INSTRUCTION AND MAINTENANCE MANUAL

ITHACO MODEL 391

DYNATRAC$^{T.M.}$ LOCK-IN AMPLIFIER

ITHACO INC
735 West Clinton Street
Ithaca, New York 14850
Phone 607-272-7640

TABLE OF CONTENTS

FIGURES AND TABLES

DRAWINGS

2.1 INSTALLATION

Since the DYNATRAC[T.M.] 391 Lock-In Voltmeter is intended mainly as bench top equipment, the only installation that is required is to connect it to a power source (see 2.2 Power and Grounding).

For those installations where rack mounting is desired, a 391S1 Rack Mounting Kit is available and should be installed, with the screws provided, in place of the two small trim panels located near the front of the unit.

2.2 POWER AND GROUNDING

Unless otherwise specified, all units are shipped wired for 100 - 130 Volts 50-400 Hz with a six foot three conductor power cord equipped with a grounded plug. It is recommended that the power cord always be connected to a grounded power source.

DYNATRAC voltmeter units may be specified wired to 200 - 260 volts 50 - 400Hz or they may be user modified according to the following procedures:

1. Disconnect unit from power source.
2. Locate TB101 on rear panel near power transformer.
3. Remove the two Buss wire jumpers from terminals 1 to 2 and 3 to 4.
4. Add a Buss wire jumper from terminal 2 to 3.
5. Remove the 1/2 amp slo-blo fuse and replace it with a 1/4 amp slo-blo fuse.

The above procedure is reversed when changing back to 115 volt operation.

[T.M.] Trademark ITHACO Inc.

3.1 GENERAL

The 391 will measure a signal that is locked in frequency and phase to the reference signal. It is capable of extremely narrow bandwidths, and does not respond to harmonics of the reference signal. The reference is normally supplied from an external source (EXT mode) by the user, but may also be derived from a built-in sine wave oscillator (INT mode), the output of which is used in the experiment.

3.2 FREQUENCY RANGE

The frequency range of the 391 is determined by the particular set of four plug-in cards used. The cards are identified by color coding as shown on Table 3.1. Each set of plug-ins covers a two decade range, and the decade desired is selected by a front panel switch.

A frequency range label is included with the plug-ins and should be fastened to the front panel with the two screws provided. Table 3.1 lists the performance of each frequency range.

The choice of plug-in depends on the particular experiment. If high noise levels are present it is advisable to choose the plug-in set of the lowest possible frequency. The same rule applies if very low drift is required. It is not recommended to use the High Dyn mode with the 10 - 100 kHz (green) plug-in set. For operation below 20 kHz where a high dynamic range is required the yellow plug-in set is preferred.

When changing the plug-in, follow this procedure (after disconnecting the power cord):

1. Unscrew the 4 screws holding the top panel in place. Slide back the top panel.

2. Replace each of the four cards one by one. The connectors are keyed to prevent incorrect installation. Note the color coding, all cards of a plug-in set must be coded with the same color.

3. Replace the top panel and the 4 screws.

4. Replace the frequency range label on the front panel.

3.3 OPERATION

3.3.1 EXTERNAL MODE

In the EXT mode the experiment must supply a suitable reference

COLOR CODE	NOMINAL FREQUENCY RANGE (Hz)	USABLE FREQ. RANGE EXT MODE (Hz)	USABLE FREQ. RANGE INT MODE (Hz)	LP CUTOFF FREQ (Hz)	IF FREQ (Hz)	IF BW (Hz)	MAX SETTLING TIME	MAX SWEEP RATE Hz/sec	MIN SWEEP TIME f TO 10f (S)	REMARKS
BROWN	.1 – 1 1 – 10	.1 – 2 .5 – 20	.1 – 1.1 1 – 11	25	55	±1	15 min 100 sec	7×10^{-5} .007	13000 1300	
RED	1 – 10 10 – 100	.5 – 20 5 – 200	1 – 11 10 – 110	250	550	±10	100 sec 10 sec	.007 .7	1300 130	
ORANGE	10 – 100 100 – 1K	5 – 200 50 – 2K	10 – 110 100 – 1.1K	2.5K	5.5K	±100	10 sec 1 sec	.7 70	130 13	
YELLOW	100 – 1K 1K – 10K	50 – 2K 500 – 20K	100 – 1.1K 1K – 11K	25K	55K	±1K	1 sec .1 sec	70 7K	13 1.3	
GREEN	10K – 100K	5K – 200K	10K – 110K	250K	480K	±10K	.01 sec	700K	.13	Do not use HI DYN mode in this Freq Range

TABLE 3.1 391 PLUG-IN CARDS

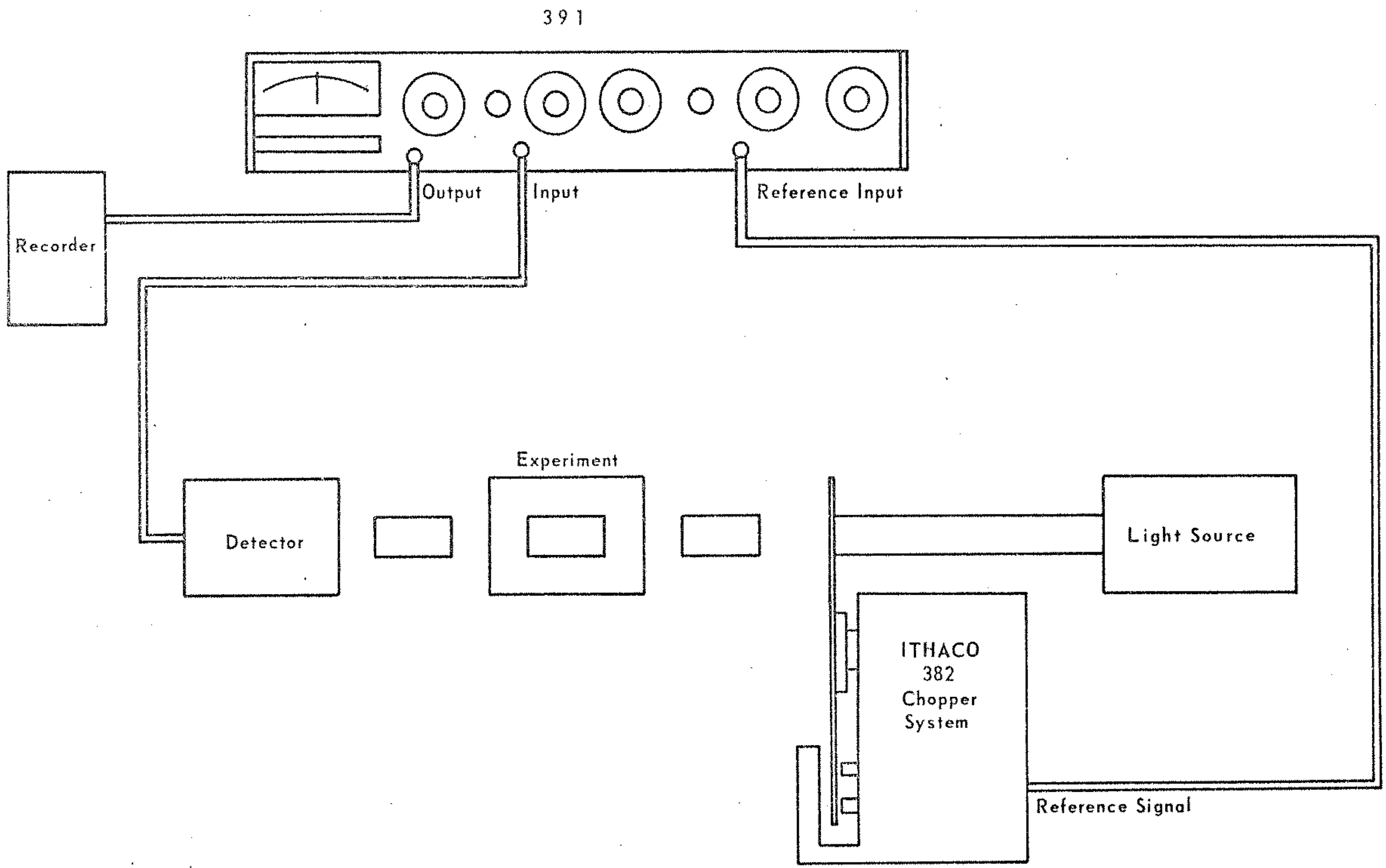


FIGURE 3.1   391 CONNECTION IN EXT MODE

setup. A chopper modulates a light beam and supplies a reference signal locked in frequency to the modulation. The photo detector detects the modulated light beam and delivers an AC signal which frequently is too weak to be detected by conventional AC voltmeters. The 391 can, however, extract the signal from noise and give an accurate reading of the detected signal. The DC output of the 391 is here connected to a recorder in order to obtain a permanent record.

The requirements to the reference signal are: .1 to 10 Vpp and two zero crossings per cycle. Any waveforms satisfying these conditions may be used. No level adjustment or tuning is necessary. The REF UNLOCK light on the front panel indicates when the 391 is out of lock.

The 391 tracks the reference frequency with an insignificant phase error throughout the nominal frequency range. Figure 3.2 shows the typical phase error for the 10 Hz - 1 KHz (orange). When operating outside the nominal range a slight phase adjustment is required.

The 391 may be used with a swept reference frequency providing the maximum sweep rate is not exceeded. Table 3.1 gives the maximum sweep rate and the minimum time to sweep the nominal frequency range. The sweep rate values in Table 3.1 are maximum values that will produce insignificant phase errors. Faster sweep rates are possible with the DYNATRAC Lock-In Voltmeter and as long as the sweep rate remains constant, any phase error will remain constant.

After a sudden change in frequency the reference circuits take a certain time to settle. The maximum settling time is given in Table 3.1 for each frequency range. When using the lowest range of a plug-in, settling time can be reduced by switching to the highest range at ten times the frequency (INT mode). After settling, switch back to the lowest range.

3.3.2 2F MODE

With the reference mode switch in the 2F position, the 391 measures the signal component at the second harmonic of the reference frequency. The condition for proper operation is that both the fundamental and the second harmonic are within the usable frequency range. The rejection of the fundamental is mainly limited by the second order distortion of the experiment and the signal amplifiers. It is advisable to keep input levels low.

Otherwise operation and performance are identical to the EXT mode.

signal to the 391 reference input. Figure 3.1 shows a typical

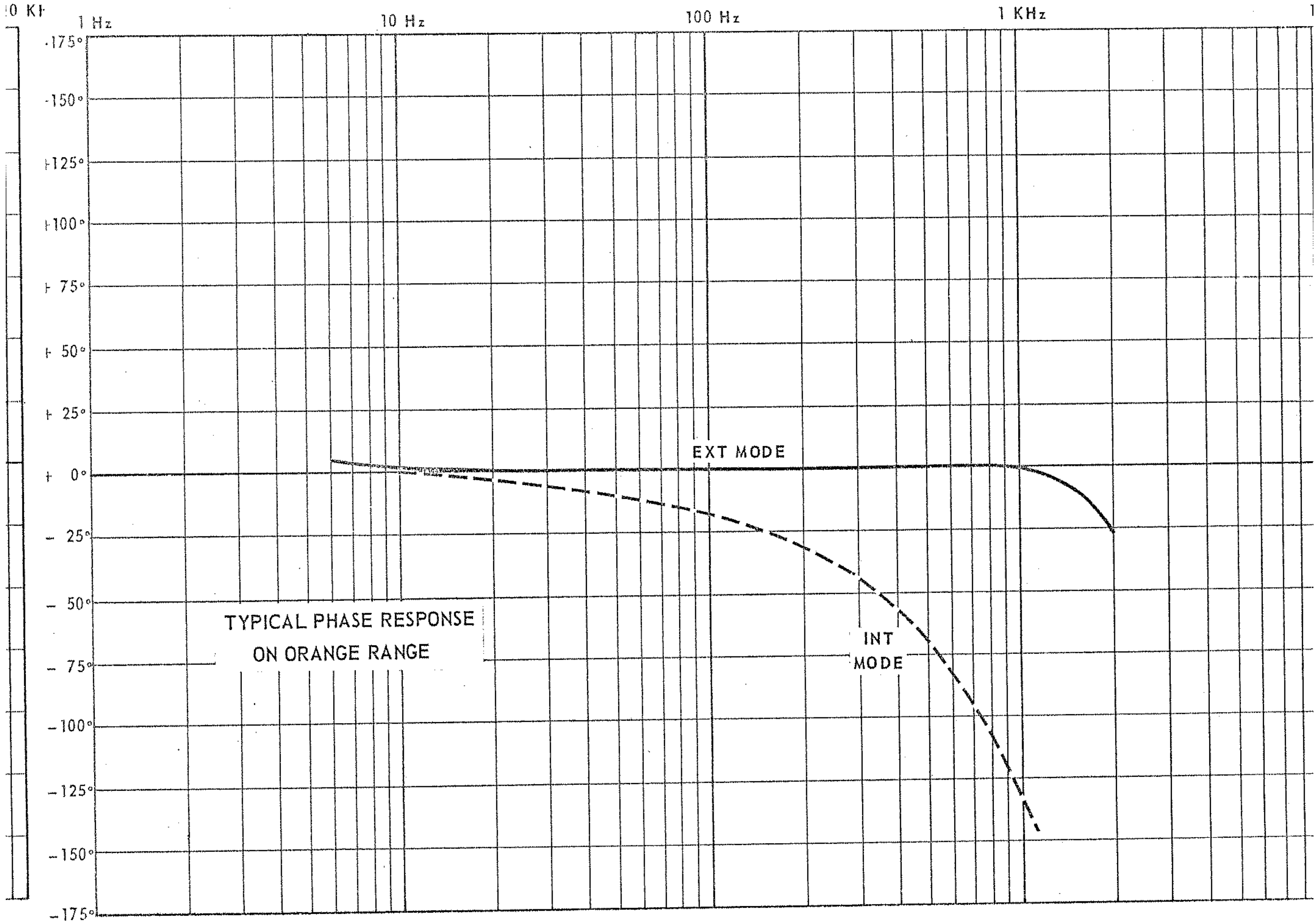

1 Hz
10 Hz
100 Hz
1 KHz
+175°
+150°
+125°
+100°
+ 75°
+ 50°
+ 25°
+ 0°
– 25°
– 50°
– 75°
–100°
–125°
–150°
–175°
EXT MODE
INT MODE
TYPICAL PHASE RESPONSE
ON ORANGE RANGE

FIGURE 3.2

In the INT mode an internal generator delivers the reference signal which is a sine wave adjustable with the level control from 0 to appr 1 V rms. The user may use it to control his experiment. A typical setup is shown in Figure 3.3. The frequency is adjusted with the frequency control and covers the nominal frequency range with a digit overlap as shown on Table 3.1. The phase compensation circuit does not operate in the INT mode and it is therefore necessary to readjust the phase controls after changing frequency. Figure 3.2 shows the phase error response for the INT mode.

Since the 391 design is optimized for operation in the EXT mode, it is recommended to use an external reference source if available.

3.3.4 PHASE ADJUSTMENT

The phase controls of the 391 provide adjustment over 370°.

A continuous control covers 0° to 100° while one switch shifts 90° and another switch shifts 180°. The total phase shift is obtained by totaling the shift of the three circuits.

In many experiments the signal has unknown phase so the phase controls must be adjusted to "peak" the signal. A convenient (and usually more accurate) way of accomplishing this is to adjust the phase controls for a null and then switch the 0°/90° switch to the other position. The output will then be maximum, but if the polarity is wrong, simply operate the 0°/180° switch to its other position.

3.4 INPUT CONNECTIONS

Proper connection of the 391 input is very important when measuring low signal levels. The floating input stage reduces the possibility of disturbing ground loops. The ground of the input stage must always be connected to the 391 chassis ground with a low impedance in order to ensure proper operation. If the voltage difference between the two grounds exceeds a few volts, the overload light will go on. A shorting bar is provided for shorting the two grounds if there is no ground connection through the experiment.

The 391 input is not a differential input, but may be used as such provided that the ground signal has a low source impedance (and resistance). If differential inputs are essential, it is recommended to use a differential preamplifier. Differential inputs are commonly used only to break ground loops, but the floating input of the 391 solves these problems in a more convenient way.

The overload light will indicate any overload condition including excessive ripple on the output voltage. If the light is on check all connections and

3.3.3 INT MODE

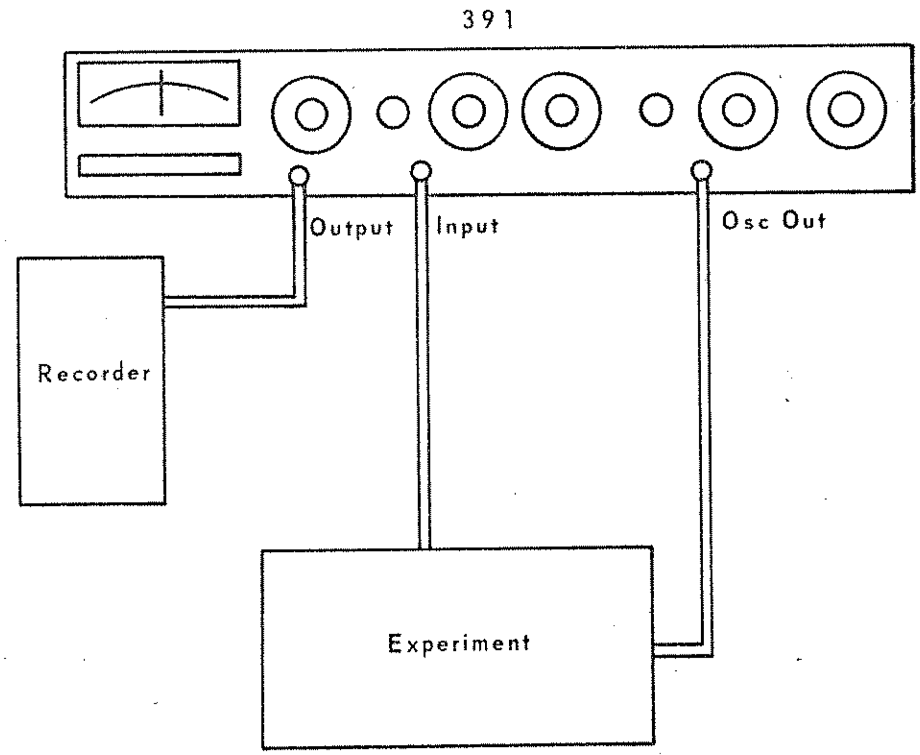


FIGURE 3.3 391 CONNECTION IN INT MODE

are:

- Sensitivity is too high causing the output to go off scale.

- Time constant too low so that the output amplifier is overloading on the peaks of the AC component (ripple).

- A non-synchronous signal is overloading somewhere in the signal path. Note that the overload level is highest in the HY DYN mode.

3.5 VOLTAGE CALIBRATION

An accurate signal for checking the calibration of the 391 is provided on the front panel. It is a square wave adjusted in the factory to have a fundamental frequency component of 10 mV rms ±1%. To check calibration simply connect the CAL output to the input with a short cable, adjust the phase controls to zero reading, switch the phase 90° to obtain a full scale 10 mV reading. Note that the calibrate signal is not in phase with the reference signal in the EXT mode.

3.6 NOISE MEASUREMENTS

The 391 provides the user with the possibility of measuring noise. With the mode switch in the NOISE position, the meter indicates the noise voltage on the input (including the 391 self-noise) measured at the effective noise bandwidth indicated on the time constant switch. The reading is accurate to 5% for a gaussian noise. The smoothing time constant is set at 1 sec and the noise mode should therefore not be used at noise bandwidths less than 10 Hz.

3.7 CONNECTING A REMOTE PREAMP

When it becomes necessary to employ a remote preamp with the 391 the following procedure should be followed:

a) Turn off main power switch.

b) Connect the 391V1 cable to the power connector on the remote preamp.

c) Connect a BNC cable from the remote preamp output BNC to the 391 input BNC.

d) Connect the other end of the 391V1 Cable to the "PREAMP POWER" connector on the 391 rear panel.

e) Reapply main power to the 391 and connect the remote preamp to the experiment.

make sure that the input is properly grounded. The other reasons for overload

If the remote preamp has a direct ground connection from input to output, the 391 front panel grounds should be treated as if there was no preamp, but if there is no ground connection (such as with the 165 in the low Z position) then leave the shorting bar in place on the 391 front panel and treat the preamp input as a floating input.

The 391V1 standard length is six feet. Contact the factory for details on special lengths.

3.7.1 GROUNDS

Units with Serial Numbers prior to 16346

A. Disconnect main power and remove the top cover.

Locate two wires, (one yellow, one white with blue tracer) that are connected to the same terminal on the next to last wafer of the Time Constant switch.

Unsolder the white/blue wire only and resolder it to the left end of R362 located on the A1 board near the front edge right behind the meter.

B. After the above change has been done, all that is necessary to change from -12dB/octave to -6dB/octave is to pull the yellow wire and its socket off pin 81 (front left hand corner of A1 card) reconnecting the pin changes back to -12dB/octave.

NOTE: When the wire is hanging loose, be sure it does not contact any ground or circuitry.

Units with Serial Numbers after 16345, see B above.

4.1 DESCRIPTION

The DYNATRAC 391 Lock-In Voltmeter uses heterodyning in order to improve performance and simplify design. It features extremely low self-noise and excellent rejection of all harmonics of the reference frequency without using a tuned front end filter. In addition to the outstanding performance, the DYNATRAC voltmeter is easy to use and has short settling times in most frequency ranges.

4.2 SIGNAL CHANNEL

A simplified block diagram of the 391 is shown in Figure 4.1. The input signal is amplified by the preamplifiers and the variable gain signal amplifier before the first mixer. A LP filter inserted between the amplifiers and the mixer serves to attenuate IF and image frequencies. It also attenuates noise and unwanted frequencies above the frequency range that could cause overload.

The first mixing of the signal occurs in the signal mixer. The injection frequency is

$$f_V = f_O + f_r$$

If the signal has the frequency f_S, the mixer output consists of the frequencies:

$$f_O + f_r - f_S \quad \text{and} \quad f_O + f_r + f_S$$

Since wanted signals have the same frequency as the reference, the mixer output is:

$$f_O \quad \text{and} \quad f_O + 2f_r$$

The first of the two mixer products is equal to the constant frequency f_O and is selected by the narrow bandpass filter before being detected in the synchronous detector.

The signal mixer outputs are differential and are fed to the differential amplifiers. The preamp, signal amp, LP filter and signal mixer are all supplied from a separate floating power supply. Any voltages on the input ground caused by ground loops will appear as common mode voltages on the differential amplifier inputs and are therefore cancelled. The DYNATRAC voltmeter may be operated in a differential input mode providing that the input ground is connected to a low impedance source.

Any synchronous detector will have a frequency dependent offset. In a regular

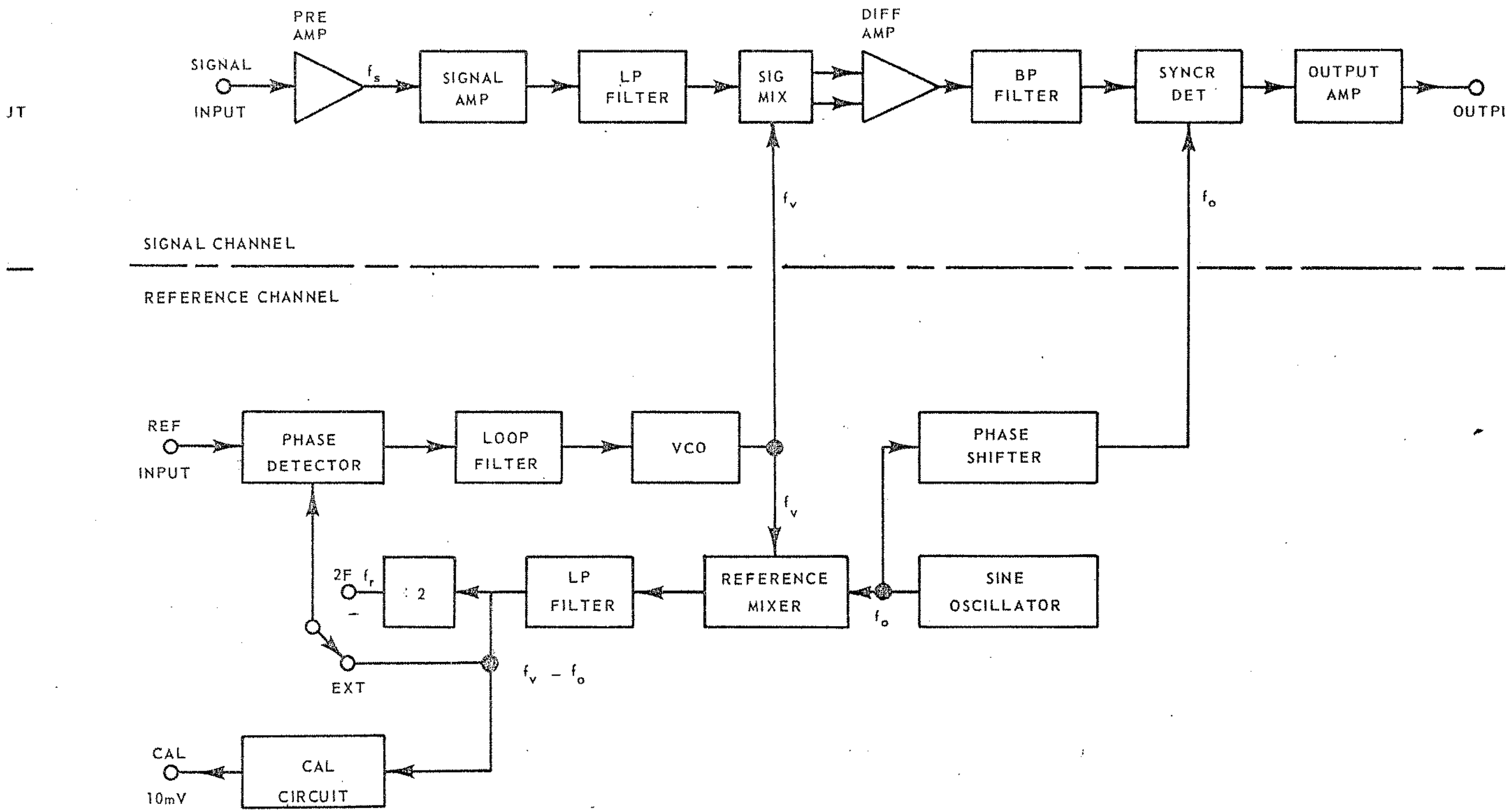


FIGURE 4.1 DYNATRAC 391 LOCK-IN VOLTMETER, EXT 2F MODES

readjustment. Since the synchronous detector in the DYNATRAC voltmeter operates at a constant frequency, this readjustment is not required. The bandpass filter is also at a fixed frequency thus increasing its stability and simplifying operation. The bandpass filter also attenuates most noise and unwanted signals because, referred to the signal input, it acts as a filter which tracks the reference frequency.

One significant advantage of the DYNATRAC system is the fact that harmonic relationships DO NOT EXIST after the first mixing. A harmonic of the reference frequency will not be a harmonic of the f_o after the signal mixer and will therefore not be detected by the synchronous detector.

The output amplifier is a two pole (12 dB per octave) low-pass amplifier with switchable time constant and gain. Three gains are available permitting the best trade off between stability and dynamic range.

4.3 REFERENCE CHANNEL

The reference circuits supply the required injections for the signal mixer and the synchronous detector. Figure 4.1 shows the reference circuits in the EXT and 2F modes.

The reference mixer mixes the VCO signal f_V with the sine wave f_o. The low-pass filter selects the difference frequency, and since the mixer operates linearly with respect to the f_o signal which is sinusoidal, the output is also sinusoidal. This internally generated reference signal is compared to the external reference in the phase detector. The error is amplified by the loop filter and corrects the VCO (Voltage Controlled Oscillator) frequency. The phase detector used includes a phase compensation circuit that controls the phase error caused by the two low-pass filters (in signal and reference channels).

The internally generated reference also drives the CAL circuit which delivers an accurate square wave with a 10 mV fundamental. (The DYNATRAC voltmeter only measures the fundamental in contrast to most lock-in amplifiers. The CAL signal is therefore adjusted to 11.1 mV amplitude.)

In the 2F mode the internal reference frequency is divided by two before the phase detector. This causes the DYNATRAC voltmeter to detect the second harmonic of the reference with excellent rejection of the fundamental.

In the INT mode (Figure 4.2) the phase detector is replaced by a frequency to voltage converter thus permitting the DYNATRAC voltmeter to generate its own reference. The frequency is adjustable with a front panel control and is available at the "OSC OUT" connector on the front panel. When operating in the INT mode, the phase control must be readjusted if the frequency is changed because the phase compensation circuit is bypassed.

In the EXT/2F modes, a front panel light indicates when the phase lock loop is not locked either due to missing reference, out of range reference or

lock-in amplifier each frequency change may therefore require an offset

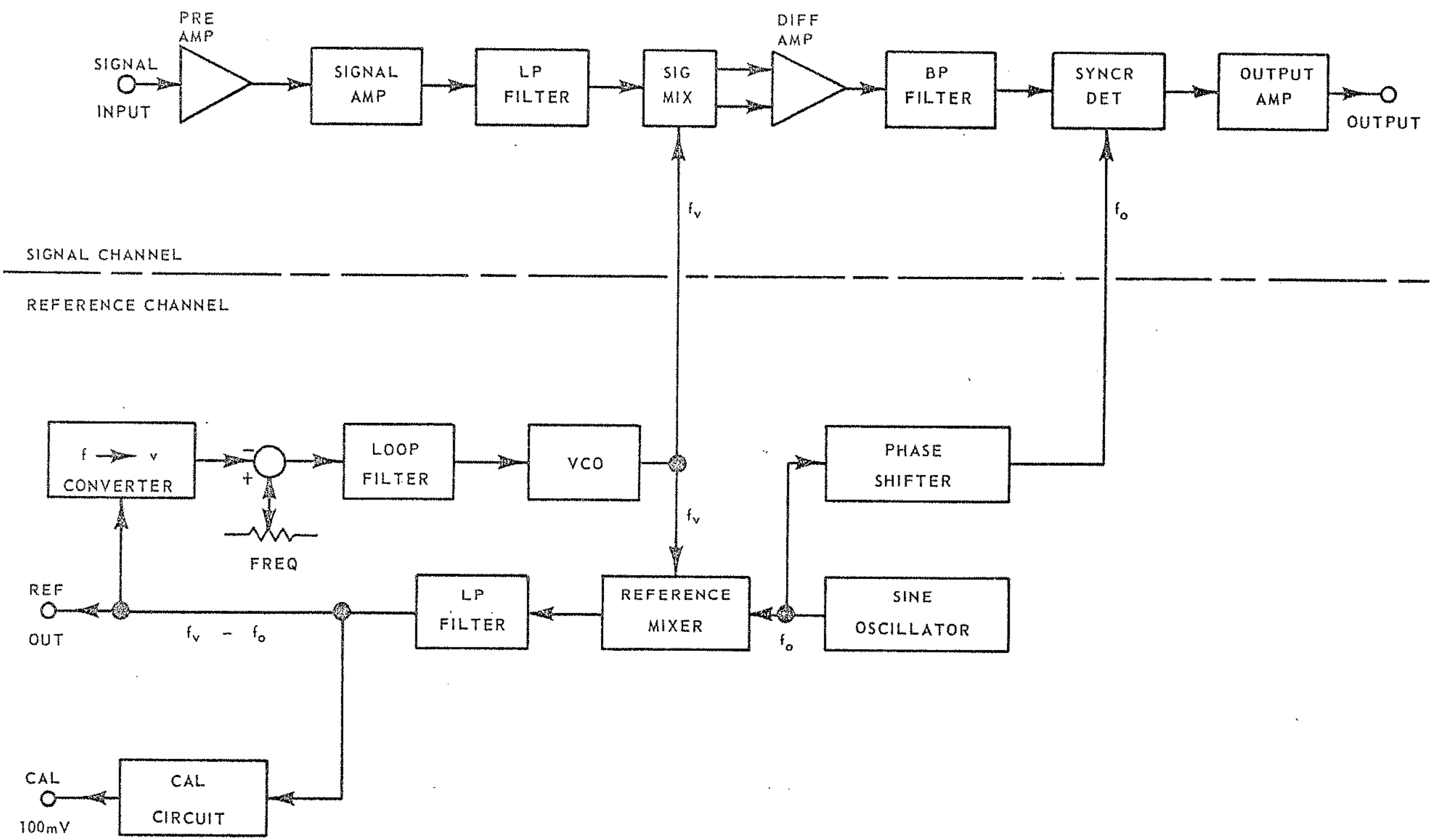


FIGURE 4.2 DYNATRAC 391 LOCK-IN VOLTMETER, INT MODE

because the loop has not yet settled. (The setting time may be as long as 15 minutes when using the .1 to 1 Hz range.) A false lock is possible when feeding in reference frequencies above the frequency range. This error is not normally indicated by the unlock light.

4.4 OVERLOAD DETECTOR CIRCUITS

The DYNATRAC voltmeter includes nine overload detectors at critical points, throughout the signal path. Independent positive and negative detectors are used in order to insure detection of asymmetrical waveforms. The overload light on the front panel indicates overload conditions.

4.5 NOISE MODE

A noise detector circuit is included in the DYNATRAC voltmeter. In the noise mode the meter will indicate the rms noise voltage at the input measured with the noise bandwidth setting of the time constant switch.

because the loop has not yet settled. (The setting time may be as long as 15

5.1 CALIBRATION OF PLUG-IN CARDS

This procedure assumes that the 391 main frame is properly calibrated* and should be used whenever a set of cards not calibrated for the particular unit is installed.

5.2 INSTRUMENTS REQUIRED:

Digital DC Voltmeter
Audio Generator
AC Voltmeter
40dB (100:1) Attenuator
Oscilloscope (or Chart Recorder for .1 to 10 Hz set)
Frequency/Period Counter

5.3 INITIAL SET-UP - Step 1

Install the plug-in cards. Refer to Figure 5.1 for locations. Set the 391 as follows:

Time Constant Switch:	.4 s position (4 s for 1 to 100 Hz range) (40 s for .1 to 10 Hz range)
Mode Switch:	HI DYN RANGE
Sensitivity Switch:	10mV position
Zero Suppress:	Off
Frequency Range Switch:	lower decade
Ref. Mode:	INT
Ref. Level Control:	Full CW
Phase Control:	0°
Phase Switches:	both 0°

Let the 391 warm up for 30 minutes with the top cover in place.

5.4 VCO ZERO ADJUSTMENT - Step 2

Short anode of CR618 to the junction of R630 and R631. They are located just to the left of the A402 (PLL OSC) plug-in card. Connect oscilloscope (or the chart recorder) to the reference output. Adjust R1102 (on A402) for zero beat on the scope.

Remove the short.

*Main frame calibration instructions will be sent at a later date

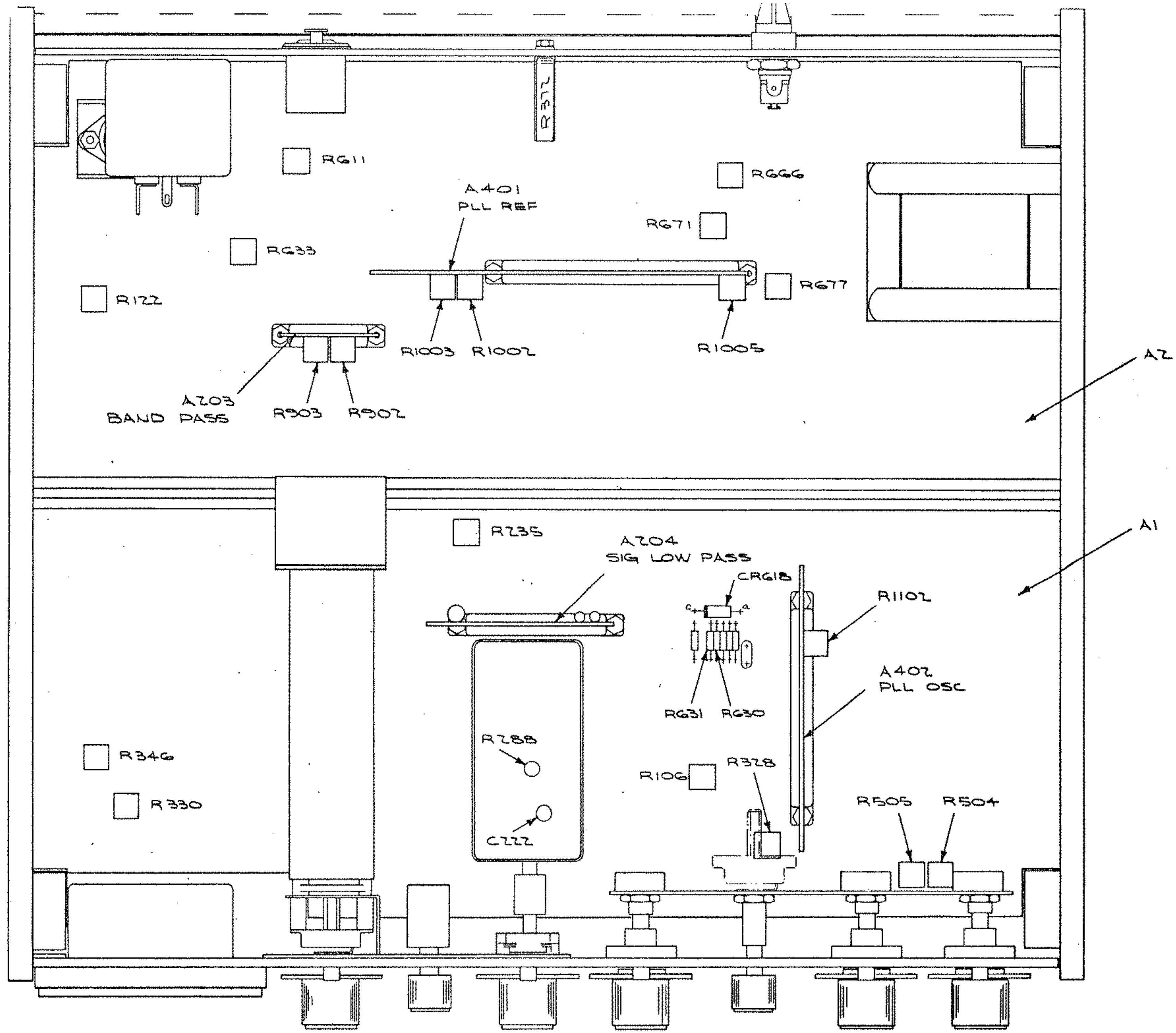


FIGURE 5.1 391 C'LIBRATION COMPONENT LOCATION

Change 391 settings as follows:

Frequency Range Switch:	Upper Decade
Reference Mode:	EXT

Connect 1V rms at fa (see Figure 5.2) to the REF input.

Short the 391 input connector and make sure the ground jumper is in place. Connect the DVM (±10V range) to the 391 output connector. Adjust the rear panel offset trimmer (R372) for zero reading on the DVM.

5.6 PHASE/GAIN CALIBRATION - Step 4

Change 391 settings as follows:

Mode:	NORM

Connect the generator output through the 40 dB attenuator to the AC voltmeter and adjust the generator level to 10 mV rms reading on the AC voltmeter. (Do not remove the connection to the 391 REF input). Connect the 10 mV signal to the 391 input connector and remove the ground jumper.

a) Switch the 0°/90° switch to 90° and adjust R903 for zero on the DVM (phase null).

b) Switch the 0°/90° switch to 0° and adjust R902 for 10.0V on the DVM (gain cal).

c) Switch the 0°/90° switch back to 90° and if necessary readjust R903 for zero volts.

d) Increase the frequency of the generator to fb and adjust R1002 for zero on the DVM. <see fig. 5.2

e) Go back to fa (see fig 5.2) and adjust R903 for zero on DVM. Repeat d and e until zero reading is obtained for both frequencies.

At fa repeat a and b if necessary until phase and gain are both correct.

The following adjustment is not required if the AC voltmeter used is accurate to 1% or better.

f) Connect the 391 CAL output to the input (the generator still supplies the reference), adjust the phase controls for zero reading of the DVM, switch the phase 90° and adjust R902 for exactly 10V on the DVM.

5.5 OUTPUT OFFSET ADJUSTMENT - Step 3

RANGE	fa	PERIOD	fb	PERIOD
Brown	1 Hz	1000 MS	10 Hz	100 MS
Red	10 Hz	100 MS	100 Hz	10 MS
Orange	100 Hz	10 MS	1 KHz	1000 μS
Yellow	1 KHz	1000 μS	10 KHz	100 μS
Green	10 KHz	100 μS	100 KHz	10 μS

FIGURE 5.2 CALIBRATION FREQUENCIES

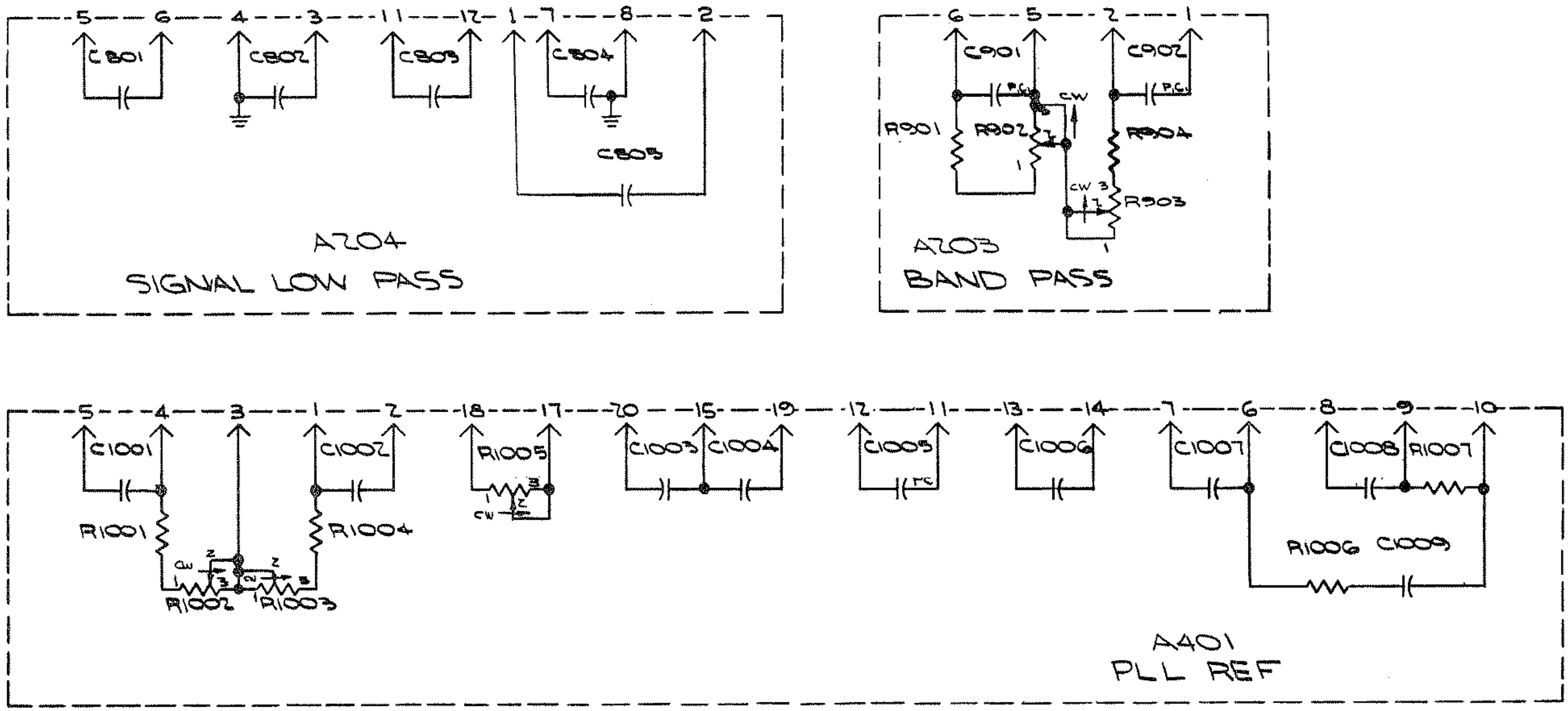
Change 391 settings as follows:

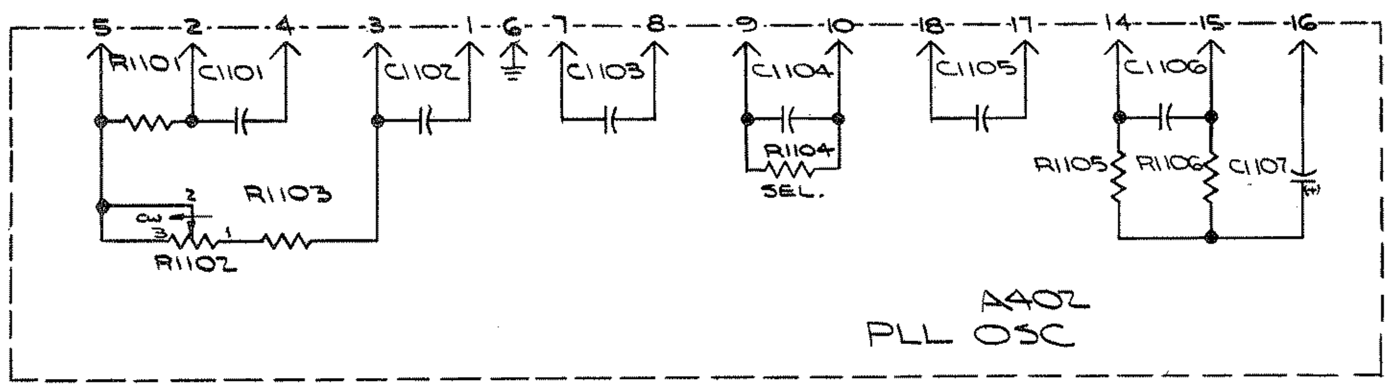
Ref Mode:	INT
Frequency Control:	10.0

Connect the Ref output to the frequency/period counter. Check that the frequency range switch is in the upper decade position. Adjust R1005 until the counter indicates fb. (It is better to measure period time at the lower frequency ranges). Allow the frequency to settle after each adjustment.

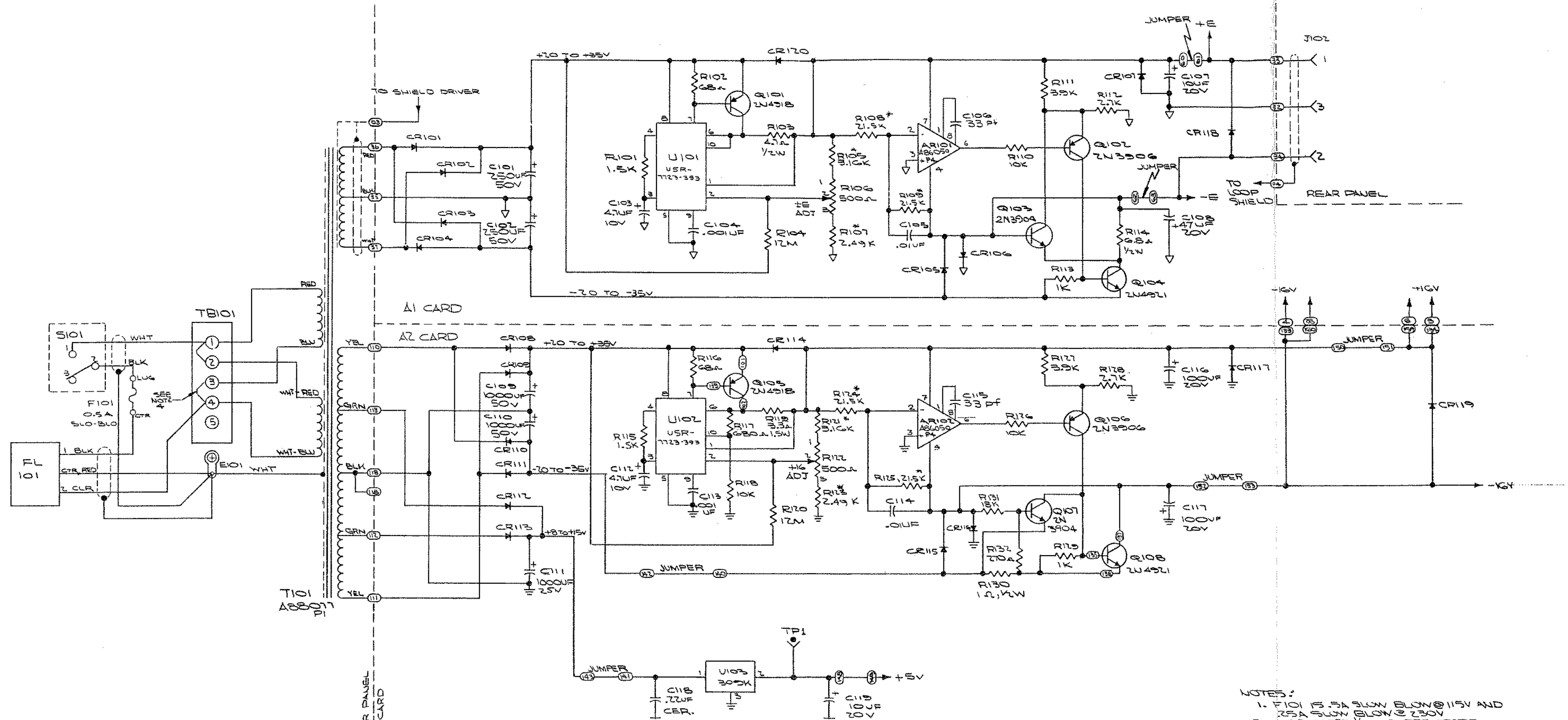
Change the Frequency Range Switch to the lower decade and adjust R1003 for fa. (Delete this adjustment for the green set.)

5.7 INTERNAL MODE FREQUENCY CALIBRATION - Step 5





TYPICAL PLUG-IN
CARD CONNECTIONS
(Values vary with range)

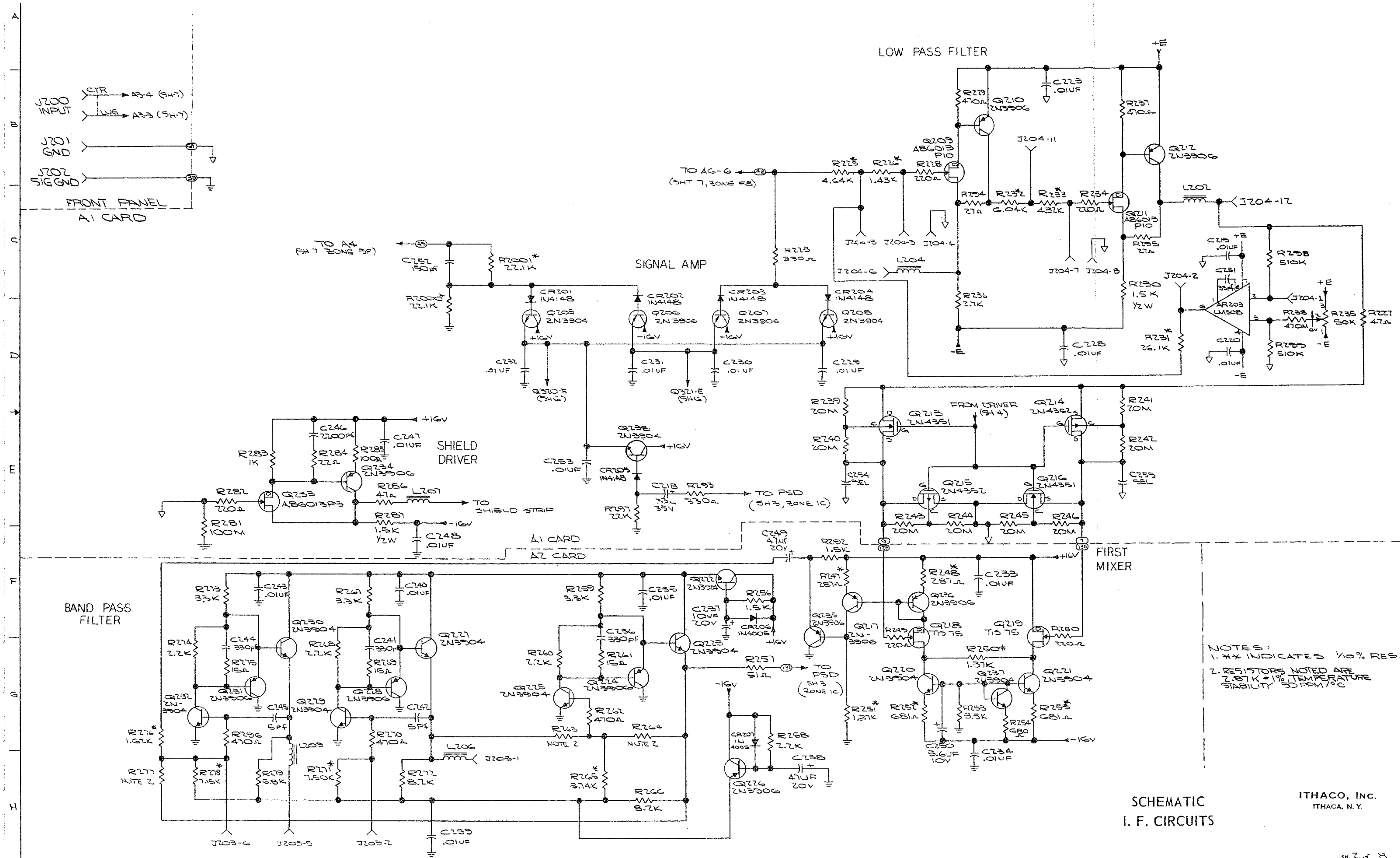


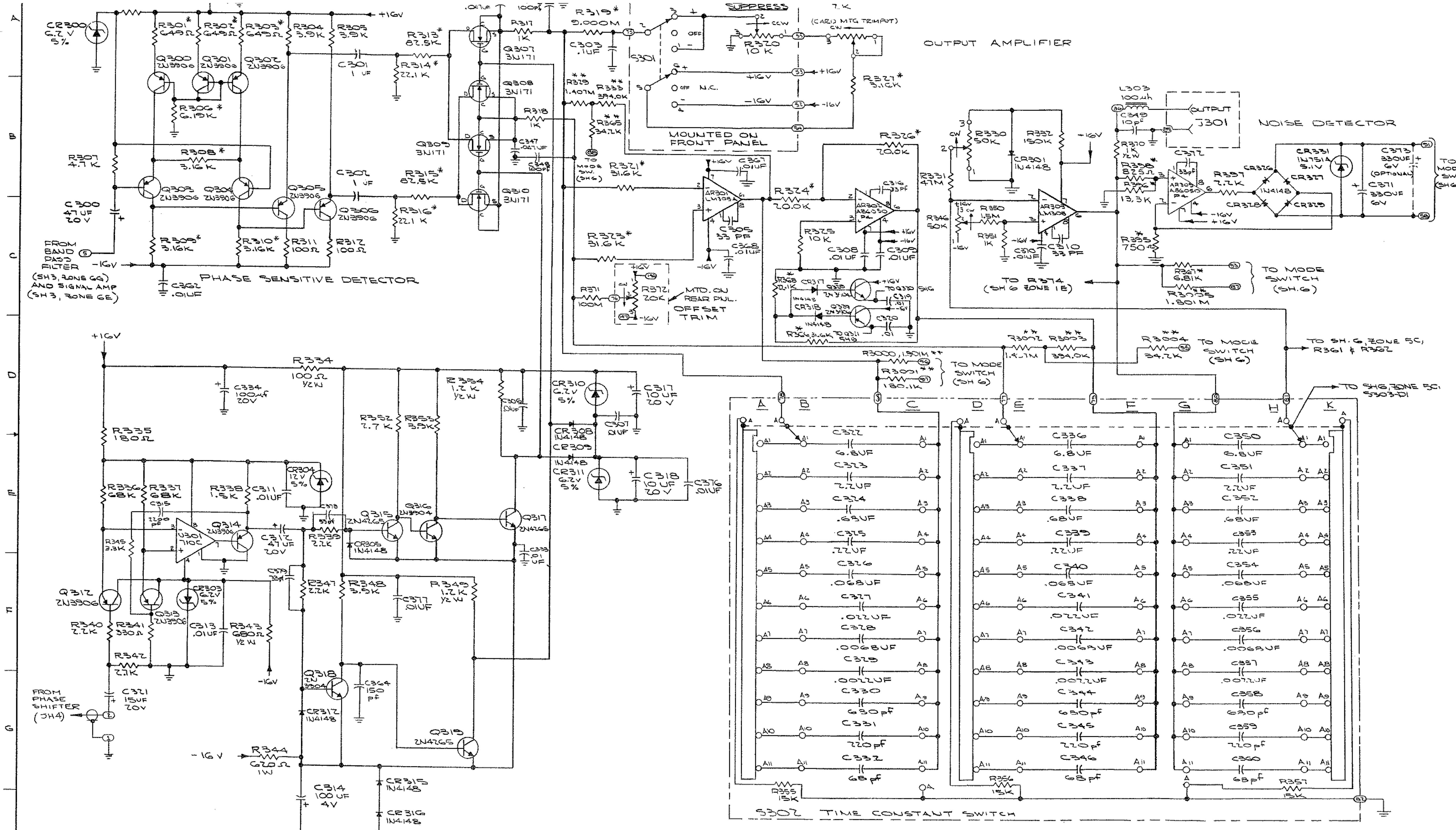
NOTES:
1. F101 IS .5A SLOW BLOW @ 115V AND .25A SLOW BLOW @ 230V
2. * INDICATES 1/8W, 1% RESISTORS
3. ALL DIODES ARE IN4003 (THIS SHEET ONLY)
4. JUMPERS SHOWN ON TB101 ARE FOR 120V OPERATION. FOR 240V OPERATION REMOVE JUMPERS BETWEEN 1 & 2 AND 3 & 4 THEN ADD A JUMPER FROM 2 TO 3

SCHEMATIC
POWER SUPPLY

ITHACO, INC
ITHACA, N. Y.

SH. 1 OF 8


LOW PASS FILTER
SIGNAL AMP
SHIELD DRIVER
FIRST MIXER
BAND PASS FILTER
FRONT PANEL
A1 CARD
A2 CARD
J200 INPUT
J201 GND
J202 SIG GND
TO A6-6 (SHT 7, ZONE E8)
TO A4 (SH 7 ZONE 5F)
TO PSD (SH 3, ZONE 1C)
TO SHIELD STRIP
FROM DRIVER (SH 4)
NOTES:
1. * INDICATES 1/10% RES.
2. RESISTORS NOTED ARE 2.87K ±1% TEMPERATURE STABILITY 50 PPM/°C
SCHEMATIC
I. F. CIRCUITS
ITHACO, INC.
ITHACA, N.Y.
SH. 3 of 8

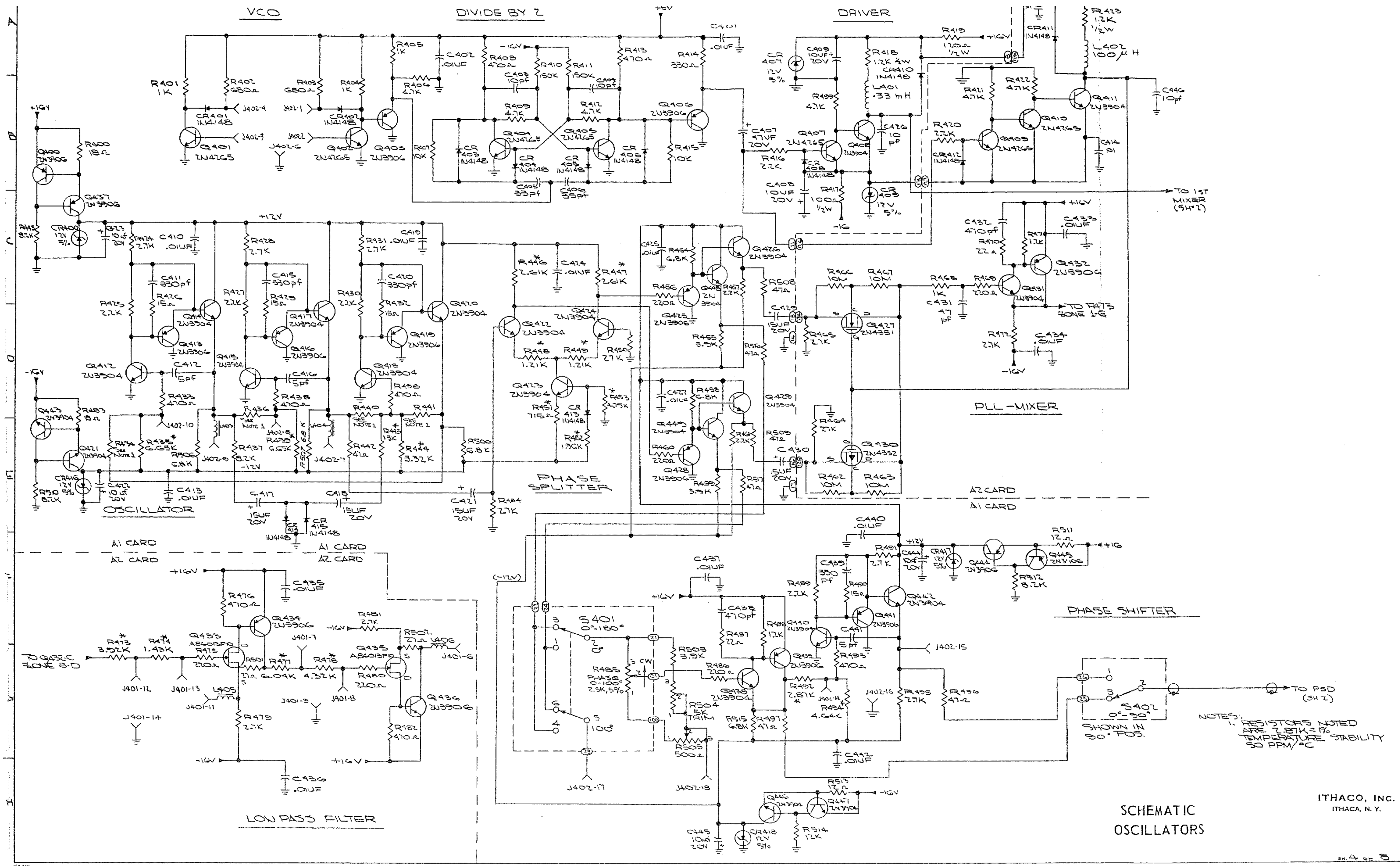


SCHEMATIC
SYNCHRONOUS DETECTOR AND OUTPUT

ITHACO, INC.
ITHACA, N.Y.

SH. 3 OF 8

6-3



SCHEMATIC
OSCILLATORS

ITHACO, INC.
ITHACA, N. Y.

SH. 4 OF 8

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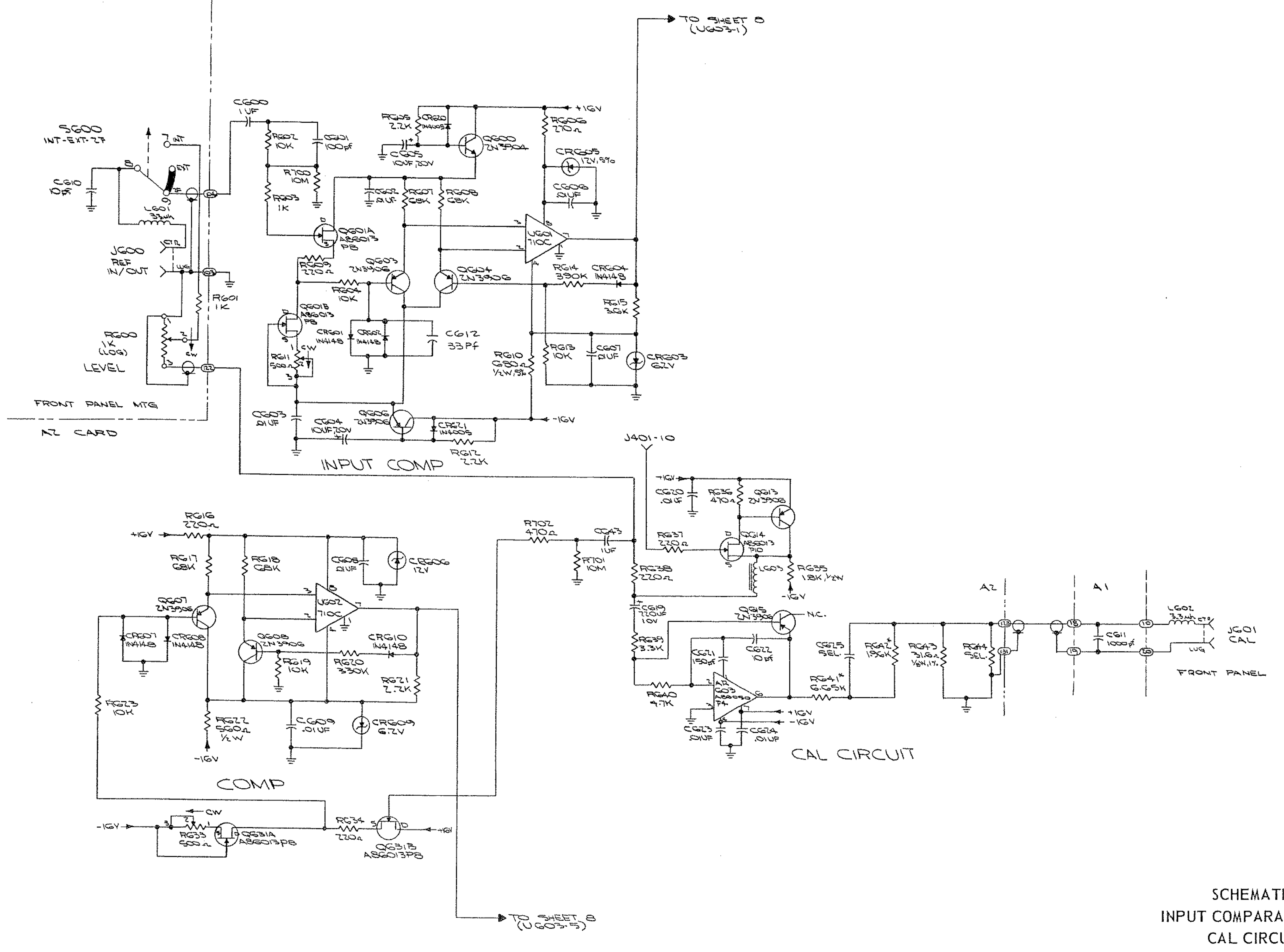
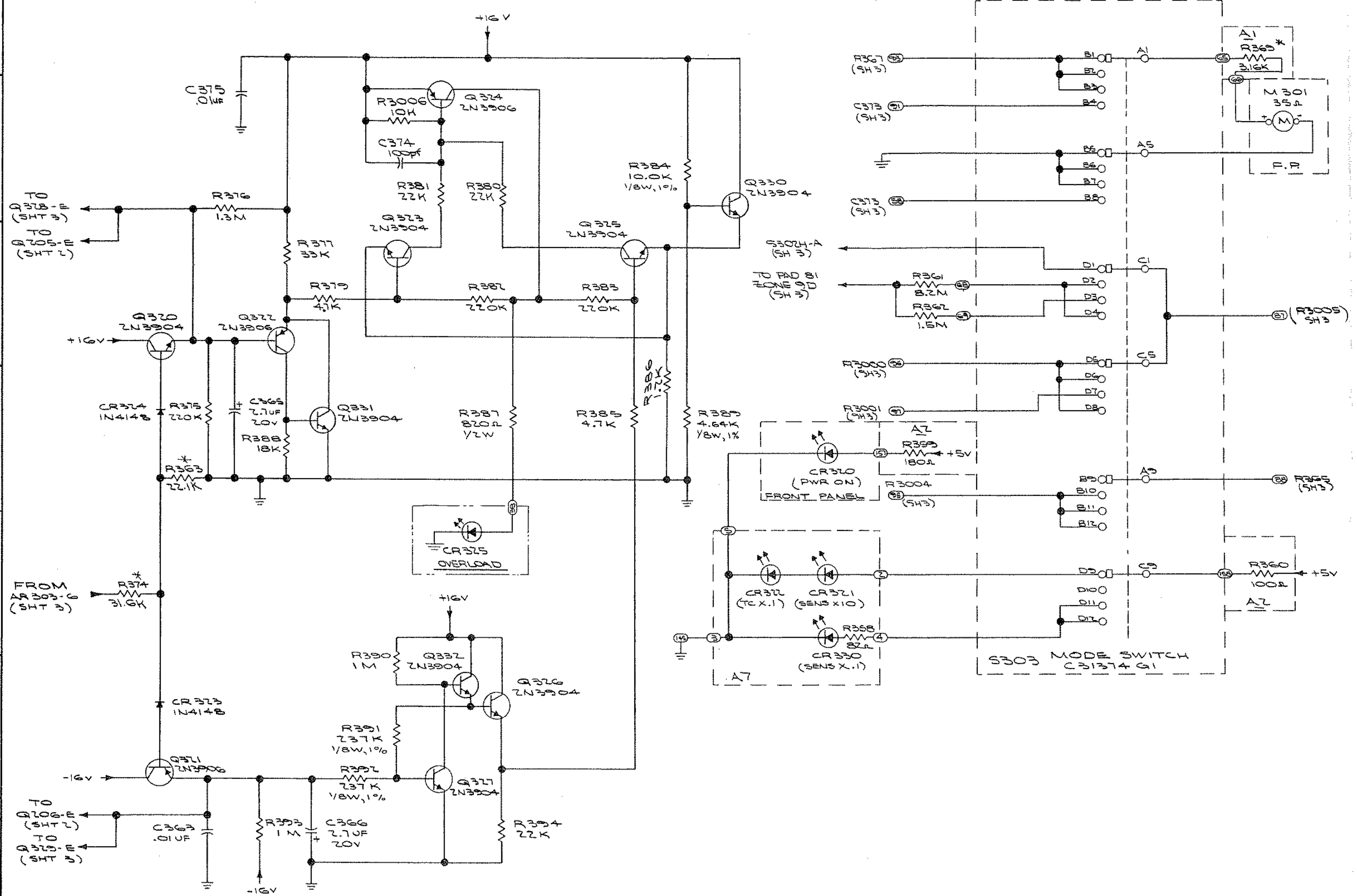


SCHEMATIC
INPUT COMPARATOR AND
CAL CIRCUIT

ITHACO, INC.
ITHACA, N. Y.

SHT 5 OF 8

6-5



NOTE:

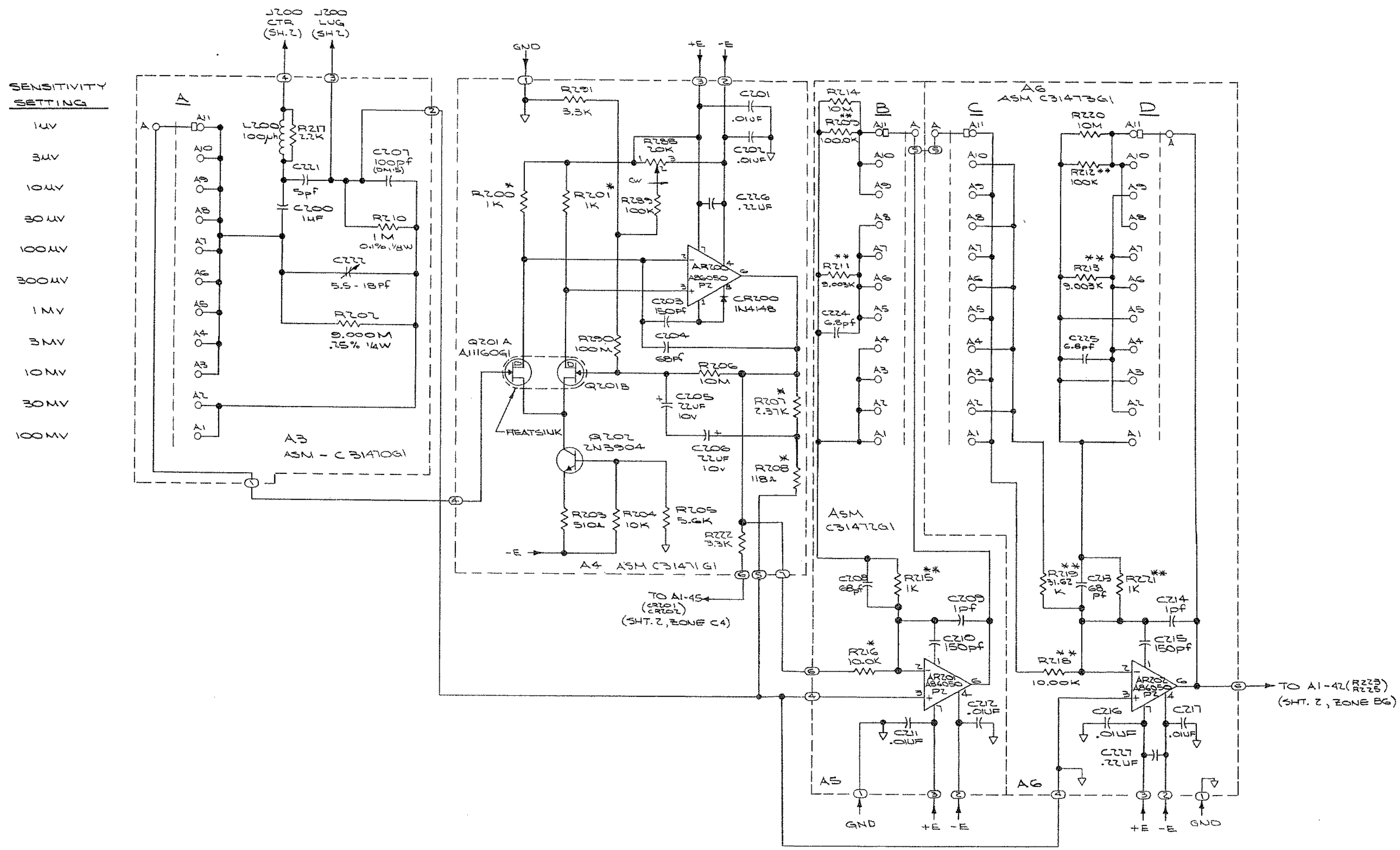
1. ALL LED'S ARE LITRONIX RED-LIT 2-04.

SCHEMATIC
OVERLOAD CIRCUIT AND
MODE SWITCH

ITHACO, INC.
ITHACA, N. Y.

SHT 6 OF 8

6-6



SCHEMATIC
SENSITIVITY SWITCH AND
INPUT MODULE

ITHACO, INC.
ITHACA, N. Y.

SHT 7 OF 8

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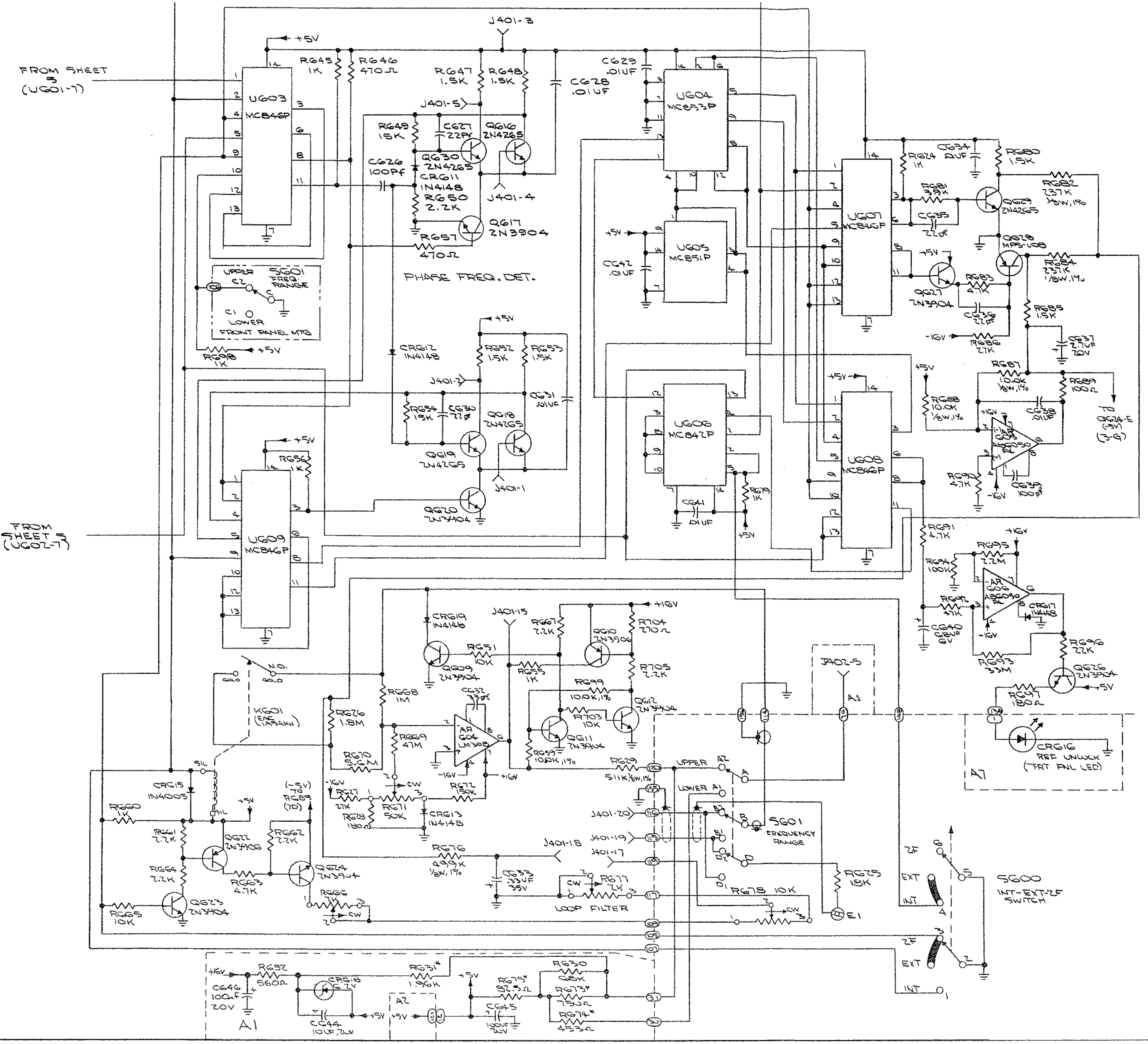
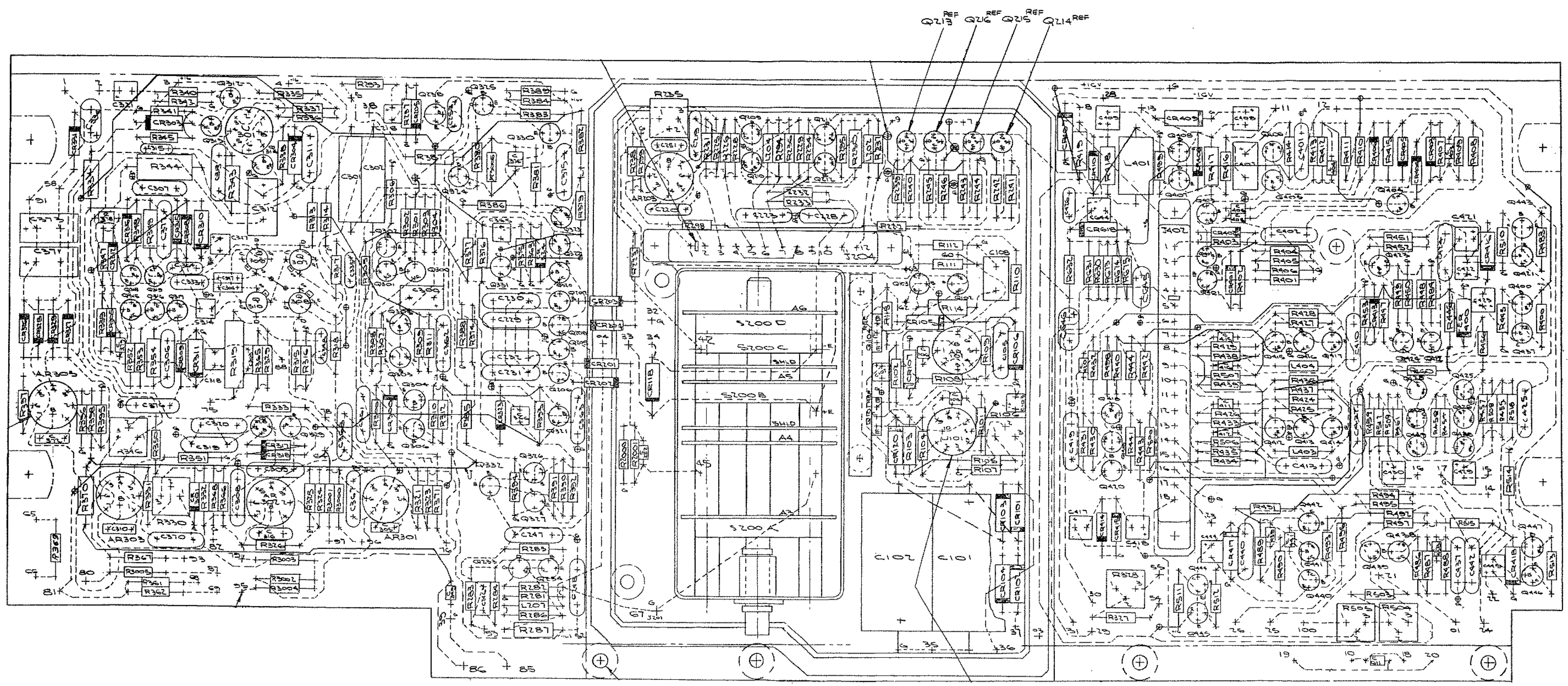


SCHEMATIC PHASE/FREQUENCY DETECTOR

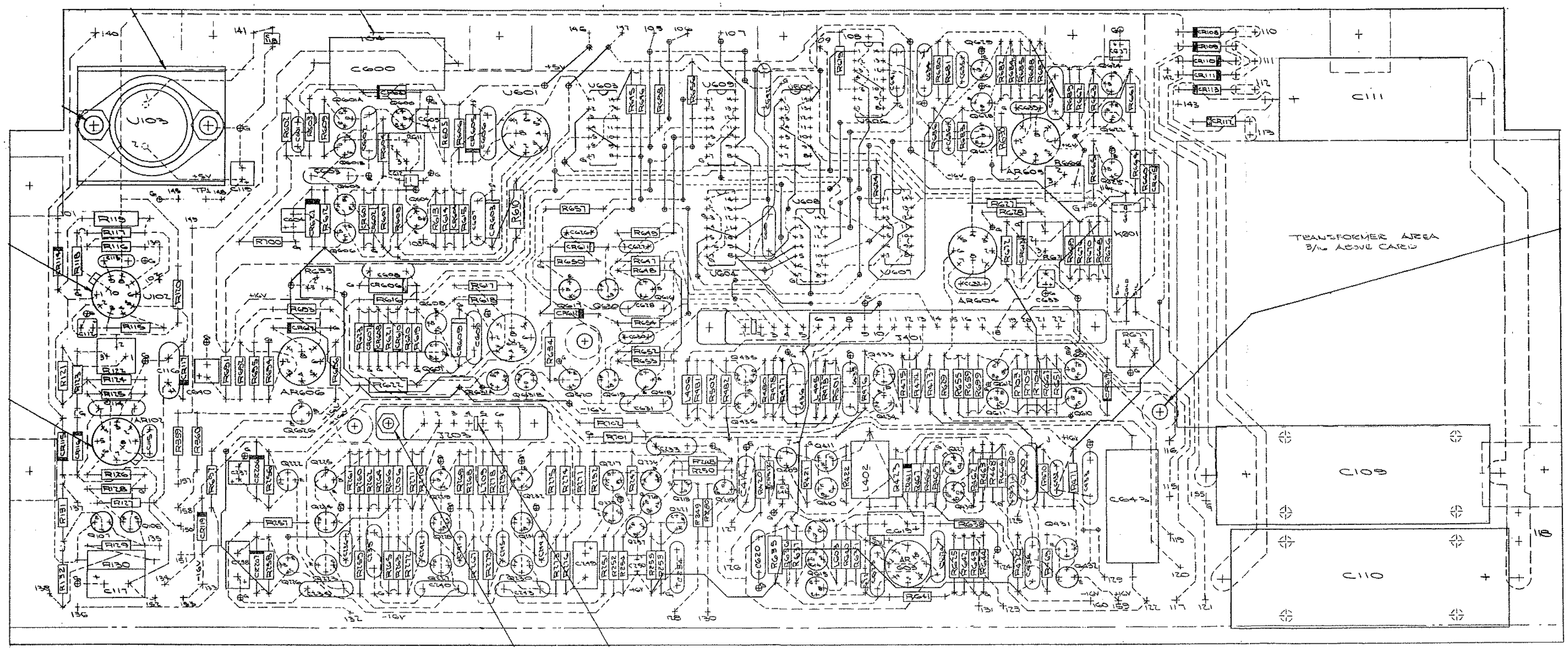
ITHACO, INC.
ITHACA, N. Y.

SHT 8 OF 8

68



A1 CARD COMPONENT LOCATION



A2 CARD COMPONENT LOCATION

ACCESSORIES

7.1 STANDARD ACCESSORY

The only standard accessory with a DYNATRAC 391 Lock-In Voltmeter is the six foot three conductor power cord. If it becomes necessary to replace it, one may be obtained from ITHACO by using the ITHACO stock number, 816000001, or by purchasing a Belden type 17258-S Replacement Cord.

7.2 OPTIONAL ACCESSORIES

Optional accessories include plug-in cards for other ranges (see Figure 7.1).

Several remote preamplifiers available are:

Model 164 Current input

Model 165 Low Z/High Z input

Model 166 Medium Z input

Model 167 High Z (100M) input

See DYNATRAC voltmeter specification sheet in Section 1 for further information.

All remote preamplifiers require a 391V1 Cable Assembly for operation with the DYNATRAC voltmeter.

Model 391S1 Rack Mounting Kit

FREQUENCY RANGE EXT	FREQUENCY RANGE INT	COLOR	FRONT PANEL LABEL	A203 BAND PASS	A204 LOW PASS	A401 PLL REF	A402 PLL OSC
0.1 Hz to 20 Hz	0.1 Hz to 11 Hz	Brown	B21868P1	B21881G1	C31404G1	C31407G1	C31406G1
0.5 Hz to 200 Hz	1 Hz to 110 Hz	Red	B21868P2	B21881G2	C31404G2	C31407G2	C31406G2
5 Hz to 2 KHz	10 Hz to 1.1 KHz	Orange	B21868P3	B21881G3	C31404G3	C31407G3	C31406G3
50 Hz to 20 KHz	100 Hz to 11 KHz	Yellow	B21868P4	B21881G4	C31404G4	C31407G4	C31406G4
.5 KHz to 200 KHz	10 KHz to 110 KHz	Green	B21868P5	B21881G5	C31404G5	C31407G5	C31406G5

When ordering single cards or labels, specify number above. When ordering a complete set of cards specify color only.

Figure 7.1

DRAWING CHANGES

DRAWING	CHANGE	FIRST S/N
Schematic - Sheet 2 Zone 9E	C255 is variable 5.5 to 18pF	16341
Schematic - Sheet 3 Zone 5C	R371 changed to 150M and connected from pad 76 to AR301-3	16341