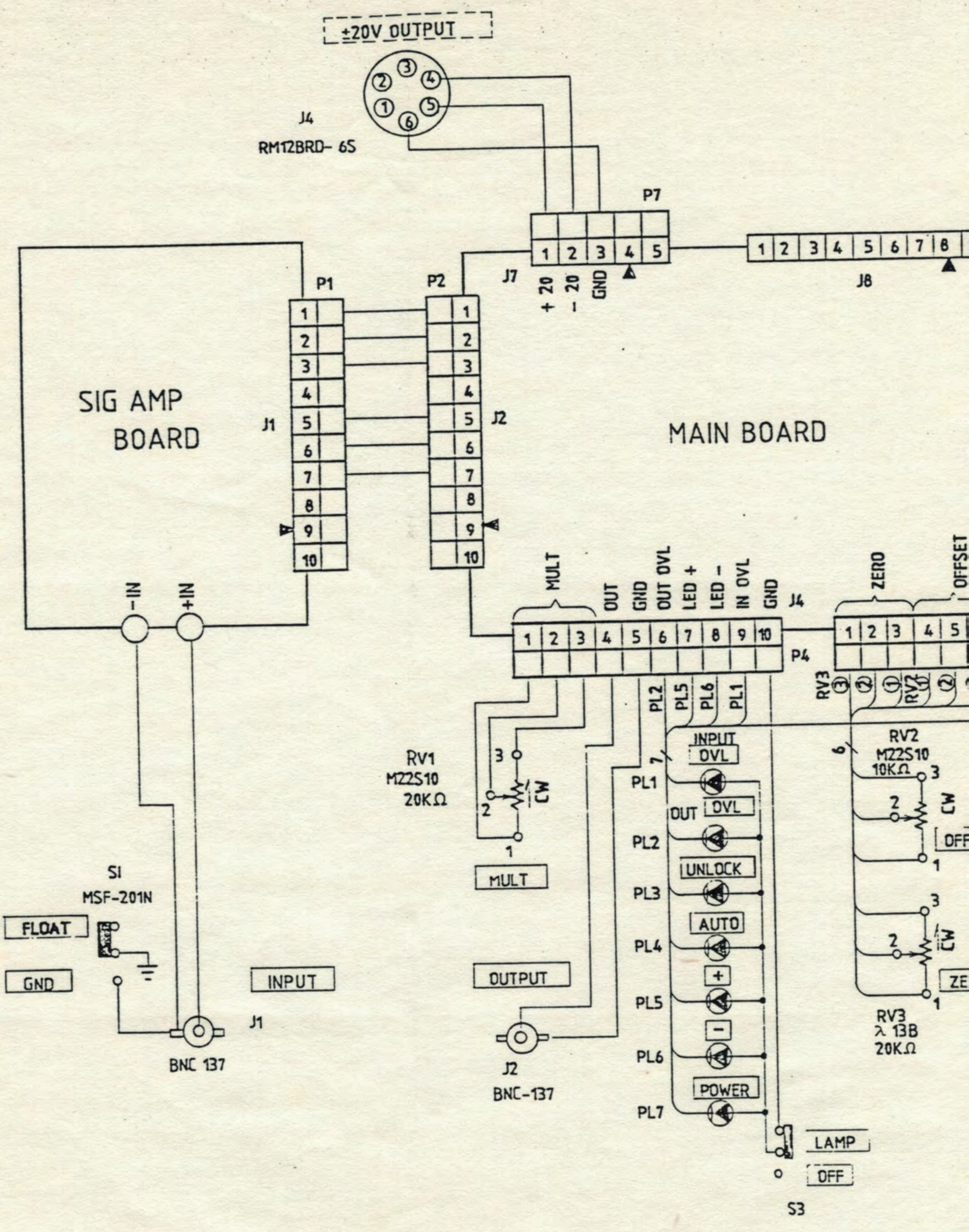


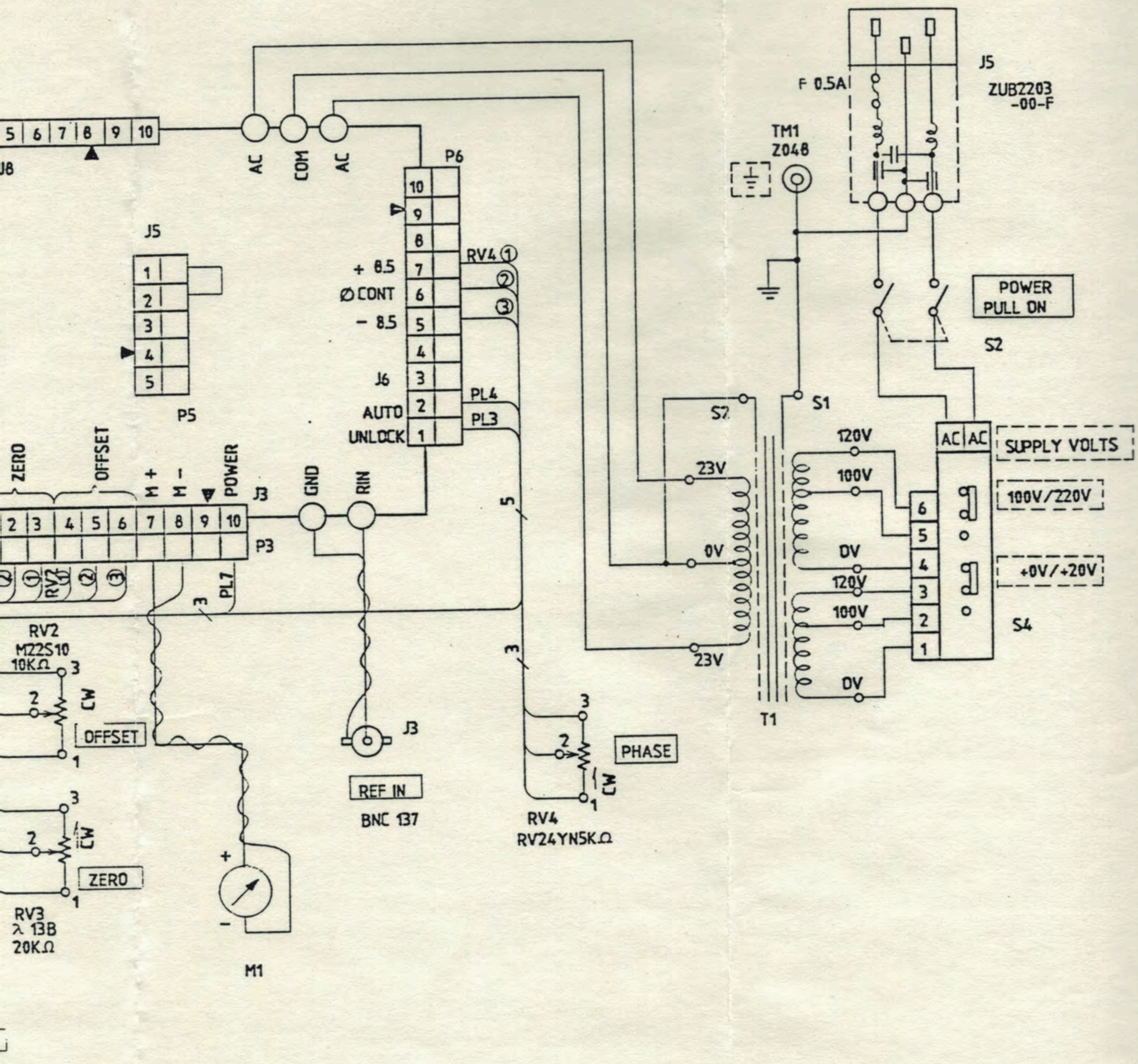
8-9 PHASE CONTROL CKT


C310 Ta
10μ/25V
C311 Ta
10μ/25V
+20V
Q301
7815M
R302
1K
D301
C302
470μ/50V
Elect
C304
0.047μ
Cer
D302
RD5.1EB
1S1886
D304
23V
AC
0.1μ
Poly
C301
47.5
R301
SIRBA10
23V
AC
C305
0.047μ
Cer
C303
470u/50V
Elect
D303
1K
R303
RD5.1EB
1S1886
D305
7915M
Q302
-20V
0V
COM

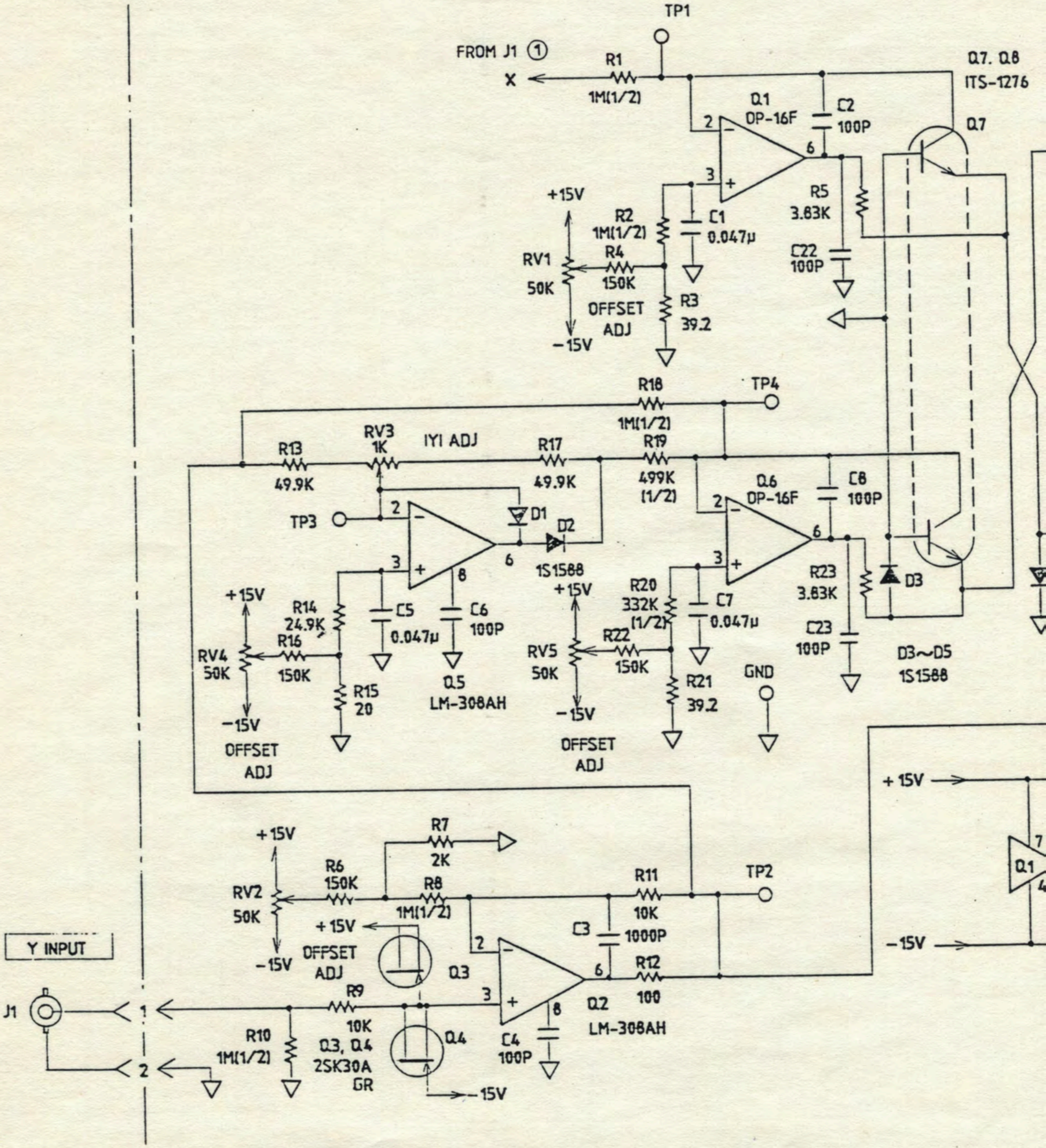


8-10 POWER SUPPLY CKT

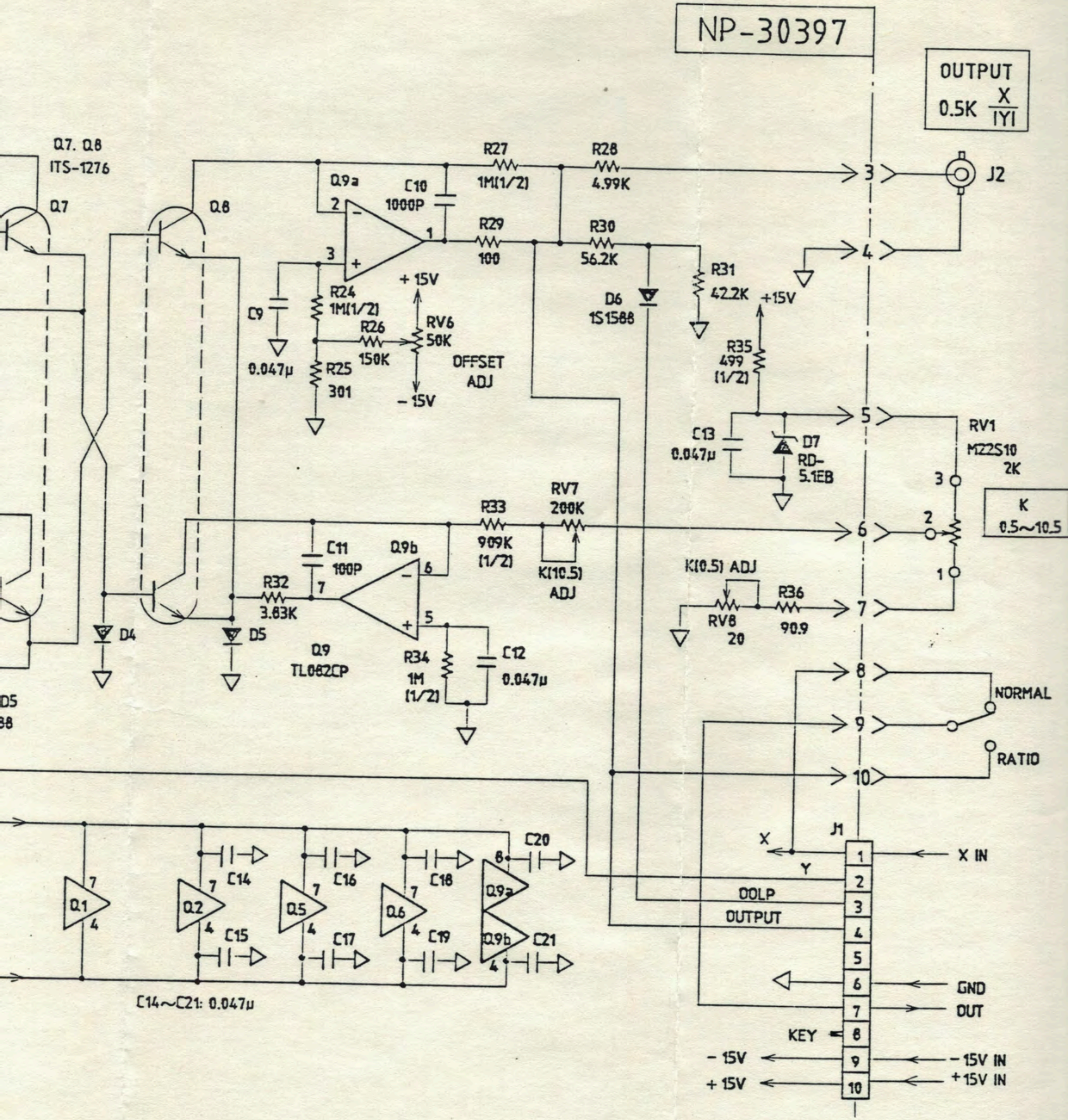

±20V OUTPUT
J4
RM12BRD- 6S
P7
+ 20
- 20
GND
J7
J8
P1
P2
SIG AMP
BOARD
J1
J2
MAIN BOARD
MULT
OUT
GND
OUT OVL
LED +
LED -
IN OVL
GND
J4
P4
ZERO
OFFSET
-IN
+IN
RV1
M22S10
20KΩ
CW
MULT
RV2
M22S10
10KΩ
RV3
λ 13B
20KΩ
PL1
PL2
PL3
PL4
PL5
PL6
PL7
INPUT
OVL
OUT
UNLOCK
AUTO
POWER
LAMP
OFF
S3
S1
MSF-201N
FLOAT
GND
INPUT
OUTPUT
J1
BNC 137
J2
BNC-137



8-11 OVERALL CKT



TP1
FROM J1 ①
X
R1
1M(1/2)
Q1
OP-16F
C2
100P
Q7. Q8
ITS-1276
Q7
+15V
R2
1M(1/2)
C1
0.047μ
R5
3.83K
C22
100P
RV1
50K
R4
150K
OFFSET
ADJ
R3
39.2
-15V
R18
1M(1/2)
TP4
R13
49.9K
RV3
1K
IYI ADJ
R17
49.9K
R19
499K
(1/2)
Q6
OP-16F
C8
100P
TP3
D1
D2
1S1588
R20
332K
(1/2)
C7
0.047μ
R23
3.83K
D3
C23
100P
D3~D5
1S1588
R14
24.9K
R16
150K
RV4
50K
R15
20
C5
0.047μ
C6
100P
Q5
LM-308AH
RV5
50K
R22
150K
R21
39.2
GND
OFFSET
ADJ
+15V
-15V
R7
2K
R6
150K
RV2
50K
R8
1M(1/2)
R11
10K
TP2
C3
1000P
R12
100
Q3
Q2
LM-308AH
Y INPUT
J1
R9
10K
R10
1M(1/2)
Q3, Q4
2SK30A
GR
Q4
C4
100P



8-12 RATIO METER CKT

SECTION 9

RATIO METER (Option 02)

9.1 INTRODUCTION

The Option 02 Ratio Meter installs in the blank panel area at the rear of the Model 3921 Lock-In Amplifier.

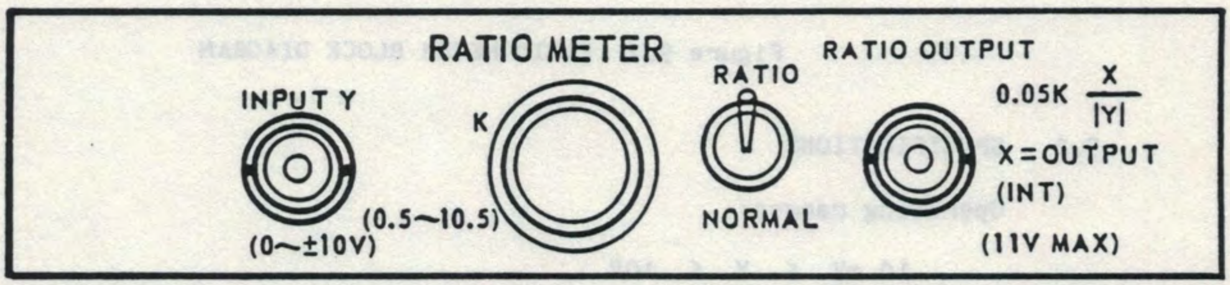


Figure 9.1 RATIO METER PANEL

The Ratio Meter provides for signal normalization using an external dc input according to the expression:

$$E_o = 0.5k \frac{X}{|Y|}$$

E_o = Ratio output

K = Multiplier, continuously variable from 0.5 to 10.5 on 10-turn dial.

X = Lock-In dc output*

$|Y|$ = Absolute value of external dc input

Typically the Ratio Meter is used to compensate for fluctuations in the excitation of the system being measured. In optical work, for example, it would correct for variations in source intensity, as explained in Section 9.4.

*LIA must be phased for positive output (meter "+" lamp on).

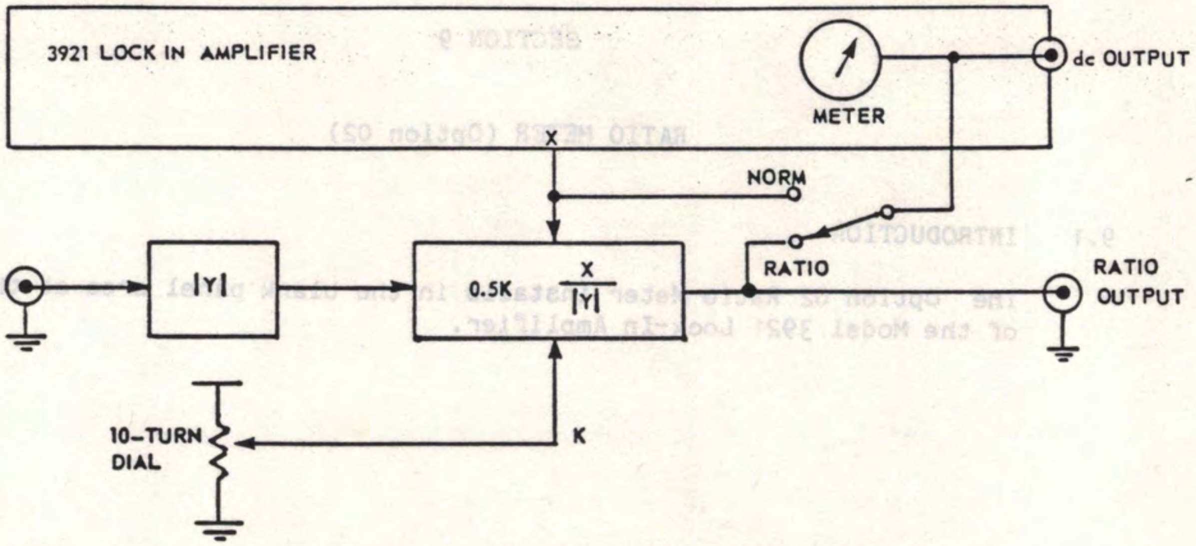


Figure 9.2 RATIO METER BLOCK DIAGRAM

9.2 SPECIFICATIONS

Operating ranges:

$$10\ \text{mV} \le X \le 10\text{V}$$
$$100\ \text{mV} \le Y \le 10\text{V}$$
$$0.50 \le K \le 10.50$$
$$0 \le E_o \le +11\ \text{V} \quad \text{(max output)}$$
$$0 < \frac{X}{|Y|} \le \frac{20}{K} \quad \text{(without overload)}$$

Accuracy (typical):

±0.2% of full scale (1V ≤ Y ≤ 10V)
±2.0% of full scale (0.1V ≤ Y ≤ 1V)

Where 10 mV ≤ X ≤ 10V, K = 10.00 and full scale E_o = 10V.

K factor dial accuracy ±1%

Output Stability (typical):

With respect to a full scale output E_o = 10 V:

K = 10 X = |Y| = 0.1 V 15 ppm/°C (typ)

K = 10 X : |Y| = 1:2 5 ppm/°C (typ)

K = 10 X : |Y| = 2:1 10 ppm/°C (typ)

Input/Output:

Y Input	BNC Connector, 1 mΩ impedance
Ratio Output	BNC connector, 5 KΩ impedance

With K=10 and X=|Y|, the Ratio Meter yields a 5 V dc output. This would cause a half scale reading on the METER (i.e., "1" on the 0 to 2 ratio scale).

9.3 INSTALLATION

When ordered together, the Model 3921 Lock-In and the Option-02 Ratio Meter will be assembled and ready to operate. To install a separately purchased Ratio Meter, follow these steps:

1. Unpack Ratio Meter from carton and inspect for damage and loose components. The carton should also contain a BNC - BNC cable and a multiconductor connection cable with three plugs.

2. Remove the two molded plastic pieces from the rear of the instrument (4 screws) and slide back top cover.

3. Remove blank panel from rear of instrument (2 screws) and replace with Ratio Meter. Install connecting cable as shown in Figure 9.3 (connectors are keyed).

4. Replace top cover and rear molded pieces.

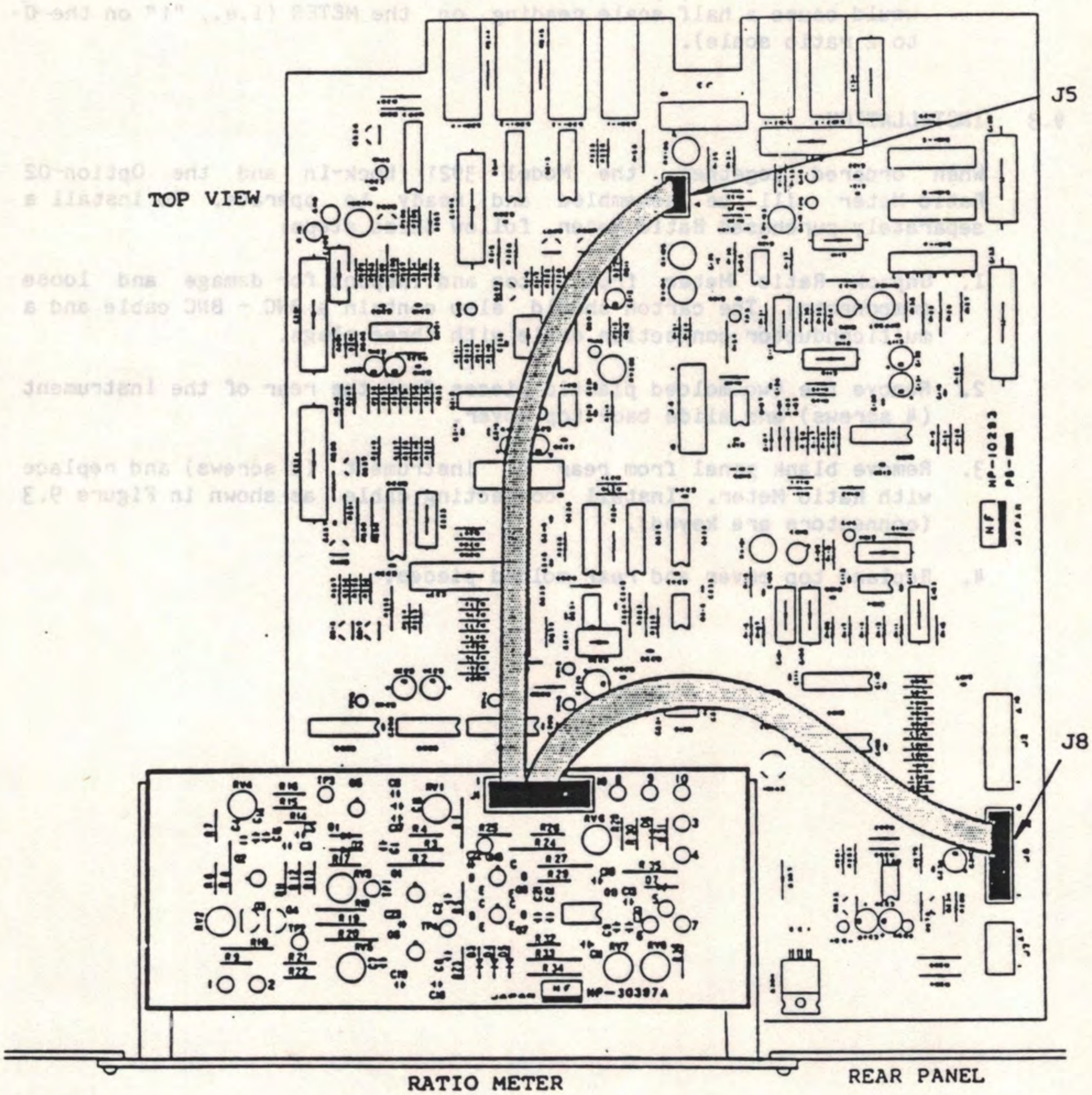


Figure 9.3 RATIO METER CONNECTION

9.4 OPERATION EXAMPLE

This section describes a dual beam, dual lock-in optical system. This type of setup gives the most accurate results but others are possible, as described in ITHACO Applications Note IAN 37.

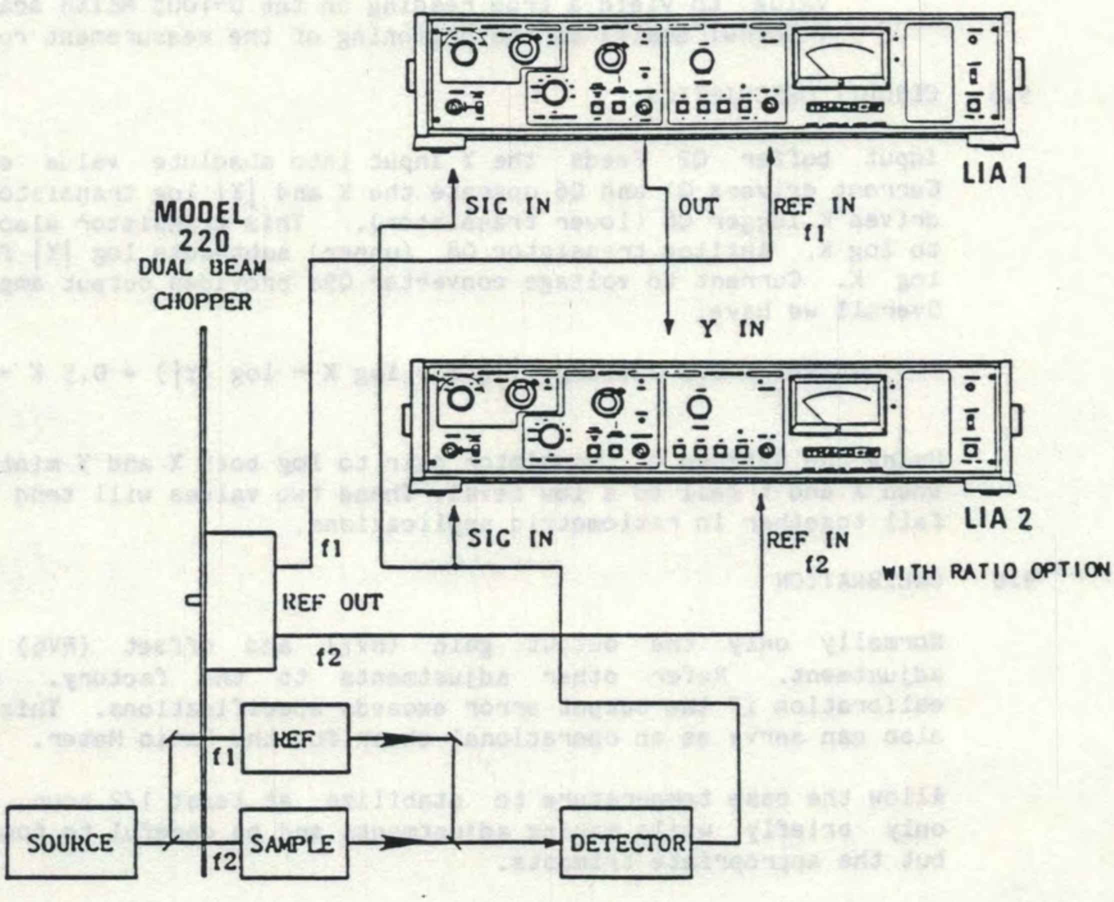


Figure 9.4 DUAL BEAM, DUAL LOCK-IN RATIOMETRIC OPTICAL SYSTEM

9.4.1 DUAL BEAM SETUP

A half mirror splits the source beam. The dual row chopper blade modulates the beams at two separate frequencies f_1 and f_2. After the signal beam f_2 passes through the experiment, a second half mirror recombines the beams to fall on a single detector. The detector output feeds to a pair of lock-in amplifiers. LIA #1 is supplied a synchronizing frequency f_1 and responds to the reference beam (Y). LIA #2 is synchronized at f_2 and responds to the experimental signal beam (X). The output of LIA #1 contains fluctuations due to source & detector instability. When its output feeds to the Ratio Meter in LIA #2, the quotient will cancel the corresponding instabilities in X, leaving only the changes due to the actual experiment in the RATIO Output. For accurate cancellation of rapid fluctuations, you must have the TIME CONSTANT and POST FILTER set the same on both lock-ins.

Next set the K value to obtain an easily read ratio output. When making relative measurements from a starting condition, adjust for an output of 1 on the 0-2 METER scale or 5.00 V on the 0-10 V OUTPUT connector. When making absolute measurements, adjust the K value to yield a true reading on the 0-100% METER scale (or 0-10 V OUTPUT scale) at the beginning of the measurement run.

9.5 CIRCUIT DESCRIPTION

Input buffer Q2 feeds the Y input into absolute value circuit Q5. Current drivers Q1 and Q6 operate the X and |Y| log transistors Q7. Q9B drives K logger Q8 (lower transistor). This transistor also adds log X to log K. Antilog transistor Q8 (upper) subtracts log |Y| from log X + log K. Current to voltage converter Q9a provides output amplification. Overall we have:

$$\text{OUTPUT} = 0.5 \text{ antilog } (\log X + \log K - \log |Y|) = 0.5\ K \frac{X}{|Y|}$$

Using the matched Q7 transistor pair to log both X and Y minimizes error when X and Y fall to a low level. These two values will tend to rise and fall together in ratiometric applications.

9.6 CALIBRATION

Normally only the output gain (RV7) and offset (RV6) will need adjustment. Refer other adjustments to the factory. Make field calibration if the output error exceeds specifications. This procedure also can serve as an operational check for the Ratio Meter.

Allow the case temperature to stabilize at least 1/2 hour. Open cover only briefly while making adjustments and be careful to touch nothing but the appropriate trimpots.

1. Open case per Section 9.3 #2.

2. Apply a 400 Hz signal and reference to the Lock-In and set MULT for a 10.00 volt X reading on the OUTPUT BNC (NORMAL/RATIO = NORMAL).

3. Apply 10.000 V to the Y input and set K to 10.00.

4. Adjust RV7 (K-ADJ) for a 5.00 V output on the RATIO output (can be measured on front panel BNC by switching NORMAL/RATIO to RATIO).

   A reading between 4.95 and 5.05 is within tolerance.

5. With NORMAL/RATIO = NORMAL, decrease the signal to the lock-in by approximately 60 dB to achieve a 10.00 mV reading at the OUTPUT BNC (use MULT control) (Y = 10.000 V).

6. Adjust RV6 (OFFSET) for a 5 mV reading on the RATIO output. (NORMAL/RATIO = RATIO).

   A reading between .0045 and .0055 volts is within tolerance.

7. Replace cover and rear molded pieces.

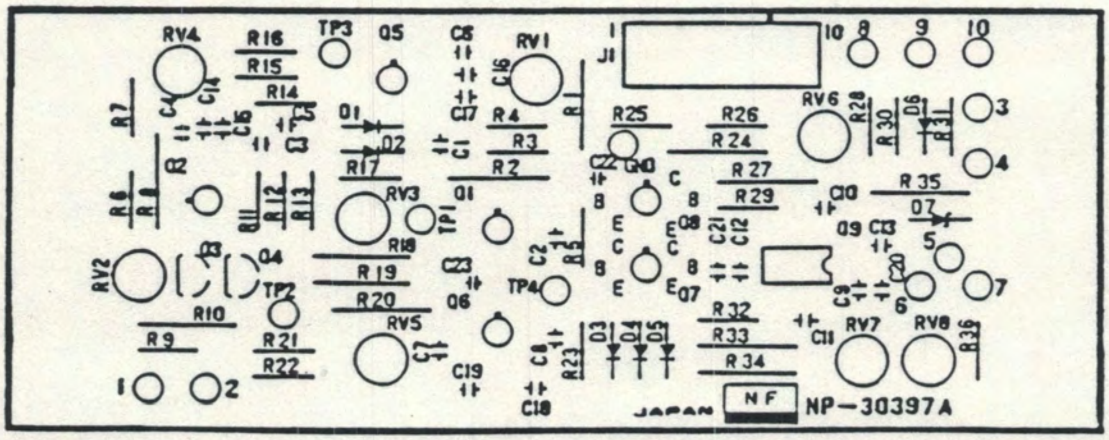


Figure 9.5 RATIO METER COMPONENT LOCATION

WARRANTY

LOCK-IN AMPLIFIERS AND ACCESSORIES

ITHACO, Inc. warrants each instrument to be free of defects in material and workmanship for a period of two years, unless otherwise specified, after shipment to the original purchaser; batteries and light beam choppers are specifically excluded. Liability under this warranty is limited to repairing or adjusting any instrument returned to the factory for that purpose. The warranty of this instrument is void if the instrument has been modified other than in accordance with written instructions from ITHACO, or if defect or failure is judged by ITHACO to be caused by abnormal conditions of operation, storage or transportation.

This warranty is subject to verification by ITHACO, that a defect or failure exists, and to compliance by the original purchaser with the following instructions:

1. **Before returning the instrument, notify ITHACO with full details of the problem; including the model number and serial number of the instrument involved.**

2. **After receiving the above information, ITHACO will give you shipping instructions or service instructions. After receipt of the shipping instructions, ship the instrument to ITHACO. Full liability for damage during shipment is borne by the purchaser. It is recommended that instruments shipped to us be fully insured and packed surrounded by at least 2 inches of shock-absorbing material.**

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

This warranty is expressly in lieu of all other obligations or liabilities on the part of ITHACO, and ITHACO neither assumes, nor authorizes any other person to assume for it, any liability in connection with the sale of ITHACO instruments.

ITHACO INC.
735 West Clinton Street
P O Box 6437
Ithaca, New York 14851-6437
Phone 607-272-7640