OPERATING AND MAINTENANCE MANUAL
FOR
ANGLE POSITION INDICATOR
MODEL 8800-S3188

NAI TM 5016A

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STATUS OF CHANGE PAGES

Following is a list of all pages in this manual, their change status and the date of change. A zero (0) in the Change Status column indicates an original issue. Changed text is indicated by a vertical bar in the margin. Changed illustrations are indicated by a vertical bar adjacent to the title.

Original - July 1983

Pages	Change Status
Title	0
A	0
i,ii	0
1-1, 1-2	0
2-1 thru 2-3	0
3-1 thru 3-3	0
4-1 thru 4-5	0
5-1 thru 5-7	0
6-1 thru 6-3	0
7-1 thru 7-15	0
8-1 thru 8-7	0

CAUTION

High voltage exists at several points in this instrument. Normal precautions consistent with good practice should be taken to eliminate shock hazard.

A potential shock hazard exists with ungrounded power source or ungrounded case operation. Operators of the instrument should be aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to persons or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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SECTION 1

GENERAL DESCRIPTION

1.1 GENERAL

This manual contains general description, installation, operating instructions, maintenance and troubleshooting procedures, replacement parts lists, and schematic diagrams for the Angle Position Indicator, Model 8800-S3188 (API).

1.2 PHYSICAL DESCRIPTION

The API (fig. 1-1) replaces the Synchro-to-Digital Converter, Model 545/100. The API is housed in a 9-1/2-inch rack panel.

1.3 FUNCTIONAL DESCRIPTION

The API is an extension of the instrument product line using the exclusive LSI TRIG-LOGIC™ processor.

It is a full tracking type II servo which follows synchros or resolvers to speeds of 1000°/second without velocity errors. It accepts the specified line-to-line levels without pre-selecting or pre-programming the input signals. The converted synchro or resolver data is presented on the front-panel using planar gas discharge information displays.

1.4 SPECIFICATIONS

Table 1-1 provides characteristics and specifications for the API.

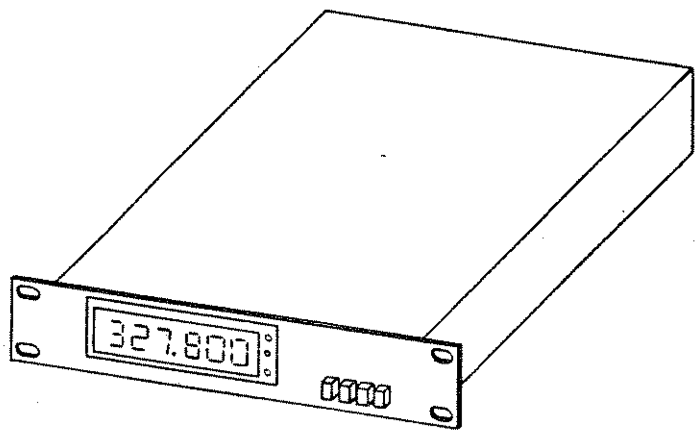

Figure 1-1. Angle Position Indicator

Table 1-1. Specifications

Item	Specification
Input specifications	
Signal inputs	11.8 V L-L, 30-45 V L-L (resolver, 400 Hz and 10 kHz); 90 V L-L (synchro, 400 Hz)
Signal input impedance	1 MΩ (min.) at 400 Hz
Reference levels	3 V thru 115 V rms, 400 Hz and 10 kHz. (All synchro or resolver data must be derived from this reference.)
Reference input impedance	100 kΩ (min.)
Power requirements	115/230 V rms ±10% or 125/250 V rms ±10%, 47 to 440 Hz
Output specifications	
Decimal readout	6 decimal digits, 0.55-inch high (6th digit inactive)
Readout resolution	0.010°

Table 1-1. Specifications (Continued)

Item	Specification
Performance specifications	
Angular accuracy	0.2° at 400 Hz and 10 kHz
Angular resolution	0.010°
Angular range	0.0° thru 359.990° in 0.010° steps continuous
Tracking characteristics (type II servo)	1000°/s with no tracking error
Settling time	Less than 4.0 seconds
Operating mode	Track only
L-L selection	Automatic L-L determination, 11.8 V, 30-45 V, or 90 V L-L displayed at front panel
Auto phase correction	Automatically corrects for signal phase shift up to ±30° (max.).
Size	7.88"W x 1.72"H x 12.5"D
Operating temperature	0° to 50°C

SECTION 2

INSTALLATION

2.1 GENERAL

This section provides instructions for unpacking, inspecting, and installing the API.

2.2 UNPACKING AND INSPECTION

This instrument has been thoroughly tested, inspected, and evaluated at the factory before shipment. Care has been taken in the design of the wrapping and packaging material to insure no damage results from mishandling.

Inspect the instrument externally. Check the front panel for signs of damage to the switches and display. Check the switches for smooth operation. Switch buttons should be secure. Check the condition of the connector and fuse on the back panel. Check covers for damage and loose screws. If the instrument passes this inspection, install it and place it in operation. If damage is found, refer to the Warranty in the back of the manual.

2.3 INSTALLATION

2.3.1 Mounting Instructions

The API may be mounted on a bench or in a standard rack, in any physical position. It requires no special cooling equipment. Mount the unit so that air flows freely around it, particularly the rear panel used to transmit the power supply heat to the ambient. Figure 2-1 provides outline dimensions for the API.

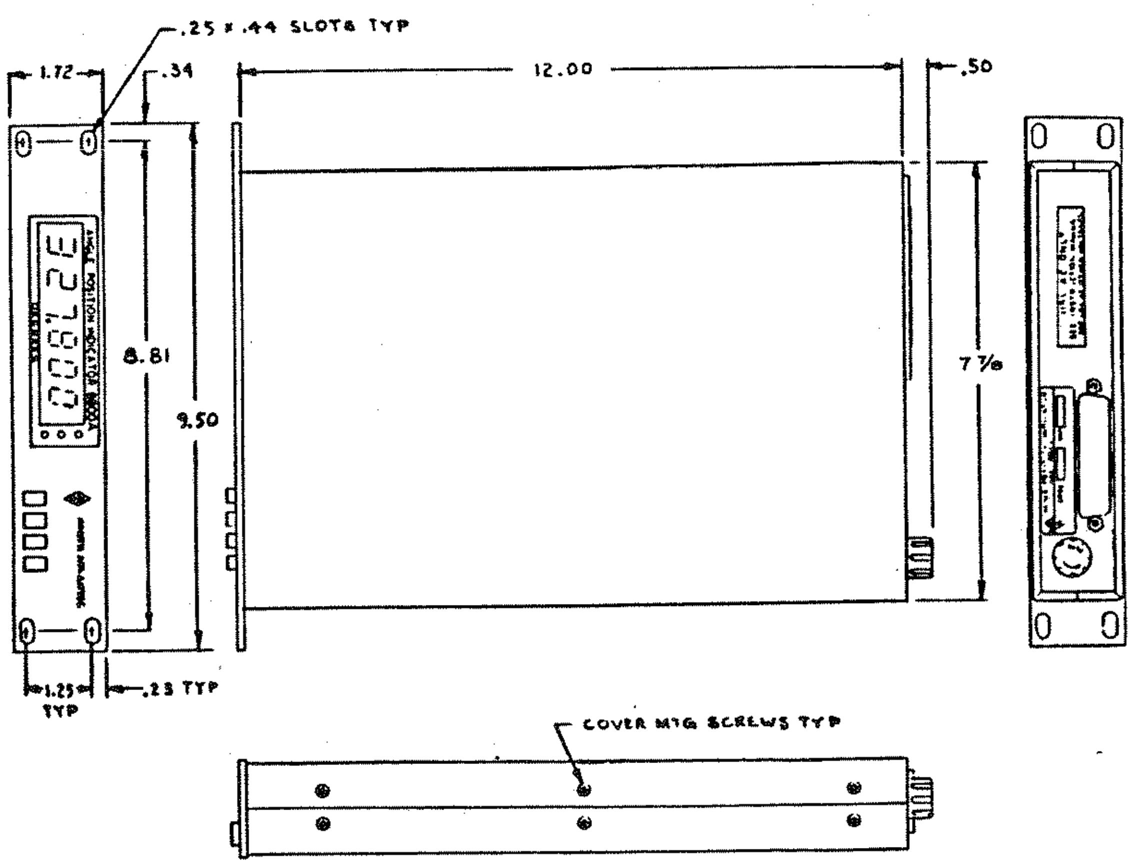

Figure 2-1. API Outline Drawing

2.3.2 Cabling Instructions

System interconnection to the API is through rear panel connector J1. Pin designations are given in table 2-1.

Table 2-1. J1 Pin Designations

Pin	Function	
1	Power input Hi	
2	Power input Lo	
3	Case ground	
4	Digital ground	
5	S1	
6	S2	
7	S3	SYN
8	*	
9	R1	
10	R2	
11	*	
12	*	
13	*	
14	*	
15	*	
16	*	
17	*	
18	*	
19	Spare	
20	*	
21	S1	
22	S2	
23	S3	RES
24	S4	
25	R1	
26	R2	
27	Data Freeze	
28	*	
29	*	
30	*	
31	*	
32	*	
33	*	
34	*	
35	*	
36	Spare	
37	Spare	
38	*	
39	*	
40	*	
41	Spare	
42	*	
43	*	
44	*	
45	*	
46	*	
47	*	
48	*	
49	*	
50	*	

*Do not use.

2.3.3 Grounding

In a high-accuracy synchro/resolver-to-digital converter it is necessary for both chassis and signal ground to be tied together. Ground loops should be avoided in system applications. For this reason, chassis ground pin 3 and signal ground pin 4 are brought out separately.

In bench applications, pins 3 and 4 should be tied together and connected to the low side of the signal source to the synchro or resolver.

In system applications, the separate pins make connections in other parts of the system possible. When not used, tie them together at the connector.

2.3.4 Internal Power Connections

The API is designed to operate from 115 V or 230 V, 47 to 440 Hz input power. It is normally set in the factory for 115 V operation. For 230 V operation move Power switch (fig. 2-2), located on the standard board near the power transformer, to 230 V position. For 125 V or 230 V operation, see schematic.

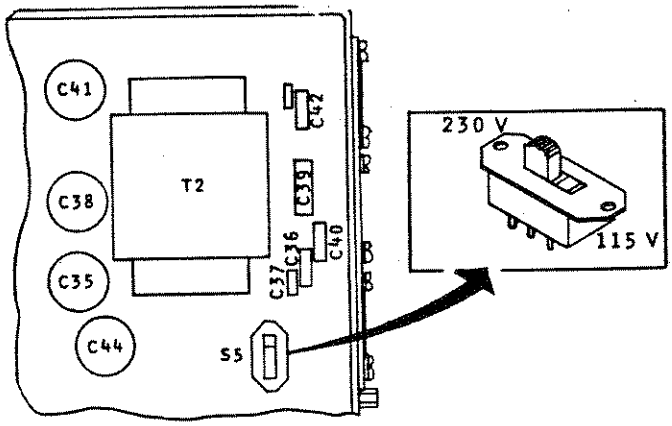

Figure 2-2. Power Programming

SECTION 3

OPERATION

3.1 GENERAL

This section provides operating procedures for the API.

3.2 SYNCHRO AND RESOLVER CONVENTIONS

Conventions for polarities, terminal designation and direction of shaft rotation for synchros and resolvers are most frequently defined in accordance with military specifications MIL-S-20708 (synchros) and MIL-R-2153 (resolvers). The unit is provided with terminal designations and electrical characteristics to these specifications. In applying the conventions, exercise caution that:

- The manufacturer of the synchro or resolver has followed the MIL specification.
- The system use has not dictated a change in convention for a different characteristic (i.e., direction reversal or angular offset).

3.2.1 Synchro Transmitter Conventions

$$E(S1-S3) = -NE(R1-R2)\sin\theta$$
$$E(S3-S2) = -NE(R1-R2)\sin(\theta+120°)$$
$$E(S2-S1) = -NE(R1-R2)\sin(\theta+240°)$$

Where E(S1-S3) is the stator voltage S1 with respect to S3. Other stator and rotor voltages are similarly defined. N is the ratio of the maximum voltage across a pair of stator terminals to the voltage across the rotor terminals. θ is the shaft angle displacement from electrical zero which satisfies these equations. A schematic of the synchro transmitter is shown in figure 3-1.

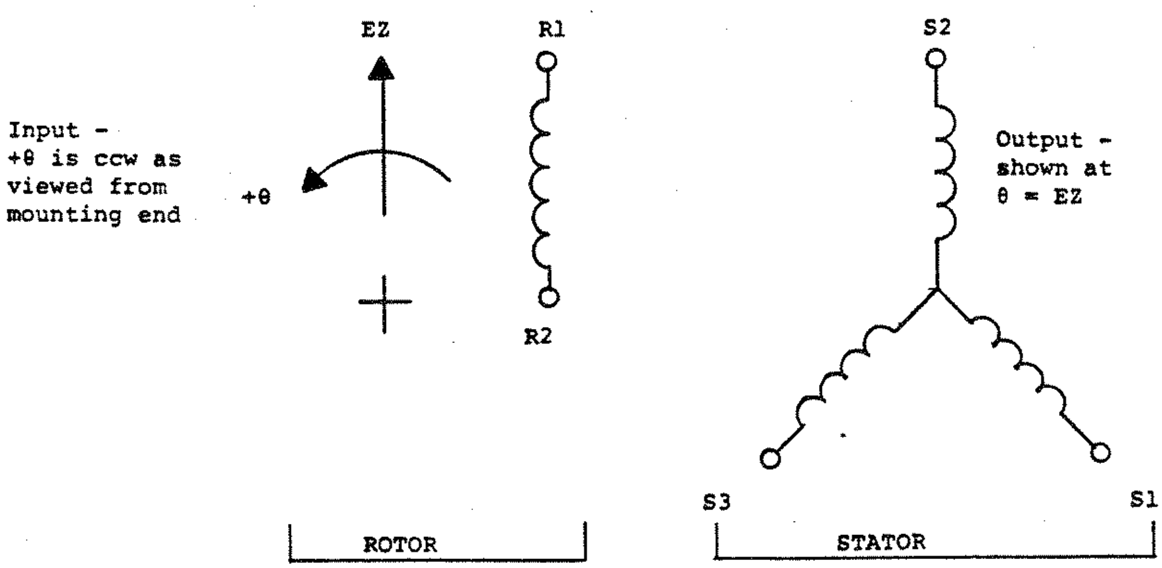

Figure 3-1. Synchro Transmitter, Schematic

3.2.2 Resolver Transmitter Conventions

For rotor energized resolvers:

E(S1-S3) = NE(R1-R3)Cos θ-NE(R2-R4)Sin θ
E(S2-S4) = NE(R2-R4)Cos θ+NE(R1-R3)Sin θ

A rotor energized resolver transmitter schematic is shown in figure 3-2. Input and output may be reversed for stator energized devices.

Since the NAI standard assumes an R2R4 energized resolver, the resolver outputs become:

E(S1-S3) = -NE (R2-R4) Sin θ
E(S2-S4) = +NE (R2-R4) Cos θ

3.3 CONTROLS AND INDICATORS

The controls and indicators for the API are described in table 3-1 and illustrated in figure 3-3.

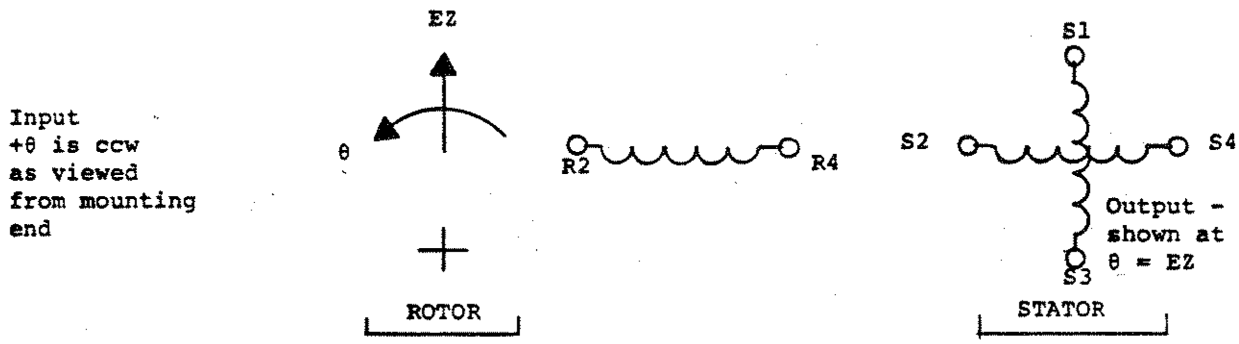

Figure 3-2. Resolver Transmitter, Schematic

Table 3-1. Controls and Indicators

Control or indicator	Function
OFF push button	Turns power off.
SYN push button	Selects synchro operation and turns on power.
RES push button	Selects resolver operation and turns on power.
Blank	Not used
Indicator	Displays, digitally, information.
115 V - 230 V Power switch (located on main board)	Allows unit to operate from either 115 V or 230 V power source.
EXT-INT Reference switch (located on main board)	Provides a means of switching reference as required in calibration procedure. Normally is set to INT.
L-L 90 V LED	When lit, indicates that input signal is 90 V L-L.
L-L 30-45 V	When lit, indicates that input signal is 30-45 V L-L.
L-L 11.8 V LED	When lit, indicates that input signal is 11.8 V L-L.

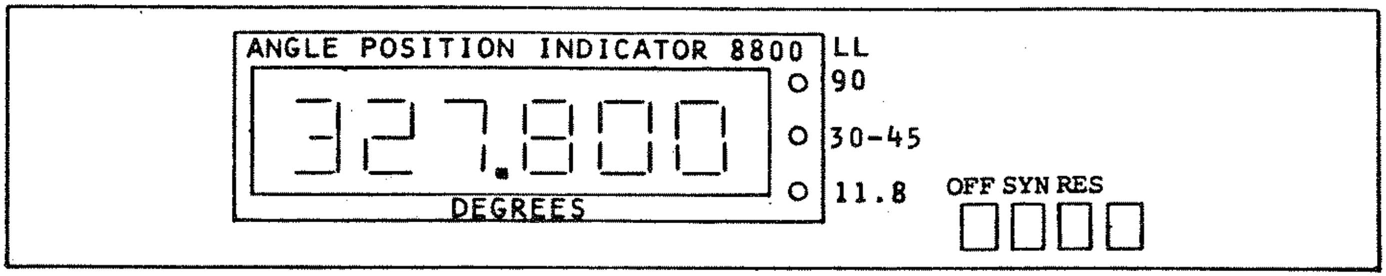

Figure 3-3. Controls and Indicators

SECTION 4

THEORY OF OPERATION

4.1 GENERAL

This section contains theory of operation for the API.

4.2 DETAILED DESCRIPTION

The API is designed with NAI's closed servo loop (refer to block diagram, fig. 4-1). This system continuously tracks the analog input data with a precision Scott-T transformer, resistive bridge, phase detector, integrator, and clock generator, driving a counter which updates the bridge to the synchro data angle input.

The heart of the system is a custom LSI TRIG LOGIC™ processor. This LSI contains analog switches, an UP/DN counter and trigonometric digital circuitry for processing the input signals.

The input signal, whether synchro (three wire) or resolver (four wire) goes directly into the precision transformer assembly, which outputs a Sin θ signal and a Cos θ signal to the coarse bridge. Both signals drive analog switches which are turned at 40° intervals. These points are referred to as αc. The signals produced within the coarse bridge circuit are Sin θ Cos αc, Sin θ Sin α, Cos θ Cos αc, and Cos θ Sin αc. These four functions are combined to derive Sin (θ-αc) error signal and Cos (θ-αc) interpolation signal, implementing the following trigonometric relationships:

$$\mathrm{Sin}(\theta-\alpha c) = \mathrm{Sin}\ \theta\ \mathrm{Cos}\ \alpha c - \mathrm{Cos}\ \theta\ \mathrm{Sin}\ \alpha c$$
$$\mathrm{Cos}(\theta-\alpha c) = \mathrm{Sin}\ \theta\ \mathrm{Sin}\ \alpha c + \mathrm{Cos}\ \theta\ \mathrm{Cos}\ \alpha c$$

Since αc takes on values at only 40° intervals, θ-αc will be somewhere between 0° and ±20°, depending upon the value of the input angle θ. The error signal Sin (θ-αc) is then balanced out in the interpolation circuit, using Cos (θ-αc) as an interpolation reference signal.

The interpolation circuit contains a precision resistor network to bridge the error signal against the interpolation reference signal. The precision resistor network as well as the analog switches of the coarse bridge are driven digitally by the counter. The range of the interpolation section is 20°. When interpolating angles larger than αc, the output of the interpolation ladder is added to αc. When interpolating angles less than αc, the interpolation bits are complemented, the CEF switch is closed and the interpolation ladder subtracts from αc. This allows the interpolation section to cover a total span of 40°.

Since the Sin function is not a linear one, interpolating a full 20° would result in rather large errors. Several methods are used to reduce the interpolation error. The first is to break up the 20° interpolation span into two 10° segments. From 0° to 9.999°, the PRG supplies Sin 10° to ladder for interpolation. From 10° to 19.999°, the Sin 10° is applied to a resistor at the summing amplifier, and the Sin 20° to Sin 10° is applied to the interpolation ladder. This reduces the interpolation error to about ±0.005°. This error is further reduced by three analog switches which perform slight amplitude changes in the ladder reference. The final mathematical error is less than ±0.001°. The result of the bridging process is an ac error signal at the output of U13 proportional to Sin (θ-αc) Cos αf Cos (θ-αc).

This equals Sin (θ-αc-αf), where αf is the digitally generated angle in the interpolation circuit.

The output of summing amplifier U13 is fed to amplifier U17 for further amplification.

Since the ac scale factor changes with coarse bridge angles, it is necessary to normalize this scale factor to maintain constant sensitivity throughout the entire 360° span. Resistor R94 is switched in and out to eliminate this change. (The change would be 40% without this normalization). In addition, gain changes to U17 are performed for line-to-line voltage changes.

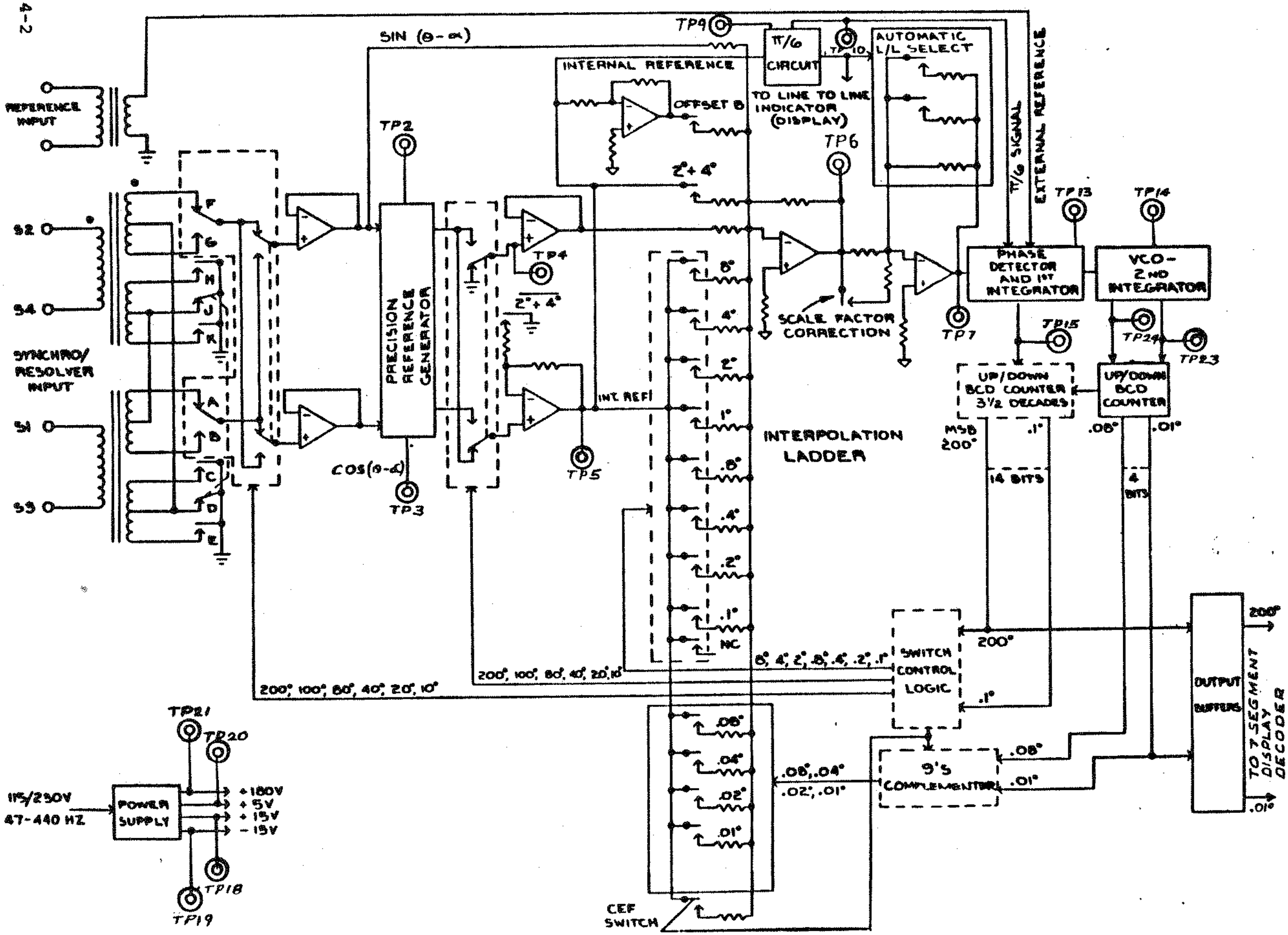

Figure 4-1. API, Block Diagram

At 11.8 V L-L, resistor R92 is the feedback. R91 is in parallel with R92 for 30-45 V L-L operation. For 90 V L-L operation, R90 and R91 are in parallel with R92. The ac scale factor at the output of U17 (TP7) is 2.5 V rms/degree at all three line-to-line levels.

In most S/D converters, reference to the null circuit is supplied externally from the same source exciting the synchro. Since all synchros generate phase shift, their output signal is phase shifted in respect to the reference, usually 5° to 10°. For optimum performance, the reference applied to an S/D converter should be phase shifted by the same angle as the synchro signal. The API contains an auto-phase circuit which eliminates the need for external reference phase correction. This circuit is able to correct for maximum phase shift of ±30°. Reference phase correction is accomplished by sampling the interpolation ladder reference. Since this signal is derived directly from the synchro input signal, it is in-phase with the synchro signal.

The interpolation reference is coupled through C10 and applied to full wave rectifier circuit U14. FET switch Q8 switches the gain of the rectifier when the interpolation reference changes amplitude so that the rectified signal at TP9 is a constant amplitude (fig. 4-2). The output of the rectifier drives the inverting input (pin 6) of comparator U15. The output of the rectifier is divided and filtered by components R73, R74, and C12. This network applies exactly 50% of the peak value of the full wave rectified signal which corresponds to the Sin of 30°. This develops a $\pi/6$ (±30°) signal at the output of the comparator (TP10). The $\pi/6$ signal is applied to the phase detector which is discussed later.

After scale factor correction is made with Q8, the output voltage of the rectifier is directly proportional to the input line-to-line voltage. The filtered voltage at C12 is buffered by voltage follower U14, and the output (TP11) is connected to two comparators. The dc voltage (TP11) is approximately 1/20th of input line-to-line voltage (rms). The two comparators sense the voltage amplitude at TP11. When the voltage is less than 0.9 V, the outputs of both comparators are low. This sets the gain of U16 for 11.8 V L-L. When the voltage is between 0.9 V and 1.8 V, the output of U15, pin 13, goes high, and switches the API to 30-45 V L-L. When the voltage at TP11 exceeds 1.8 V, both comparator outputs go high, switching the API to 90 V L-L. The outputs of the comparators are decoded by U16 to drive the line-to-line indicator LEDs on the front panel.

The null circuit receives the $\pi/6$ signal, the external reference, and the ac error signal from U17. This circuit performs three discrete functions: (1) phase-sensitive detection, (2) clock pulse generation, and (3) count up/count down signal. In addition, an Auto-phase defeat switch is provided so that, if necessary, the synchro information may be referenced to the external reference. With the Auto-phase switch in the external position, the phase detector operates as a normal full wave detector. This mode of operation is explained first.

The external reference applied to J1 is isolated and stepped down by transformer T3. This signal is squared by comparator U15. At this point the signal splits. One side is connected to U21, pin 6, the other inverted by U20. This inverted signal connects to U21, pin 8. Since the $\pi/6$ signal is grounded by S6, the NAND gates function as inverters. This two-phase reference signal is buffered and drives the phase detector switches. The third grounding switch remains open.

The ac error signal from U17 is coupled through C15 to U18. With the Auto-phase switch in the external position, U18 operates as a non-inverting unity gain buffer. The signal at TP8 is identical to that at TP7, except that any dc offset present at TP7 is blocked by C15. This signal is applied to one of the phase detector switches. The ac error signal at TP8 is also inverted by U19 and fed to another phase detector switch. These two switches alternately open and close in phase with the external reference and form a phase-sensitive full wave detector. The output of the phase

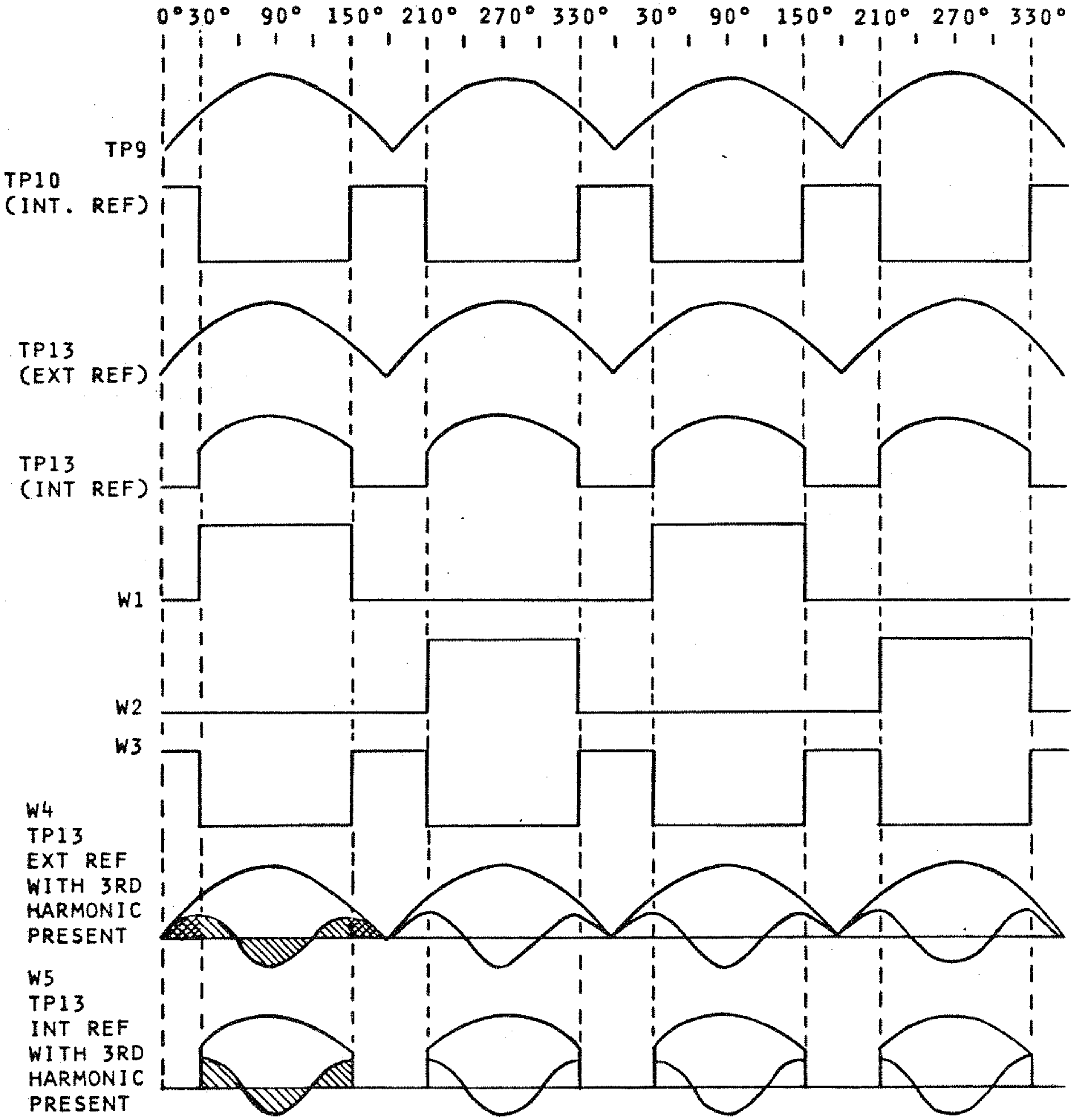

Figure 4-2. Null Circuit Waveforms

detector is a dc signal whose amplitude is proportional to the in-phase portion of the ac error signal. Polarity depends on whether the ac error signal is in-phase or 180° out-of-phase with the reference. U23 integrates the phase detector output.

When the Auto-phase switch is in the INT position, the $\pi/6$ signal is digitally combined with the external reference square wave. The $\pi/6$ signal removes 30° of the leading and trailing edges which reduces the switch closure angle from 180° to 120° (waveforms W1 and W2, fig. 4-2). Grounding switch Z22, pin 2 is closed when the other switches are both open to insure no signals leak through to the integrator during the $\pi/6$ interval (waveform W3, fig. 4-2). Since this reduces the gain of the phase detector, resistor R97 is grounded by the Auto-phase switch, increasing the gain of U18 proportionately.

In addition to automatic phase correction, the $\pi/6$ null circuit provides complete rejection of the third harmonic and all multiples of the third harmonic. A normal full wave detector provides a 3:1 attenuator of 3rd harmonics and an attenuation of all other odd harmonics proportional to the ratio of the harmonic to the fundamental (i.e., 7th harmonic 7:1, etc.). For all odd harmonics, not a multiple of the third harmonic, the $\pi/6$ phase detector provides the same attenuation as the full wave phase detector. Both types provide complete rejection of even harmonics.

A circuit in the null circuit, not mentioned, consists of a half-wave rectifier and filter, comprising of CR20, R104, R107, and C16. Comparator U14 monitors the voltage across C16 and trips when the ac error is greater than 10 V rms. This occurs when the angular error between the API and synchro exceeds 4°. This will cause the internal signal supplied to the $\pi/6$ circuitry randomly to change amplitude until the converter slews closer to the input angle. This results in a momentary disruption of the $\pi/6$ signal applied to the phase detector. To insure proper operation of the phase detector, the $\pi/6$ signal is disabled by comparator U14, pin 10 until the error is reduced. The API uses a Type II servo, which does not require a continuous error signal to generate clock pulses. Depending upon the phase relationship with the reference and the direction of the synchro rotation, an ac error signal will either accelerate or decelerate the clock until clock rate matches the rate of the incoming synchro data. At this point, the ac error signal drops to zero and the clock continues to run at its present rate until an ac error signal again appears to accelerate or decelerate it.

The VCO consists of integrator U24 and two sections of comparator U25. In operation, a dc voltage from U23 charges C23 through R117 and R118 until the output of U24 reaches the trip point of one of the comparators. When this occurs, CR25 or CR26 is forward biased and C23 discharged until the comparator flips back to its original state. The cycle is then repeated. The up clock pulses are derived from U25, pin 1 and the down clock pulses are derived from U25, pin 2. The output of U24 is also fed to comparator U25, pin 10 to develop an up/down signal for the LSI counter.

The clock lines drive the BCD up/down counter. The counter outputs (decoded and complemented) close the loop with the coarse bridge and interpolation circuits. The digital word, in BCD form, from the LSI goes to the output buffers. These buffers isolate the LSI and go to the display board for decoding to drive the seven segments of the Beckman Planar Gas Discharge Information Display.

SECTION 5

MAINTENANCE

5.1 GENERAL

This section contains cleaning, performance tests, and alignment procedures for the API.

WARNING

High voltages exist at several points in this instrument. Normal precautions should be taken to avoid shock hazard.

CAUTION

The API contains the following CMOS integrated circuits. Handle these ICs with extreme care. Never remove an IC with the power on. Use only properly grounded test equipment.

U3 - LSI	Z1 - 74C00
U16 - 4011	Z2,5,8,11,14 - MC14519
U21 - 4011	Z3,6,9,12,15 - MC14560
U26 - 4011	Z4,7,10,13,16 - MC14561
U27 - 4027	
U28 - 4030/14070	
U29 - 4069	

5.2 CLEANING

No special cleaning procedures or fluids are required. The switches in the API are prelubricated and require no additional lubrication. The switches should not be cleaned with solvents. Removal of the protective lubricant may cause oxidation and subsequent switch failure. Follow good housekeeping practices to keep the instrument free of dust and dirt.

5.3 PERFORMANCE CHECK

Perform the following procedure every six months to ensure proper operation of the equipment. When a malfunction is detected, refer to the alignment procedure of this manual before attempting troubleshooting.

5.3.1 Equipment Required

Table 5-1 lists the test equipment required to test and align the API. The minimum use/critical specification column lists the parameters required for alignment and are not for the purpose of alternate equipment selection. Satisfactory performance of alternates should be verified before use.

Table 5-1. Test Equipment Required

Item	Minimum use/critical spec	Manufacturer & Model
Mating connector	Connector wired for functions to be tested.	NAI P/N 783718
Sync/res simulator	Frequency: 400Hz & 10kHz ±10% Range: 00.000° to 359.999° Accuracy: 10 arc sec., 400Hz 20 arc sec., 10kHz Modes: Synchro or resolver	NAI Model 530/20
Variable oscillator	Frequency: 400Hz & 10kHz ±10% Output voltage: 0-12V rms Power: 115Vac ±10%	Krohn-Hite 4000AR

Table 5-1. Test Equipment Required (Continued)

Item	Minimum use/critical spec	Manufacturer & Model
Power amplifier	Frequency: 400Hz & 10kHz ±10% Output gain: X10 Distortion: 0.6% Load regulation: ±1% Power: 115Vac ±10%, 60Hz	Krohn-Hite DCA-10R
Digital voltmeter	Range: 0-120V rms Accuracy: ±2% Resolution: 4 digits Power: 115Vac ±10%, 60Hz	Keithley 179 DVM
Oscilloscope	Horizontal sweep time: 1ms Vertical sensitivity: 1V/cm Rise time: 24ns Input range: 1 megohm Paralleled by approximately 33pf	Tektronix 465
Phase angle voltmeter	Frequency: 400Hz ±10% Sensitivity: 300V to .003V Mode: In-phase Accuracy: ±2% F.S. Phase: ±1 degree	NAI Model 213C or 225
Frequency counter	Display range: 1 to 10^5 counts Frequency: 400Hz & 10kHz ±10% Accuracy: ±1 count Input impedance: 1 megohm shunted by 20pf	Monsanto Model 101B
AC power source	Frequency: 400Hz ±10% Range: 0V to 120V rms Distortion: 0.6% max. Output rating: 20VA Load regulation: ±1% Phase: Single	Elgar Model 501C-103
Ratio Box	Ratio Range: 0-1.000000 in 6 decades Terminal Linearity: 100ppm, max. 10KHz	NAI 503C

5.3.2 Setup

a. Set the synchro/resolver simulator mode switch to OFF.

b. Wire the test connector and connect equipment as shown in figure 5-1. (Ratio Box not required for 400Hz.)

c. Turn all power switches (except the API) on and allow the test equipment to stabilize for 15 minutes.

d. Adjust the oscillator and amplifier for 400Hz ±10%, 26V rms ±5%. Monitor the output level with DVM and frequency counter.

e. Set the synchro/resolver simulator for 11.8 V L-L, 400 Hz resolver output (00.000°).

5.3.3 400 Hz Angular Accuracy Test

a. Set up equipment per figure 5-1 (Ratio Box not required). Depress API RES

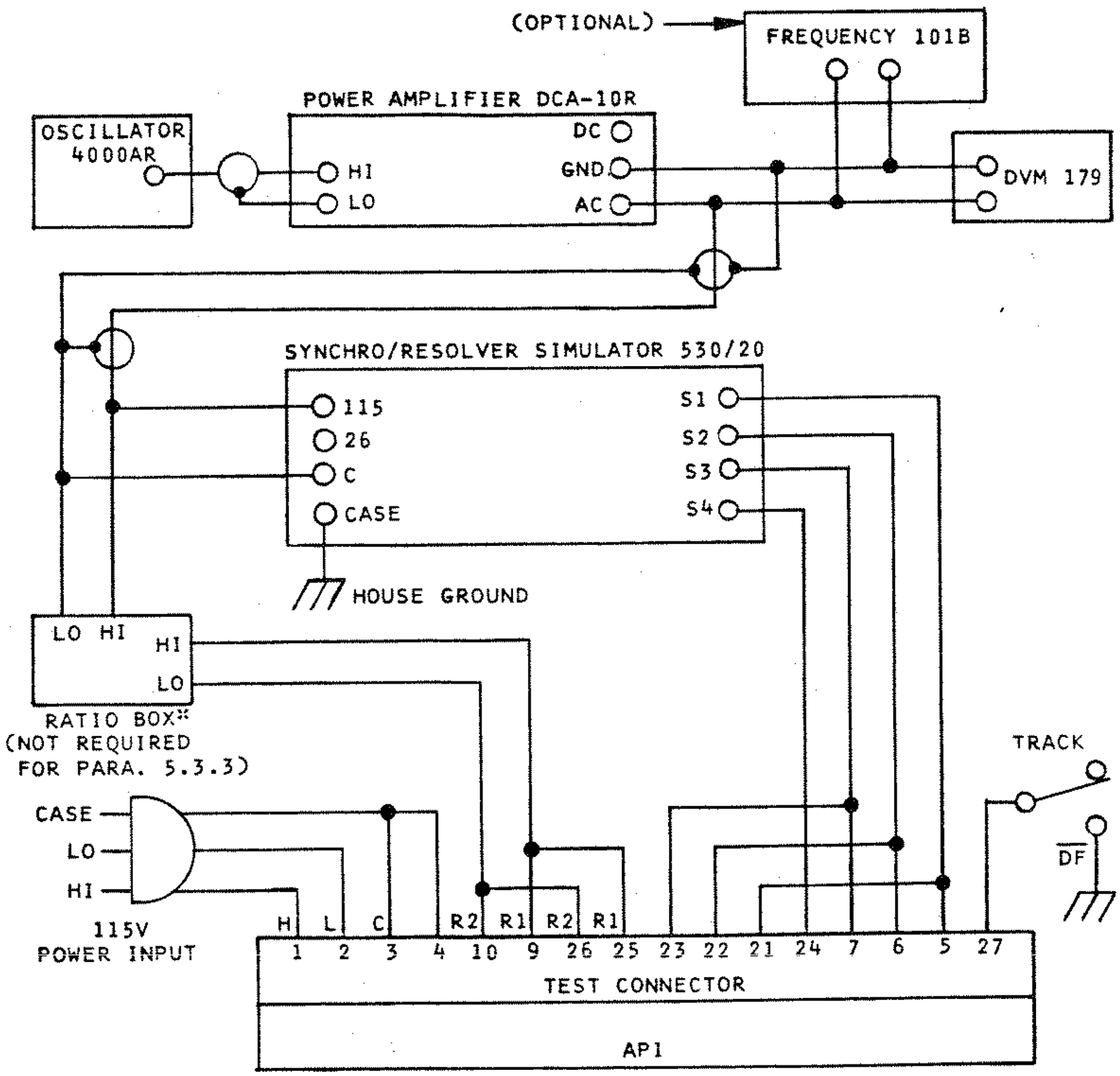

Figure 5-1. Test Setup

button and note that the API has settled to within 0.2° (max.) of the angle set on the synchro/resolver simulator. Verify that 11.8 V L-L indicator is lit.

b. Advance the synchro/resolver simulator from 10° through 350.000° (in 10° steps), 1° through 9° (in 1° steps), 0.1° through 0.9° (in .1° steps), and 0.01° through 0.09° (in .01° steps), respectively. API should read within ±0.2° of the input angle.

c. Adjust the oscillator and amplifier for 400 Hz ±10%, 115 V rms ±2 V. Monitor the output level with the DVM. Depress API SYN button and set synchro/resolver simulator for 90 V L-L synchro output. Note that the API has settled to within 0.2° (max.) of the angle set on the synchro/resolver simulator. Verify that 90 V L-L indicator is lit.

d. Repeat step b above for 90 V L-L synchro output.

5.3.4 10 kHz Angular Accuracy Test

a. Set up equipment as shown in figure 5-1. Turn synchro/resolver simulator mode switch to OFF.

b. Adjust the oscillator and amplifier for 10 kHz ±10%, 30 V rms ±5%. Monitor the output of the amplifier with the DVM.

c. Set the synchro/resolver simulator for 115 V L-L, 10 kHz resolver output (00.000°).

d. Depress API RES button and note that the API has settled to within 0.2° (max.) of the angle set on the synchro/resolver simulator. Verify that 30-45 V L-L indicator is lit.

e. Advance the synchro/resolver simulator 10° through 350.00° (in 10° steps), 1° through 9° (in 1° steps), 0.1° through 0.9° (in .1° steps), 0.01° through 0.09° (in .01° steps), and 45° through 315° (in 90° steps), respectively, for 30 V L-L input. API should read within ±0.2° of the input angle.

f. Increase the input voltage to 45 V rms ±5% as monitored with the DVM. Using ratio box, apply 10 kHz ±10%, 30 V rms ±5% to API reference input pins. Note that the API has settled to within 0.2° (max.) of the angle set on the synchro/resolver simulator. Verify and record that 30-45 V L-L indicator is lit.

g. Repeat step e above for 45 V L-L input.

5.4 CALIBRATION

Table 5-2 provides the calibration procedure for the API. Perform this procedure at least once a year to insure optimum performance. Refer to table 5-1 for the required test equipment.

Access is accomplished easily by removing the top and bottom covers. First remove six screws on the right and six screws on the left sides of the unit. The covers may then be lifted off, exposing all necessary test points.

Table 5-2. Calibration Procedure

Step	Procedure	Indication	Corrective action
1	SETUP		
a.	Set the synchro/resolver simulator mode switch to OFF to avoid damage to the equipment and to prevent dangerous voltages from existing at the output terminals when power switches are turned on.		
b.	Turn all power switches (with the exception of the API) on and allow the test equipment to stabilize.		

Table 5-2. Calibration Procedure (Continued)

Step	Procedure	Indication	Corrective action
c.	Wire up the test connector and connect equipment as shown in figure 5-1. (Ratio Box not required.)		
d.	Set the synchro/resolver simulator for 11.8 V L-L, 400 Hz synchro output at 0.000 degrees.		
2	COARSE BRIDGE PRECISION REFERENCE GENERATOR ADJUSTMENT		
a.	Depress SYN pushbutton on the API. Adjust the synchro/resolver simulator for 0.000 degrees angle position indicator display and set the toggle switch to $\overline{DF}$. Adjust synchro/resolver simulator for 0.000 degrees.		
b.	Connect the low side of the DVM to TP1 (ground) and connect the high side to TP4.	The voltage at TP4 should be between +0.5 mV dc and +3 mV dc.	
c.	Connect the high side of the DVM to TP2.	Adjust R19 until the voltage at TP2 is the same as that measured at TP4 ±100 microvolts.	
d.	Repeat step c, above, using TP3 and R26.		
e.	Connect the high side of the DVM to TP5.	Adjust R29 for 0 mV ±100 microvolts.	If these results cannot be obtained, refer to troubleshooting procedure. If ok, continue to step 3.
3	AC NULL ADJUSTMENTS		
a.	Connect the high side of the DVM to TP7 and adjust R55 for 0 V ±200 mV.		
b.	With the DVM at TP7, set the synchro/resolver simulator to 10.000 degrees. Set the toggle switch to TRACK and manipulate the simulator so that the API displays 10.000 degrees. Set toggle switch to $\overline{DF}$ and return synchro/resolver simulator to 10.000 degrees. Record DC level at TP7.		
c.	Set the toggle switch to TRACK. Manipulate the synchro/resolver simulator so that the API displays 9.990 degrees. Set toggle switch to $\overline{DF}$ and return synchro/resolver simulator to 9.990 degrees. Record DC level at TP7.	Readjust R29 until the DC level at TP7 is the same as in b, above. Repeat steps b and c, above, until the DC level at TP7 is the same for both steps.	
d.	Set the toggle switch to TRACK. Manipulate the synchro/resolver simulator so that the API display indicates 0.000 degrees. Set the toggle switch to $\overline{DF}$ and return synchro/resolver simulator to 0.000 degrees.		
e.	Connect the DVM to TP12.	Adjust R103 for 0 mV ±500 microvolts.	If the above results cannot be obtained, refer to troubleshooting proecure. If ok, continue to step 4.
4	π/6 ADJUSTMENT		
a.	Connect the low side of the scope to TP1 (ground) and the high side to TP9 (use a X10 probe).		

Table 5-2. Calibration Procedure (Continued)

Step	Procedure / Indication / Corrective action
b.	Set the vertical sensitivity to .2V division (full wave rectified sine wave 1.2mV peak) and the time base to 0.5 milliseconds/division. Adjust the scope time base and triggering so that the scope triggers on each successive peak. Adjust R65 so that peaks are of equal height. If these results cannot be obtained, refer to troubleshooting procedure. If ok, continue to step 5.
5	PHASE DETECTOR (VCO THRESHOLD ADJUSTMENT)
a.	Connect the PAV to TP7. Adjust the synchro/resolver simulator for an in-phase null at TP7 (angle on synchro/resolver simulator should be 0.000 degrees ±.002 degrees).
b.	Connect the DVM to TP14. Adjust R116 for 0 V ±200 mV.
c.	Switch the Auto-Phase switch (S6) on the main board from INT to EXT. Note the DC level change at TP14. If it changes when switched between the two positions, adjust R103 until the change has been eliminated.
d.	Return Auto-Range switch (S6) to INT. Readjust R116 for 0 V ±200 mV at TP14. If these results cannot be obtained, refer to troubleshooting procedure. If ok, continue to step 6.
6	MONITONICITY ADJUSTMENT
a.	Connect the PAV to TP7. Set toggle switch to TRACK and manipulate the synchro/resolver simulator until the API displays 20.000 degrees. Set the toggle switch to $\overline{DF}$ and adjust the synchro/resolver simulator for an in-phase null at TP7. (Synchro/resolver simulator should be 20.000 degrees ±.002 degrees.) Record synchro/resolver simulator setting.
b.	Set toggle switch to TRACK and manipulate the synchro/resolver simulator until the API displays 19.990 degrees. Set the toggle switch to $\overline{DF}$ and adjust the synchro/resolver simulator for an in-phase null at TP7. (Synchro/resolver simulator should be 19.990 degrees ±.002 degree). Record synchro/resolver simulator setting.
c.	Subtract the synchro/resolver simulator setting recorded in step b, above, from that recorded in step a. The difference should be 0.01 degree. Adjust R63, if necessary, to obtain this difference.
d.	Repeat steps a through c, above, until the desired result is obtained.
e.	Remove all test leads from API, and install the top and bottom covers. Secure covers with the screws previously removed. Test according to paragraphs 5.3.3 and 5.3.4 to insure the API meets the specifications.

SECTION 6

TROUBLESHOOTING

6.1 GENERAL

This section contains troubleshooting procedures for the API.

CAUTION

Use an extraction tool (Augat T114-1) to remove components (DIP) from their sockets to prevent damage.

6.2 VISUAL INSPECTION

Many troubles may easily be found by visual inspection. After removing the top and bottom covers, thoroughly inspect the API. Some obvious causes of trouble are:

- Cable connectors not properly seated.
- IC's improperly seated in their sockets.
- Broken wires or loose components.
- Burnt components indicating thermal overload. Locate the cause and correct.
- Metallic particles shorting adjacent lands on PC board. Inspect both sides of the board and brush-clean all exposed board completely to remove dust particles.

6.3 PRELIMINARY CHECKS

Make the following checks before troubleshooting:

a. All input signals and power levels are at their correct levels and frequencies.

b. All programming to rear connector J1 is correct.

c. The API is properly grounded.

d. Switch S5 on the main board is in the proper position (115 V or 230 V).

6.4 TROUBLESHOOTING

6.4.1 Power Supply Troubleshooting

Check the power supply for correct levels as the first step in troubleshooting after the preliminary checks have been completed. Use figure 6-1 as a guide for troubleshooting the power supply.

6.4.2 Display Board Troubleshooting

Refer to figure 6-2 when one or two of the display segments are always on or off or when the letters A, B, C, D, E, or F are displayed.

6.4.3 Main Board Troubleshooting

Refer to figure 6-3 when it has been determined (after performing paragraph 6.4.1) that the problem is on the main board.

NOTE

When a component (i.e., is said to be defective, it also refers to the associated components of the defective part (resistors, capacitors, diodes, etc.).

If API display is operating within specifications and the L-L LED's are not operational, or are incorrect, proceed to B of figure 6-3, sheet 2.

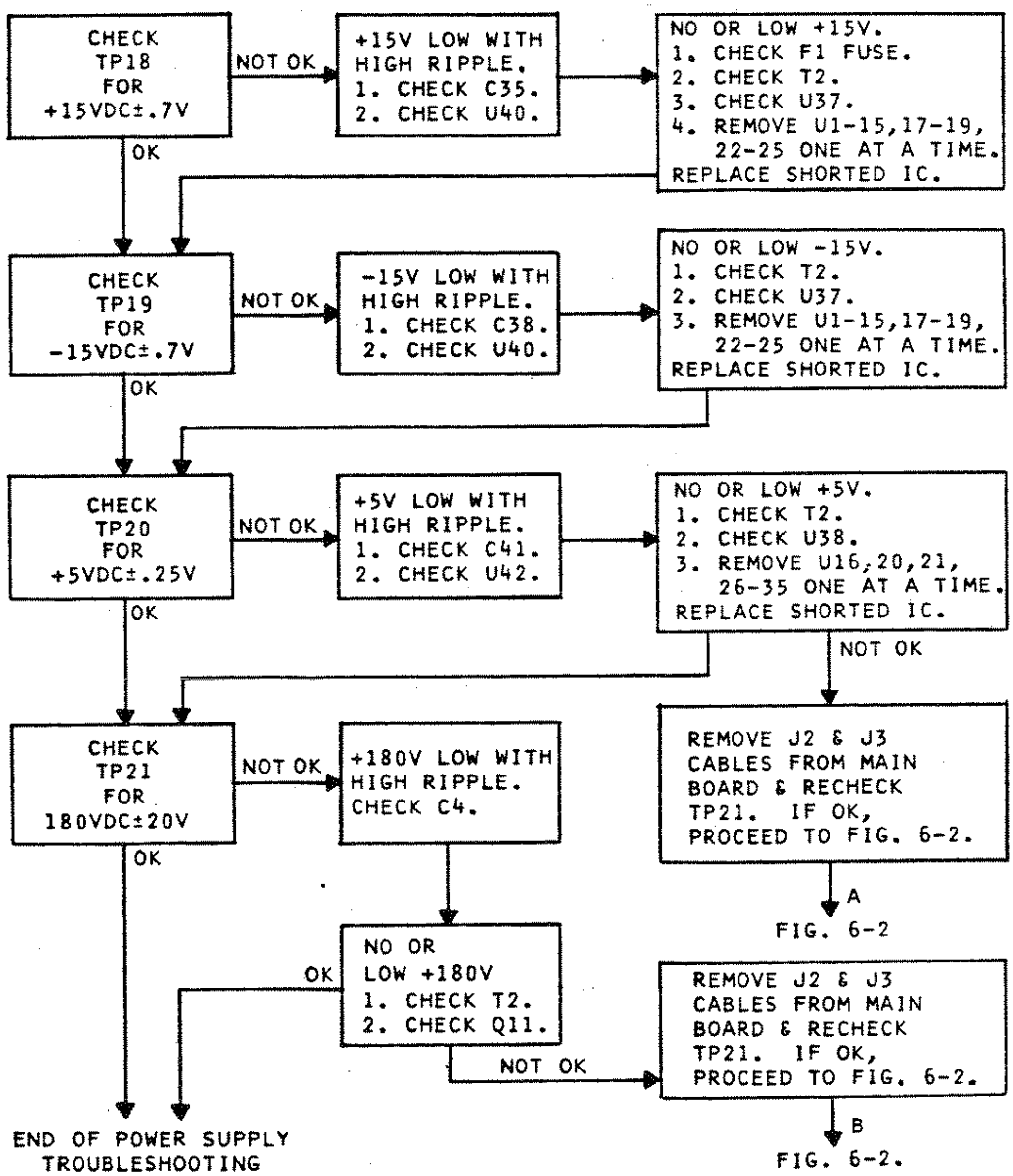

Figure 6-1. Power Supply Troubleshooting

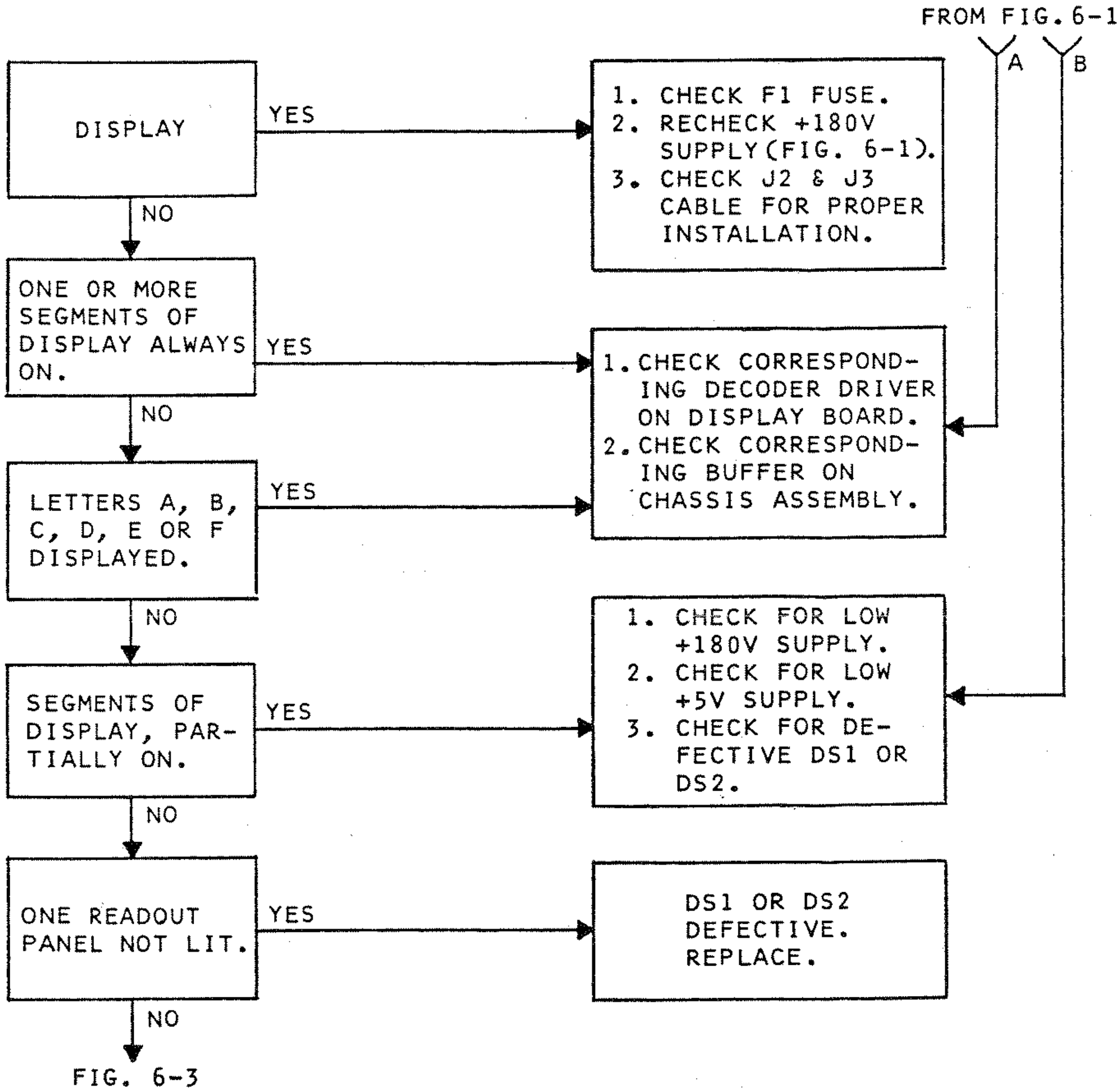

Figure 6-2. Display Board Troubleshooting

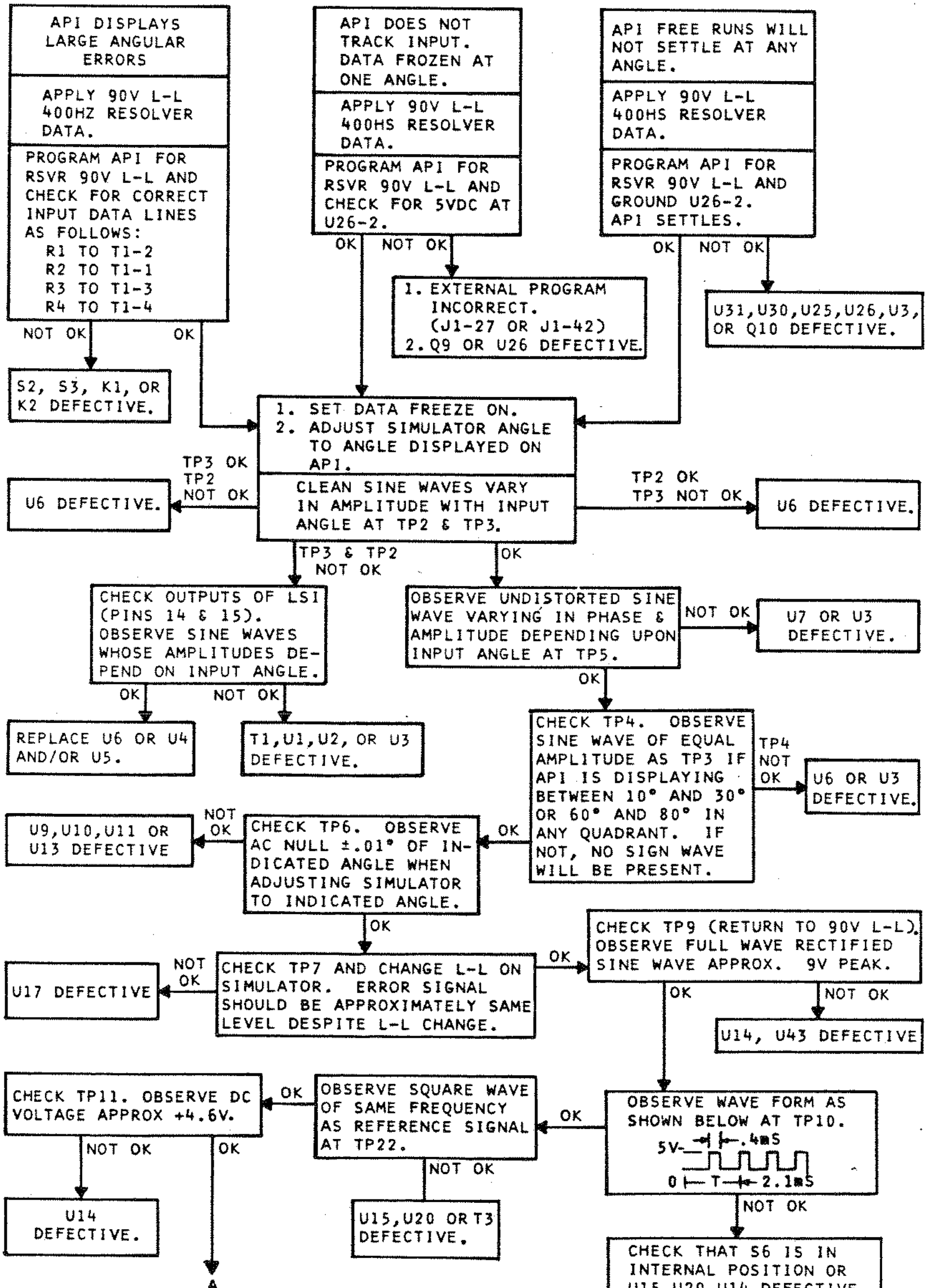

Figure 6-3. Main Board Troubleshooting (Sheet 1 of 2)

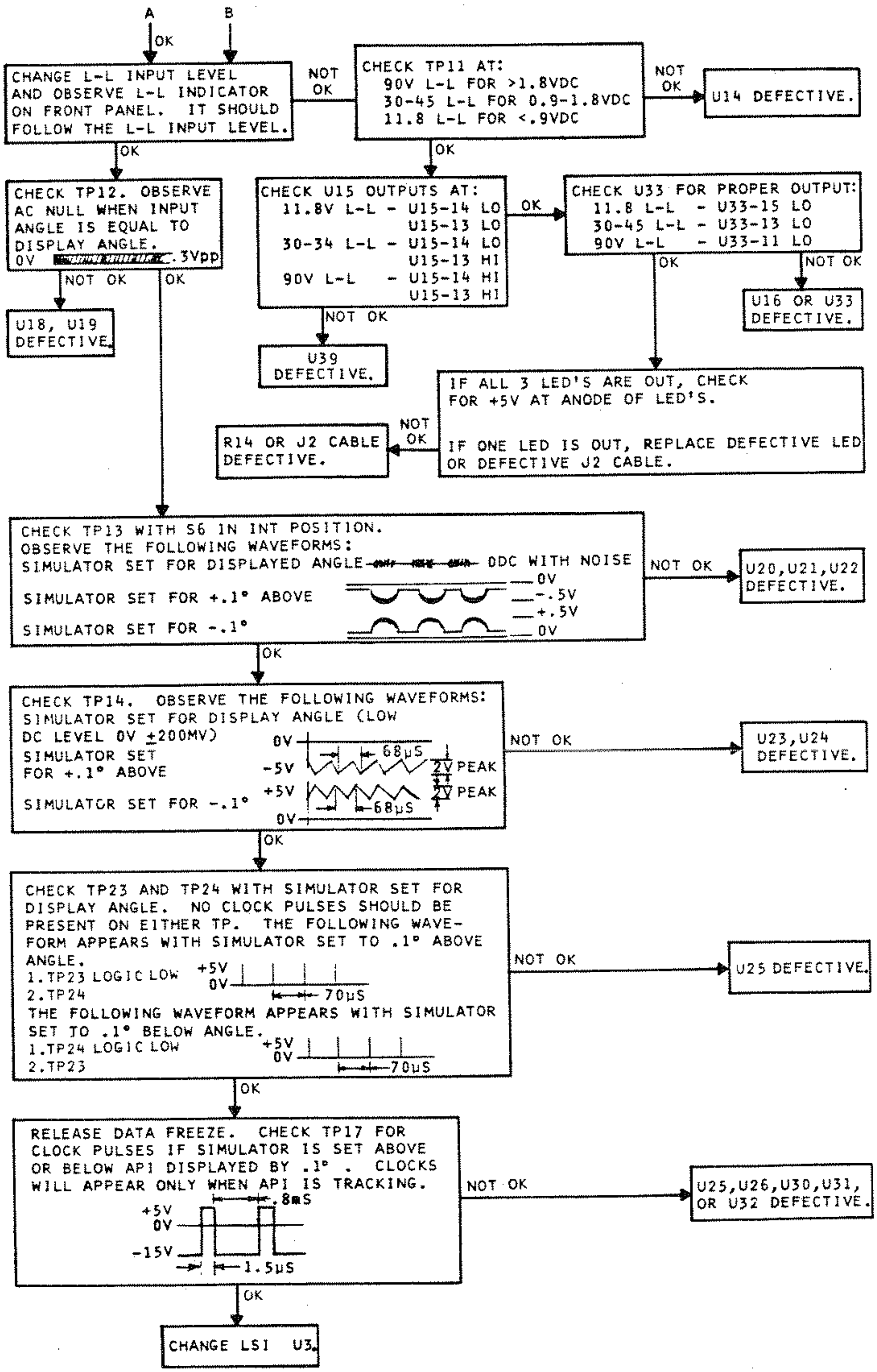

Figure 6-3. Main Board Troubleshooting (Sheet 2 of 2)

SECTION 7

PARTS LIST

This section provides a vendor codes list, parts lists, and parts locator diagrams for the API.

List of Manufacturers

Code	Manufacturer's Name and Address
00779	AMP, Inc., Harrisburg, Pennsylvania
01121	Allen-Bradley Company, Milwaukee, Wisconsin
01295	Texas Instruments, Dallas, Texas
02111	Spectrol Electronics, City of Industry, California
04713	Motorola Semiconductor, Phoenix, Arizona
06751	Semcor Components Inc., Phoenix, Arizona
06776	Robinson Nugent, New Albany, Indiana
07187	Sperry Flight Systems, Phoenix, Arizona
07263	Fairchild Camera, Mountain View, California
07342	North Atlantic Industries, Hauppauge, New York
09182	Hewlett-Packard Co., Berkley Heights, New Jersey
09922	Burndy Corp., Norwalk, Connecticut
12040	National Semiconductor, Danbury, Connecticut
16299	Corning Glass Works, Raleigh, North Carolina
17896	Siliconix, Inc., Santa Clara, California
28480	Hewlett-Packard Co., Palo Alto, California
30870	Republic Machinery Co., Los Angeles, California
32997	Bourns Inc., Riverside, California
51167	Aries Electronics, P.O. Box 231, Frenchtown, New Jersey
55261	LSI Computer Systems, Inc., Melville, New York
56289	Sprague Electric Co., North Adams, Massachusetts
73138	Beckman Instruments, Fullerton, California
75915	Littlefuse, Inc., Des Plaines, Illinois
79727	Continental Electronics, Philadelphia, Pennsylvania
82110	Gudebrod Brothers Silk Co., Philadelphia, Pennsylvania
91637	Dale Electronics Corp., Columbus, Nebraska
*	Illinois Capacitors, Inc., Morton Grove, Illinois
**	Any qualified vendor.

Table 7-1. Angle Position Indicator

Description	NAI P/N	Qty
Chassis	787101	1
Display Board	783739	1
Front Panel Assy.	548406	1
Front Panel	298009	1
Filter	205782	1
Cover, Top & Bottom	500891	1 ea.

Table 7-2. Replacement Parts List: Chassis Assembly (787101)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
C5	Capacitor, Mica, 15pf, 200V, ±10%	807629		CK05BX150K	4
C6	Same as C5				
C7	Capacitor, Ceramic, .1µf, 100V, ±10%	880640		CK06BX104K	22
C8	Same as C7				
C9	Same as C7				
C10	Capacitor, Tantalum, 10µf, 15V, ±10%	880073	06751	TS2K-20-106	2
C11	Same as C5				
C12	Same as C10				
C13	Same as C7				
C14	Same as C7				
C15	Capacitor, Ceramic, 1µf, 50V, ±10%	805155		CK06BX105K	2
C16	Same as C15				
C17	Same as C7				
C18	Capacitor, Ceramic, .39uf, 50V, ±10%	808193	56289	5CX7R394X9100C5	1
C19	Capacitor, Ceramic, .33µf, 50V, ±10%	882457		CKR06BX334XP	1
C20	Capacitor, Ceramic, .068µf, 100V, ±10%	805468		CK06BX683K	1
C21	Same as C7				
C22	Capacitor, Ceramic, .82uf, 100V, ±10%	805076		CK05BX824K	1
C23	Capacitor, Ceramic, 3900pf,200V, ±10%	805449		CK06BX392K	1
C24	Same as C7				
C25	Capacitor, Ceramic, 27pf, 200V, ±10%	808401		CK05BX270K	2
C26	Same as C25				
C27	Same as C7				
C30	Same as C7				
C31	Same as C5				
C32	Same as C7				
C33	Same as C7				
C34	Same as C7				
C35	Capacitor, Aluminum, 470µf, 35V, ±10%	807685	56289	503D477G035ER	2
C36	Capacitor, Tantalum, .22µf, 35V, ±20%	801297	56289	150D224X0035	2
C37	Same as C7				
C38	Same as C35				
C39	Capacitor, Tantalum, 2.2µf, 35V, ±10%	802914	56289	150D225X8035B2	1

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
C40	Capacitor, Tantalum, 1µf, 35V, ±20%	801343	56289	150D105X0035A2	1
C41	Capacitor, Aluminum, 1000µf, 16V, ±10%	807686	56289	503D108G016ER	1
C42	Same as C36				
C43	Same as C7				
C44	Capacitor, Aluminum, 10µf, 250V, -10+75%	885188	*	106RAR-250APX	1
C45	Same as C5				
C46	Same as C7				
C47	Same as C7				
C48	Same as C7				
C49	Same as C7				
C50	Same as C7				
C51	Same as C7				
C53	Capacitor, Ceramic, 4700pf, 200V, ±10%	805153		CK06BX472K	2
C54	Same as C53				
C55	Same as C7				
CR5	Diode, Signal 1N	808974	07263	1N4148	22
CR7	Same as CR5				
CR8	Same as CR5				
CR9	Same as CR5				
CR10	Same as CR5				
CR11	Same as CR5				
CR12	Same as CR5				
CR13	Same as CR5				
CR14	Same as CR5				
CR15	Same as CR5				
CR16	Same as CR5				
CR17	Diode	883449	**	1N6263	3
CR18	Same as CR17				
CR19	Same as CR5				
CR20	Same as CR5				
CR21	Same as CR5				
CR22	Same as CR17				
CR23	Transistor	807607	04713	2N4123	5
CR24	Same as CR23				
CR25	Same as CR5				
CR26	Same as CR5				
CR27	Same as CR5				
CR28	Same as CR5				

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
CR29	Same as CR5				
CR30	Same as CR5				
CR31	Same as CR5				
CR32	Diode	804477	04713	1N4001	3
CR33	Same as CR32				
CR34	Same as CR32				
CR35	Diode, 190V, 500mV, ±5%	808157	04713	1N5280B	1
CR36	Same as CR5				
F1	Fuse, .5A, 3AG (115V unit)	880795	75915	312.500	1
	Fuseholder (3AG) (for F1)	800137	75915	342004	1
J1	Connector, 50-pin	808198	00779	206971-1	1
J2	Connector, 16-pin	885419	51167	16-0513-10	1
J3	Connector, 14-pin	885420	51167	14-0513-10	1
K1	Relay	808015	00779	53451-1	2
K2	Same as K1				
Q1	Transistor	808809	17896	J105-18	6
Q2	Same as Q1				
Q3	Same as Q1				
Q4	Same as Q1				
Q5	Same as Q1				
Q6	Same as Q1				
Q7	Same as CR23				
Q8	Transistor	804583	01295	T1S73	1
Q9	Same as CR23				
Q10	Same as CR23				
Q11	Transistor	807690	04713	MPSA43	1
R1	Resistor, Composition 510KΩ,1/8W,±5%	807623		RC05GF514J	6
R2	Same as R1				
R3	Resistor, Composition 24kΩ,1/4W,±5%	801393	01121	CB2435	7
R4	Same as R3				
R5	Same as R1				
R7	Resistor, Composition 47kΩ,1/4W,±5%	801638	01121	CB4735	3
R8	Same as R1				
R9	Resistor, Composition 510kΩ,1/4W,±5%	880099	01121	CB5145	7
R10	Same as R9				
R11	Same as R9				
R12	Same as R9				
R13	Same as R9				
R14	Same as R9				
R15	Resistor, Matched Set	807726-3	07342		1

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
R16	Resistor, Matched Set	807726-1	07342		
R17	Resistor, Matched Set	807726-2	07342		
R18	Resistor, Comp., 180kΩ, 1/4W, ±5%	882398		RCR07G184JP	2
R19	Potentiometer, 100k	807625	02111	62-1-1-104	2
R20	Resistor, Comp., 160Ω, 1/4W, ±5%	804212	01121	CB1615	2
R21	Resistor, Matched Set	807727-3	07342		1
R22	Resistor, Matched Set	807727-1	07342		
R23	Resistor, Matched Set	807727-2	07342		
R24	Same as R18				
R25	Same as R20				
R26	Same as R19				
R27	Resistor, M.F., 158kΩ, 1/10W, ±1/2%	808359	01121	CC1583D	1
R28	Resistor, M.F., 750Ω, 1/10W, ±1/2%	808360	01121	CC7500RD	1
R29	Potentiometer, 20kΩ (square)	808229	02111	RT-24C2X	2
R30	Resistor, M.F., 20kΩ, 1/10W, ±.5%	808226	16299	NC5-20K, 1/10W	2
R31	Resistor, Comp., 10kΩ, 1/4W, ±5%	880092	01121	CB1035	14
R32	Same as R30				
R33	Resistor, M.F., 2.10MΩ, 1/10W, ±1%	808107	01121	CC2104	1
R34	Resistor, M.F., 698kΩ, 1/10W, ±.5%	808108	16299	NC5-698K, 1/10W	1
R35	Resistor, Matched Set	807728-3	07342		1
R36	Resistor, Matched Set	807728-4	07342		
R37	Resistor, Matched Set	807728-5	07342		
R38	Resistor, Matched Set	807728-6	07342		
R39	Resistor, Matched Set	807728-7	07342		
R40	Resistor, Matched Set	807728-8	07342		
R41	Resistor, Matched Set	807728-9	07342		
R42	Resistor, Matched Set	807728-10	07342		
R43	Resistor, M.F., 250kΩ, 1/10W, ±.5%	806106	16299	NC5-250K, 1/10W	1
R44	Resistor, M.F., 499kΩ, 1/10W, ±1%	806929	16299	NC5-499K, 1/10W	1
R45	Resistor, M.F., 1MΩ, 1/10W, ±1%	807692	91637	DC-1/8	2
R46	Resistor, M.F., 2MΩ, 1/10W, ±1%	807691	91637	DC-1/8	1
R48	Same as R46				
R49	Resistor, M.F., 976kΩ, 1/10W, ±1%	808097	01121	CC9763F	1

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
R50	Resistor, Matched Set	807728-2	07342		
R51	Resistor, M.F., 1.05MΩ, 1/10W, ±1%	808144	01121	CC1054F	1
R52	Resistor, M.F., 26.7kΩ, 1/10W, ±1%	807634	01121	CC2672F	2
R53	Same as R9				
R54	Resistor, Comp., 430Ω, 1/4W, ±5%	801399	01121	CB4315	1
R55	Resistor, Variable, 100k	808690	32997	3279-1-104	1
R56	Resistor, Comp., 270Ω, 1/4W, ±5%	880079	01121	CB2715	1
R57	Resistor, Comp., 470Ω, 1/4W, ±5%	880567	01121	CB4715	1
R58	Resistor, Matched Set	807728-1			
R59	Resistor, M.F., 4.02kΩ, 1/10W, ±1%	808316	16299	NC55-4.02K	2
R60	Resistor, M.F., 59kΩ, 1/10W, ±1%	808184	01121	CC5902F	2
R61	Same as R60				
R62	Same as R59				
R63	Potentiometer, 200kΩ	808362	01121	A2A204	1
R65	Potentiometer, 100kΩ	807062	32997	3299W-104	1
R66	Resistor, Comp., 3.9MΩ, 1/4W, ±5%	807480	01121	CB3955	1
R67	Resistor, M.F., 30.1kΩ, 1/10W, ±1%	880646	16299	NC4-30.1K	2
R68	Same as R67				
R70	Resistor, M.F., 24.9kΩ, 1/10W, ±1%	808096	01121	CC2492F	2
R71	Same as R70				
R72	Resistor, M.F., 40.2kΩ, 1/10W, ±1%	884538		RN55C4022F	1
R73	Resistor, M.F., 27.4kΩ, 1/10W, ±1%	808098	01121	CC2742F	1
R74	Resistor, M.F., 100kΩ, 1/10W, ±1%	806992		RN55D1003F	3
R75	Resistor, Comp., 6.8kΩ, 1/4W, ±5%	880090	01121	CB6825	7
R76	Same as R3				
R77	Resistor, M.F., 49.9kΩ, 1/10W, ±1%	807635	01121	CC4992F	5
R78	Same as R31				
R79	Resistor, M.F., 10.7kΩ, 1/10W, ±1%	808478	01121	CC1072F	1
R80	Same as R31				
R81	Resistor, M.F., 3.48kΩ, 1/10W, ±1%	808355	16299	NA55-3.48K	1
R82	Same as R31				
R83	Resistor, Comp., 10MΩ, 1/4W, ±5%	803389	01121	CB1065	2

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
R84	Same as R83				
R85	Same as R31				
R86	Resistor, Comp., 5.1 KΩ, 1/4W, ±5%	880089	01121	CB5125	1
R88	Same as R31				
R89	Same as R7				
R90	Resistor, M.F., 56.2kΩ, 1/10W, ±1%	807476	16299	C4-56.2K, 1/10W	1
R91	Resistor, M.F., 124kΩ, 1/10W, ±1%	807414		RN55D1243F	1
R92	Resistor, M.F., 267kΩ, 1/10W, ±1%	807641	01121	CC2673F	1
R93	Resistor, M.F., 4.99kΩ, 1/10W, ±1%	808182	01121	CC4991F	1
R94	Resistor, M.F., 16.2kΩ, 1/10W, ±1%	806559	16299	NC4 16.2K, 1/10W	1
R95	Same as R7				
R96	Same as R75				
R97	Resistor, M.F., 634kΩ, 1/10W, ±1%	808146	01121	CC6343F	1
R98	Same as R74				
R99	Resistor, Comp., 100kΩ, 1/4W, ±5%	880846	01121	CB1045	7
R100	Resistor, M.F., 20kΩ, 1/10W, ±1%	807409		RN55D-2002F	3
R101	Same as R100				
R102	Same as R31				
R103	Potentiometer, 20kΩ	808110	73138	62P-R-20K	1
R104	Resistor, M.F., 10kΩ, 1/10W, ±1%	806103	16299	NC4-10K, 1/10W	3
R105	Same as R31				
R106	Resistor, M.F., 78.7kΩ, 1/10W, ±1%	807288		RN55D7872F	1
R107	Same as R77				
R108	Same as R45				
R109	Same as R77				
R110	Same as R75				
R111	Same as R31				
R112	Resistor, M.F., 90.9kΩ, 1/10W, ±1%	808185	01121	CC9092F	1
R113	Resistor, M.F., 249 kΩ, 1/10W, ±1%	808472	01121	CC2493F	1
R114	Same as R99				
R115	Resistor, M.F., 100Ω, 1/10W, ±1%	808143	01121	CC1000F	1
R116	Same as R29				

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
R117	Same as R31				
R118	Same as R74				
R119	Resistor, M.F., 8.06kΩ, 1/10W, ±1%	807016		RN55D8061F	1
R120	Same as R99				
R121	Same as R3				
R122	Same as R75				
R123	Same as R3				
R124	Resistor, Comp., 130kΩ, 1/4W, ±5%	801394	01121	CB1345	1
R125	Same as R3				
R126	Same as R52				
R127	Same as R100				
R128	Resistor, M.F., 13.3kΩ, 1/10W, ±1%	807633	01121	CC1332F	2
R129	Resistor, M.F., 3.32kΩ, 1/10W, ±1%	807631	01121	CC3321F	4
R130	Same as R129				
R131	Same as R77				
R132	Same as R128				
R133	Same as R129				
R134	Same as R129				
R135	Same as R77				
R136	Same as R75				
R137	Resistor, Comp., 13kΩ, 1/4W, ±5%	880094	01121	CB1335	3
R138	Same as R75				
R139	Same as R137				
R140	Same as R137				
R141	Same as R99				
R142	Same as R99				
R145	Resistor, Comp., 91kΩ, 1/4W, ±5%	803240	01121	CB9135	1
R146	Same as R3				
R147	Resistor, Comp., 18kΩ, 1/4W, ±5%	802183	01121	CB1835	1
R148	Same as R31				
R149	Same as R31				
R150	Same as R31				
R151	Same as R99				

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
R152	Same as R31				
R153	Resistor, Comp., 330Ω, 1/4W, ±5%	880080	01121	CB3315	1
R154	Same as R75				
R155	Same as R99				
R156	Resistor, Comp., 510kΩ, 1/8W, ±5%	807623		RC05GF514J	1
R162	Same as R69				
R163	Same as R69				
S1	Switch, Pushbutton	808703	07342	808703	1 set
S5	Switch, Slide, DPDT	808112	79727	GF126	2
S6	Same as S5				
T1	Transformer, Scott-T	808029	07342	808029	1
T2	Transformer, Power	550506	07342	550506	1
T3	Transformer, Reference	550507	07342	550507	1
TP1-15	Terminal	880007	00779	87022-9	24
TP17-25	Same as TP1-15				
U1	Integrated Circuit	807626	12040	LM339N	4
U2	Same as U1				
U3	Integrated Circuit, LSI	807155-MOS	55261	2201N	1
U4	Integrated Circuit	807797	12040	LF356C	7
U5	Same as U4				
U6	Integrated Circuit	807530	07263	µA4136PC	4
U7	Same as U4				
U8	Integrated Circuit	808089	12040	LF13202(N)	4
U9	Same as U6				
U10	Same as U6				
U11	Same as U8				
U12	Same as U8				
U13	Integrated Circuit	808145	12040	LF357C	2
U14	Same as U6				
U15	Same as U1				
U16	Integrated Circuit	808092-MOS	04713	MC14011BF	4
U17	Same as U13				
U18	Same as U4				

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
U19	Same as U4				
U20	Integrated Circuit	808188	12040	DM74L04N	1
U21	Same as U16				
U22	Same as U8				
U23	Same as U4				
U24	Same as U4				
U25	Same as U1				
U26	Same as U16				
U28	Integrated Circuit	808091-MOS	04713	MC1407BP	1
U29	Integrated Circuit	808090-MOS	04713	MC14069BP	1
U30	Same as U16				
U31	Integrated Circuit	807700-MOS	12040	74C192	1
U32	Integrated Circuit	807702-MOS	04713	MC14561	1
U33	Integrated Circuit	808357	12040	DM81LS95N	3
U34	Same as U33				
U35	Same as U33				
U37	I.C., Diode Bridge, 50V	807704	30870	VM08	2
U38	Same as U37				
U39	I.C., Diode Bridge, 400V	807705	30870	VM48	1
U40	Voltage Regulator	808388	12040	LM340T-15	1
U41	Voltage Regulator	808390	12040	LM320T-15	1
U42	Voltage Regulator	808389	12040	LM340T-15	1
U43	Integrated Circuit	885063	12040	LF353H	1
VP1	Varistor	807699	03508	V130LA10A	2
VP2	Same as VP1				
XU1	Socket, I.C., 14-pin	807473	00779	640357-3	16
XU2	Same as XU1				
XU3	Socket, 25-pin	808363	06776	SB-25-T	2
XU4	Socket, I.C., 8-pin	805671	82110	Type A23-2052	10
XU5	Same as XU4				
XU6	Same as XU1				
XU7	Same as XU4				
XU8	Socket, I.C., 16-pin	808197	00779	640358-3	5

Table 7-2. Replacement Parts List: Chassis Assembly (787101) (Continued)

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
XU9	Same as XU1				
XU10	Same as XU1				
XU11	Same as XU8				
XU12	Same as XU8				
XU13	Same as XU4				
XU14	Same as XU1				
XU15	Same as XU1				
XU16	Same as XU1				
XU17	Same as XU4				
XU18	Same as XU4				
XU19	Same as XU4				
XU20	Same as XU1				
XU21	Same as XU1				
XU22	Same as XU8				
XU23	Same as XU4				
XU24	Same as XU4				
XU25	Same as XU1				
XU26	Same as XU1				
XU28	Same as XU1				
XU29	Same as XU1				
XU30	Same as XU1				
XU31	Same as XU8				
XU32	Same as XU1				
XU33	Socket, I.C., 20-pin	808408	09922	DILB20P-108	3
XU34	Same as XU33				
XU35	Same as XU33				
XU43	Same as XU4				

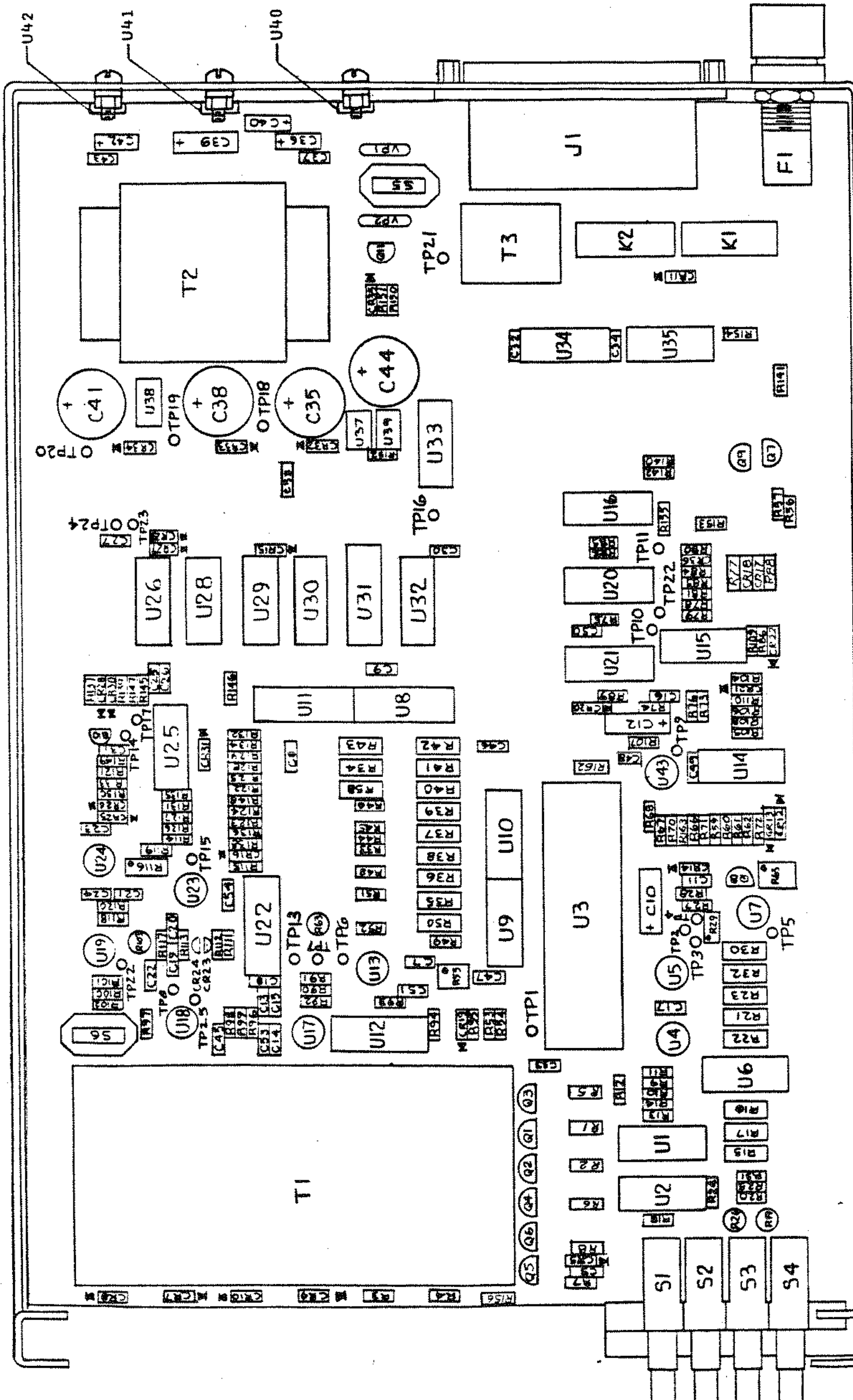

Figure 7-1. Main Chassis, Parts Locator

Table 7-3. Replacement Parts List: 360° Display Board, 783739

Ref. Des.	Description	NAI P/N	Code	Mfr. P/N	Total Qty
DS1	Display, Readout	807670	73138	SP353	2
DS2	Same as DS1				
DS3	LED	807394	28480	5082-4484	3
DS4	Same as DS3				
DS5	Same as DS3				
R1	Resistor, Comp., 430kΩ, 1/4W, ±5%	802519	01121	CB4345	1
R2	Resistor, Comp., 2.2kΩ, 1/4W, ±5%	800079	01121	EB2225	6
R3	Same as R2				
R4	Same as R2				
R5	Same as R2				
R6	Same as R2				
R7	Same as R2				
R8	Resistor, Comp., 13kΩ, 1/4W, ±5%	880094	01121	CB1335	6
R9	Same as R8				
R10	Same as R8				
R11	Same as R8				
R12	Same as R8				
R13	Same as R8				
R14	Resistor, Comp., 150Ω, 1/4W, ±5%	880200	01121	CB1515	1
U1	Integrated Circuit	806945	07187	DD700	6
U2	Same as U1				
U3	Same as U1				
U4	Same as U1				
U5	Same as U1				
U6	Same as U1				
W1	Cable, Flat-Flex, 16-conductor	808117	00779	5107-651-74	1
W2	Cable, Flat-Flex, 14-conductor	808116	00779	5107-651-157	1

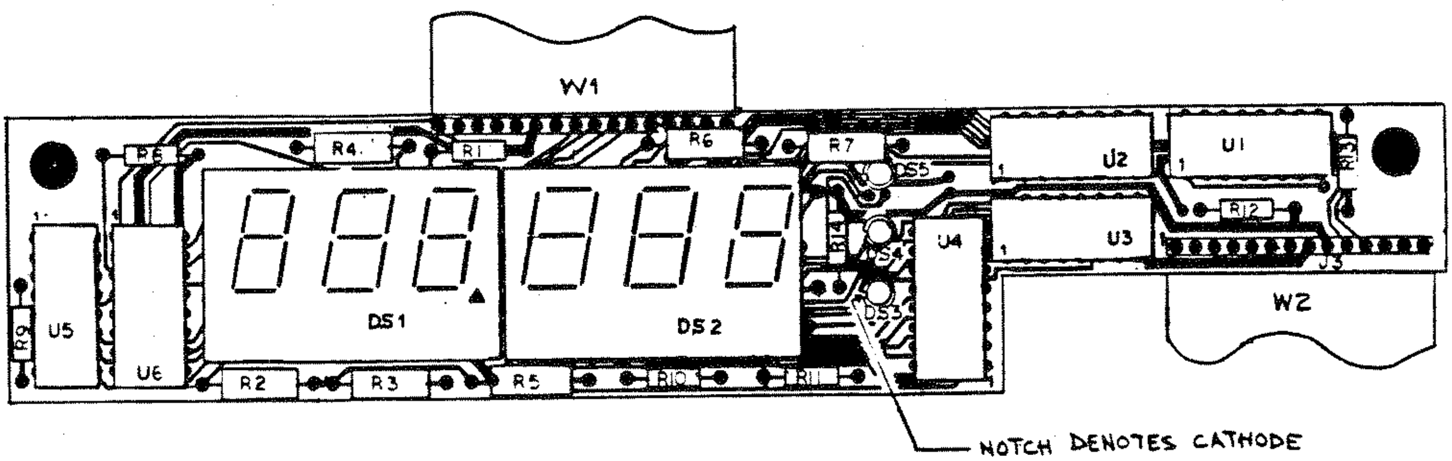

Figure 7-2. 360° Display Board, Parts Locator

SECTION 8

UNIT SCHEMATICS

This section contains schematic diagrams for the API.

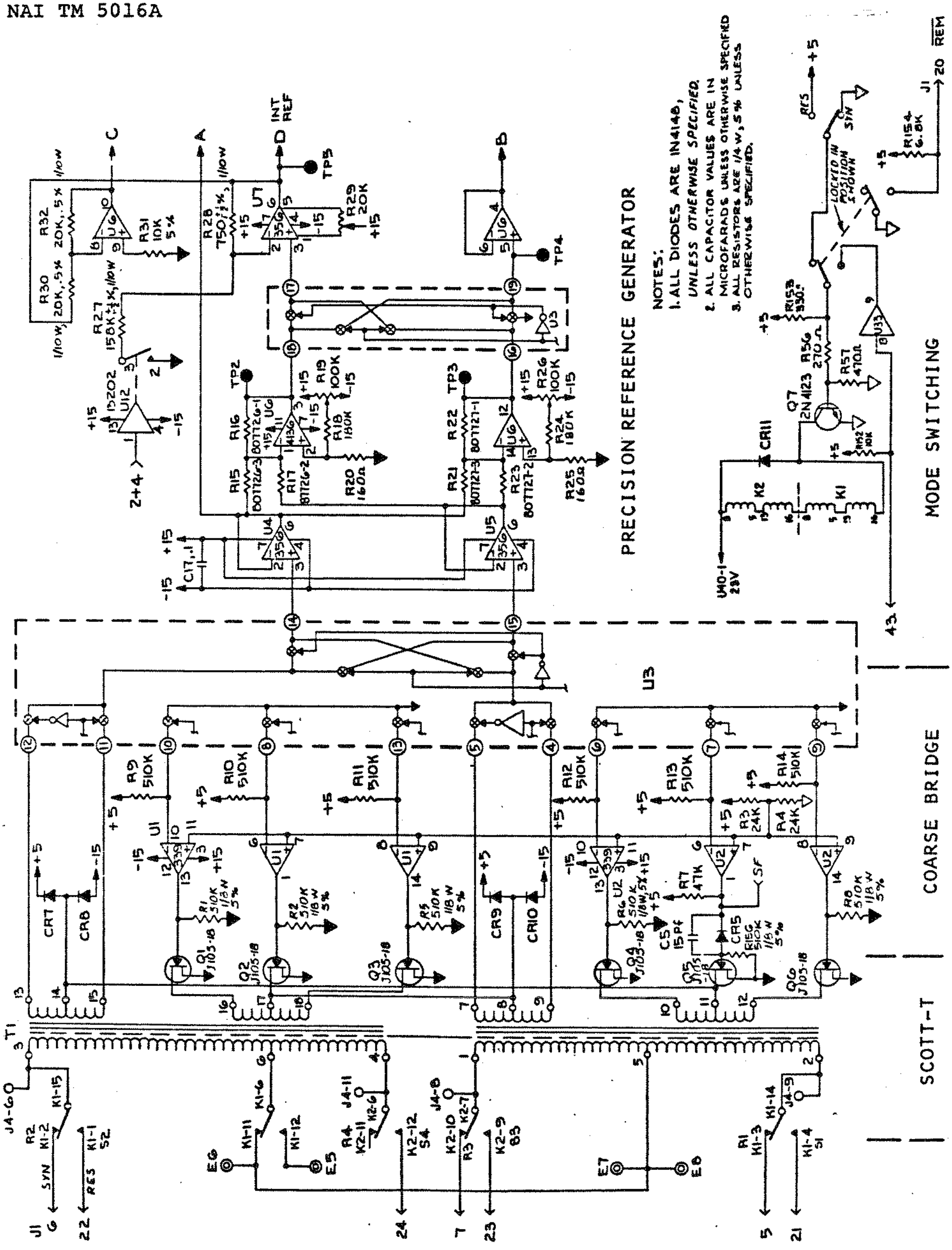

Figure 8-1. Main Chassis (Sh 1 of 5), Schematic

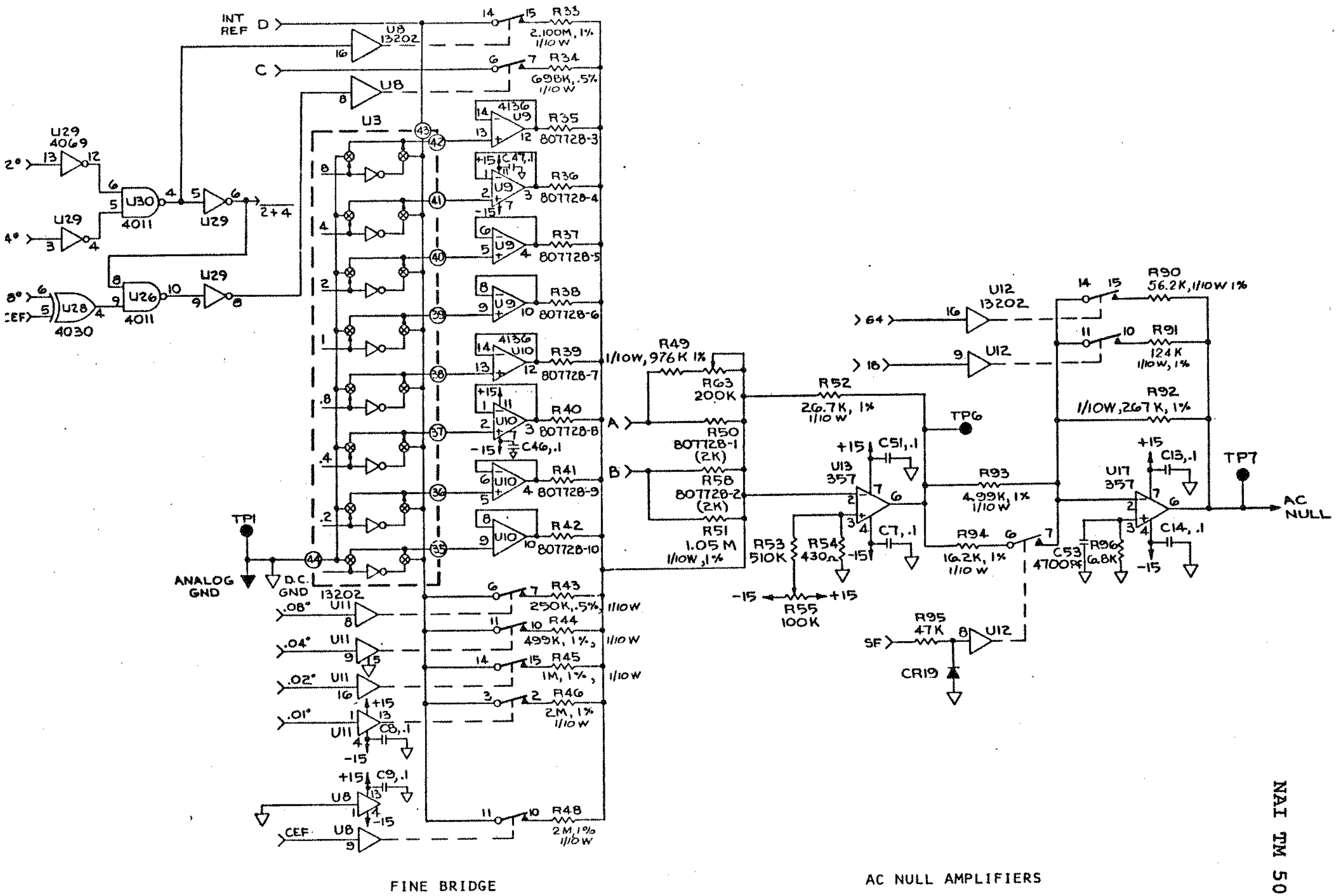

Figure 8-1. Main Chassis (Sh of 5), Schematic

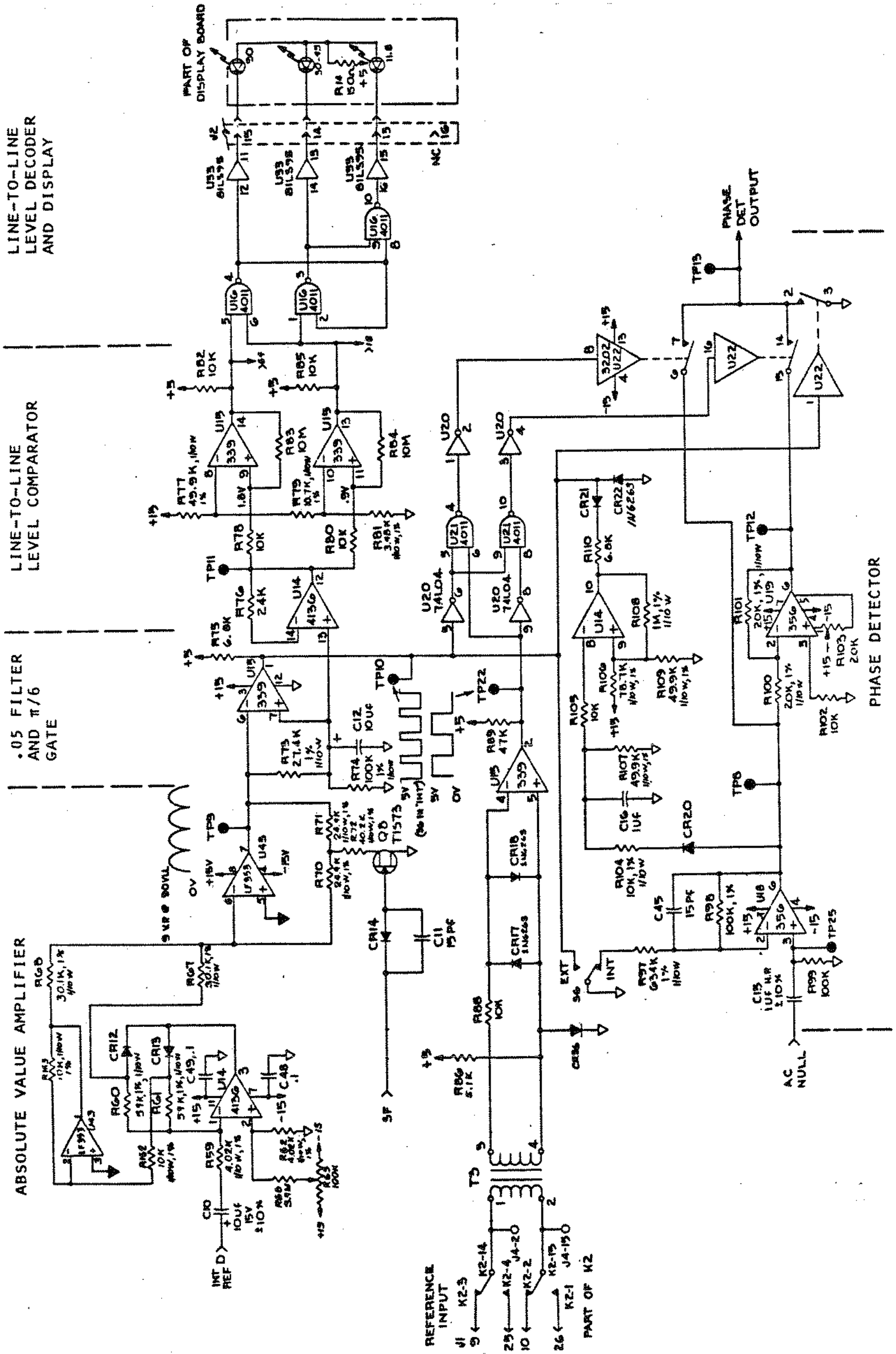

Figure 8-1. Main Chassis (Sh 3 of 5), Schematic

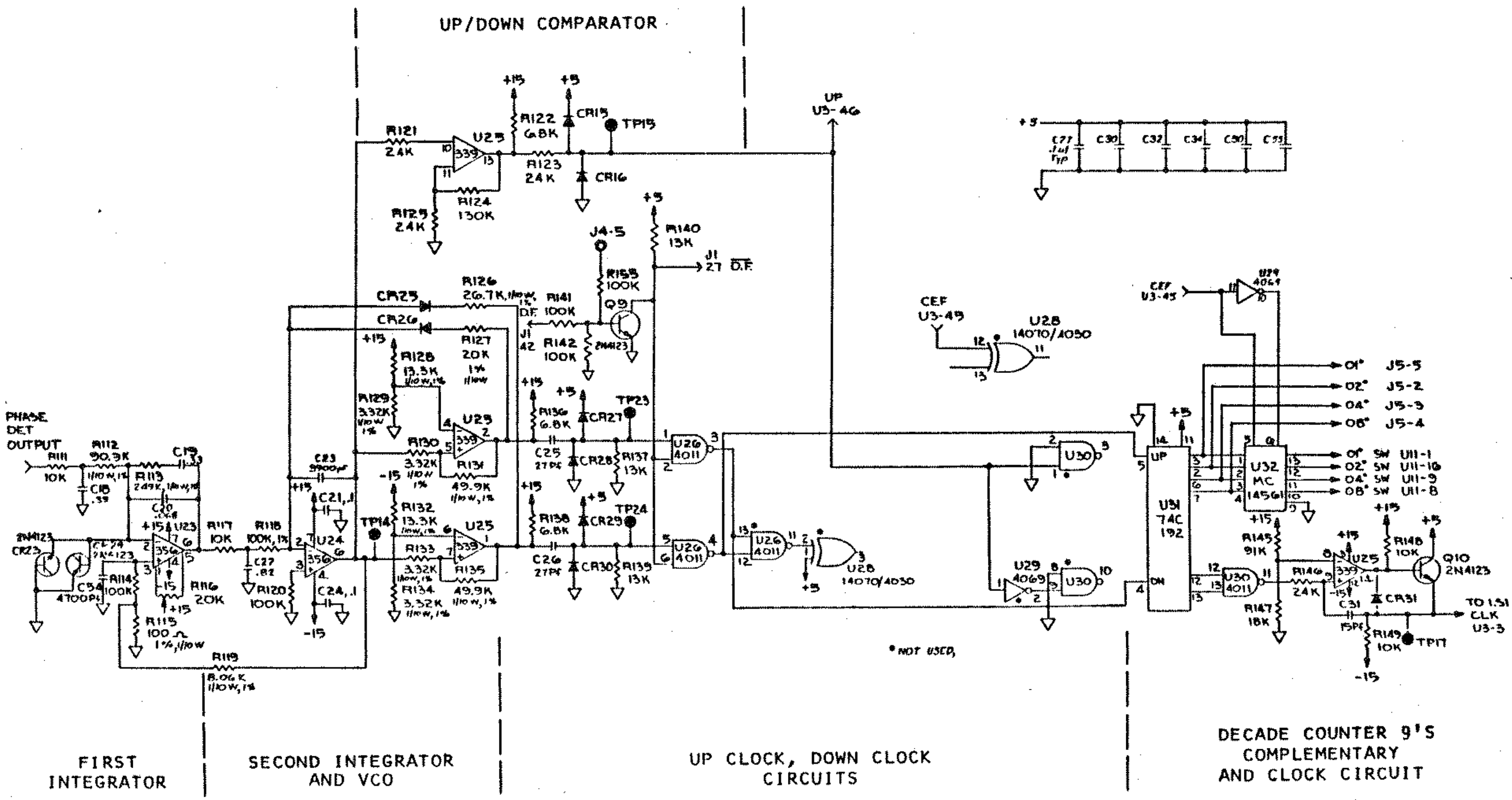

Figure 8-1. Main Chassis (Sh 4 of 5), Schematic

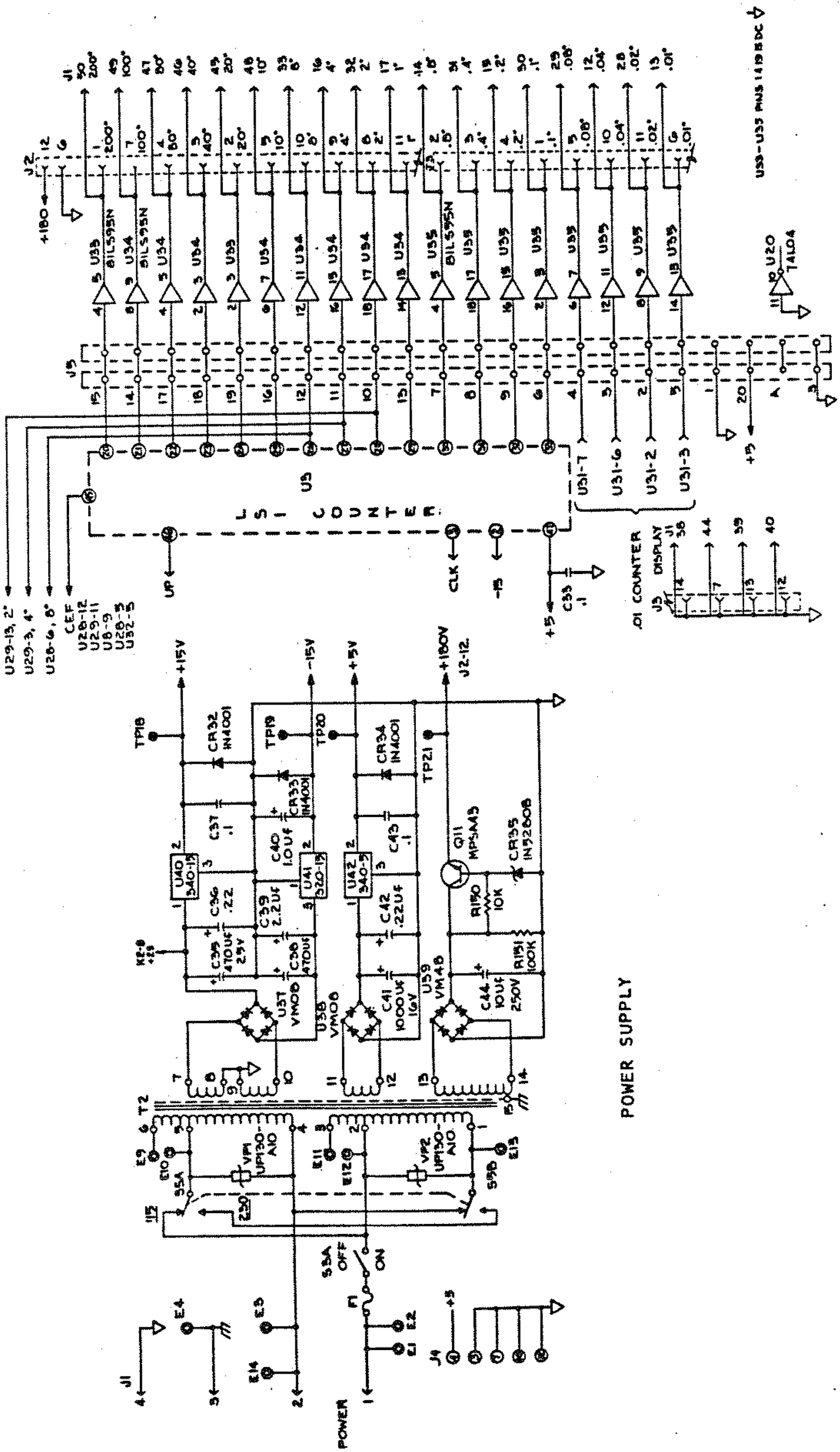

Figure 8-1. Main Chassis (Sh 5 of 5), Schematic

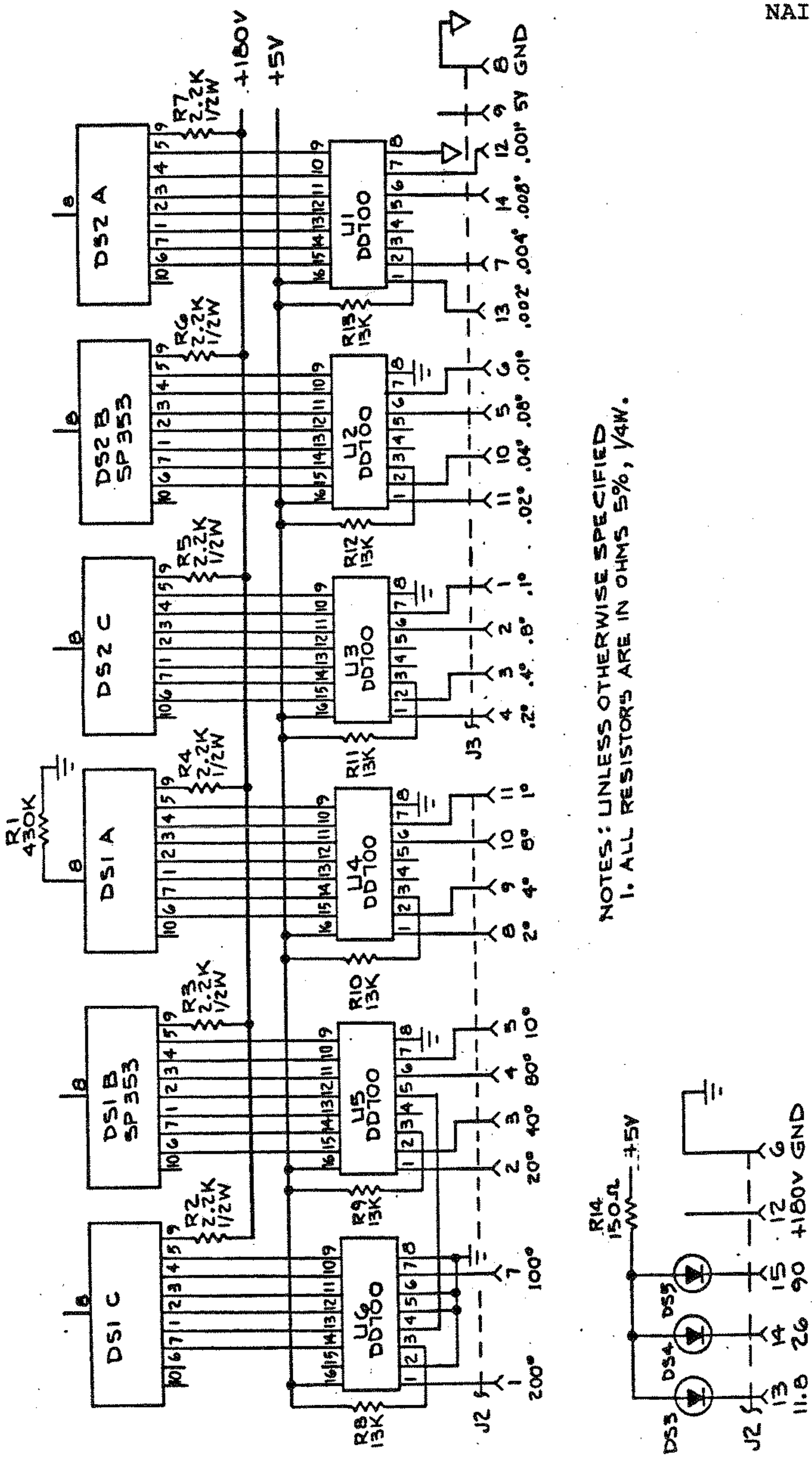

Figure 8-2. 360° Display Board, Schematic

WARRANTY

A. The Seller warrants Products against defects in material and workmanship for one year from the date of original shipment. The Seller's liability is limited to the repair or replacement of Products which prove to be defective during the Warranty period. There is no charge under the Warranty except for transportation charges. The Purchaser shall be responsible for Products shipped until received by the Seller.

B. The Seller specifically excludes from the Warranty 1) calibration, 2) fuses, and 3) normal mechanical wear, e.g.; end-of-life on assemblies such as switches, relays, gear trains, etc. is dependent upon number of operations or hours of use, and end-of-life may occur within the Warranty period.

C. The Seller is not liable for consequential damages or for any injury or damage to persons or property resulting from the operation or application of Products.

D. The Warranty is voided if there is evidence that Products have been operated beyond their design range, improperly installed, improperly maintained or physically mistreated.

E. The Seller reserves the right to make changes and improvements to Products without any liability for incorporating such changes or improvements in any Products previously sold, or for any notification to the Purchaser prior to shipment. In the event the Purchaser should require subsequently manufactured lots to be identical to those covered by this Quotation, the Seller will, upon written request, provide a quotation upon a change control program.

F. No other Warranty expressed or implied is offered by the Seller other than the foregoing.

CLAIMS FOR DAMAGE IN SHIPMENT

The purchaser should inspect and functionally test the Product(s) in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or if insured separately, with the purchaser's insurance company.

SHIPPING

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in a sealed plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.