2640A/2645A

NetDAQ Data Acquisition Tools

Service Manual

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SAFETY TERMS IN THIS MANUAL

This instrument has been designed and tested in accordance with IEC publication 1010-1 (1992-1), Safety Requirements for Electrical Measuring, Control and Laboratory Equipment, and ANSI/ISA-582.01-1994, and CAN/CSA-C22.2 No. 1010.1-92. This User Manual contains information, warning, and cautions that must be followed to ensure safe operation and to maintain the instrument in a safe condition. Use of this equipment in a manner not specified herein may impair the protection provided by the equipment.

This instrument is designed for IEC 1010-1 Installation Category II use. It is not designed for connection to circuits rated over 4800 VA.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

CAUTION statements identify conditions or practices that could result in damage to equipment.

SYMBOLS MARKED ON EQUIPMENT

WARNING Risk of electric shock. Refer to the manual.

GROUND Ground terminal to chassis (earth).

Attention Refer to the manual. This symbol indicates that information about usage of a feature is contained in the manual. This symbol appears on the rear panel ground post and by the fuse compartment.

AC POWER SOURCE

The instrument is intended to operate from an ac power source that will not apply more than 264V ac rms between the supply conductors or between either supply conductor and ground. A protective ground connection by way of the grounding conductor in the power cord is required for safe operation.

USE THE PROPER FUSE

To avoid fire hazard, for fuse replacement use only the specified unit: 15/100 ampere, 250V, time delay.

GROUNDING THE INSTRUMENT

The instrument utilizes controlled overvoltage techniques that require the instrument to be grounded whenever normal mode or common mode ac voltages or transient voltages may occur. The enclosure must be grounded through the grounding conductor of the power cord, or through the rear panel ground binding post.

USE THE PROPER POWER CORD

Use only the power cord and connector appropriate for the voltage and plug configuration in your country.

Use only a power cord that is in good condition.

Refer power cord and connector changes to qualified service personnel.

DO NOT OPERATE IN EXPLOSIVE ATMOSPHERES

To avoid explosion, do not operate the instrument in an atmosphere of explosive gas.

DO NOT REMOVE COVER DURING OPERATION

To avoid personal injury or death, do not remove the instrument cover without first removing the power source connected to the rear panel. Do not operate the instrument without the cover properly installed. Normal calibration is accomplished with the cover closed. Access procedures and the warnings for such procedures are contained in this manual. Service procedures are for qualified service personnel only.

DO NOT ATTEMPT TO OPERATE IF PROTECTION MAY BE IMPAIRED

If the instrument appears damaged or operates abnormally, protection may be impaired. Do not attempt to operate the instrument under these conditions. Refer all questions of proper instrument operation to qualified service personnel.

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Chapter 1
Introduction and Specification

Introduction 1-1.

This Service Manual supports performance testing, calibration, servicing, and maintenance of the 2640A NetDAQ™ and 2645A NetDAQ networked data acquisition units (Figure 1-1). NetDAQ networked data acquisition units are 20-channel front ends that operate in conjunction with a host computer to form a networked data acquisition system. The host computer and instruments are interconnected using an Ethernet network, and the host computer runs the NetDAQ *Logger for Windows* application to provide an operating environment for the instruments, including testing and calibration.

The 2640A and 2645A networked data acquisition units are identical in operation and appearance, and vary only in emphasis: The 2640A emphasizes precision and supports up to 100 measurements per second, with 5 ½ digits of resolution, .02% accuracy, and 150-volt common mode voltage (300 volts on channels 1 and 11), while the 2645A emphasizes increased measurement speed supporting up to 1000 measurements per second, with 4 ½ digits of resolution, .04% accuracy, and 50-volt common mode voltage. Refer to Table 1-1 for a summary of instrument specifications. For complete instrument specifications, see "Specifications" later in this chapter.

The instruments measure dc volts, ac volts, ohms, temperature, frequency, and dc current. Temperature measurements use thermocouples or resistance-temperature detectors (RTDs). Refer to Table 1-2 for a summary of instrument measurement capabilities. In addition, there are eight digital input/output lines, one totalizing input, one external trigger input, one trigger output, and one master alarm output. The instruments can be ac or dc powered. An RS-232 serial port is supplied for servicing and maintenance procedures.

The term "instrument" is used in this manual to refer to both units. The model number (2640A or 2645A) is used when discussing characteristics unique to one instrument. Instrument assemblies are identical except for the A3 Analog/Digital Converter printed circuit assembly (pca), which is specific to the 2640A (mechanical switching for measurement signals) and 2645A (solid-state switching for measurement signals).

The instrument is designed for bench-top, field service, and system applications. A dual vacuum-fluorescent display uses combinations of alphanumeric characters and descriptive annunciators to provide prompting and measurement information during setup and operation modes. Some features provided by the instrument are listed in Table 1-3. For additional information regarding instrument features and capabilities, refer to the *NetDAQ Users Manual* (PN 942623).
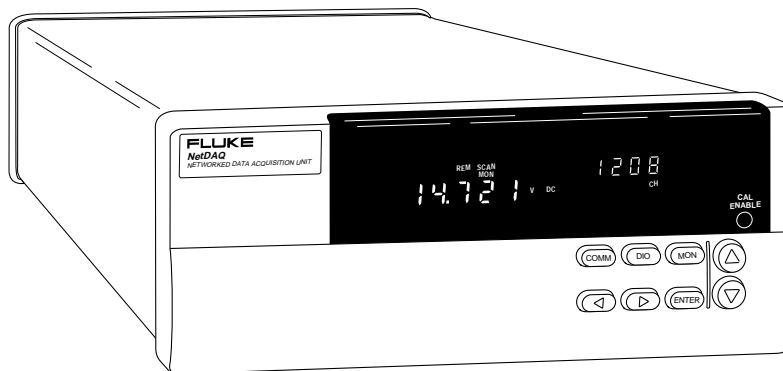
Figure 1-1. 2640A/2645A NetDAQ Networked Data Acquisition Units

Table 1-1. Summary of 2640A/2645A Specifications

Specification	2640A	2645A
Maximum Normal Mode Voltage	150/300V [1]	50V
Maximum Common Mode Voltage	150/300V [1]	50V
Input (Overload) Protection	1600V	300V
Maximum Reading Rates (Volts DC Only)	143 readings/second (scanning 20 channels)	1000 readings/second (scanning 20 channels)
Maximum Single Channel Scan Reading Rates [2]	80 readings/second (Drift Correction enabled)	250 readings/second (Drift Correction enabled)
	120 readings/second (Drift Correction disabled)	400 readings/second (Drift Correction disabled)
Volts DC Accuracy (90 day), 1V dc input	0.02%	0.04%
Thermocouple Accuracy (90 day)	0.3°C	0.6°C
Resistance-Temperature Detectors (RTDs) Resolution	0.003°C	0.03°C
Resistance-Temperature Detectors (RTDs) Accuracy	0.12°C	0.2°C
Time to Change Functions (Between V dc, V ac, Frequency, and Ohms)	6 ms	6 ms

[1] The 300V value is for channels 1 and 11 only; the 150V value is for all other channels.

[2] Drift Correction refers to an automatic internal measurement step performed with each scan to correct for drift due to changes in ambient temperature and humidity.

Table 1-2. Summary of 2640A/2645A Measurement Capabilities

Capability	2640A	2645A
Volts DC Measurements	Ranges: 90 mV 300 mV 3V 30V 150/300V [1] Autorange	Ranges: 90 mV 300 mV 3V 30V 50V Autorange
Volts AC Measurements	Ranges: 300 mV 3V 30V 150/300V [1] Autorange	Ranges: 300 mV 3V 30V Autorange
Resistance Measurements	Ranges: 300 Ω 3 kΩ 30 kΩ 300 kΩ 3 MΩ Autorange	Ranges: 30 kΩ 300 kΩ 3 MΩ Autorange

Table 1-2. Summary of 2640A/2645A Measurement Capabilities (cont)

Capability	2640A	2645A
Temperature Measurements (Thermocouple) [2]	Thermocouples: J K R S E T B C N	Thermocouples: J K R S E T B C N
Temperature Measurements (RTD) (Two-wire)	RTD R0: 10 to 1010	(None)
Temperature Measurements (RTD) (Four-wire)	RTD R0: 10 to 1010	RTD R0: 10 to 1010
Frequency Measurements [3]	Ranges: Autorange	Ranges: Autorange
Amperes DC Measurements [4]	Ranges: 4 to 20 mA 0 to 100 mA	Ranges: 4 to 20 mA 0 to 100 mA

[1] 300V range available only on channels 1 and 11.

[2] Open thermocouple detection is supported on a per-channel basis.

[3] Minimum frequency is 20 Hz. Signal strength must be at least 50 mV ac rms.

[4] Shunt resistor required (enter value; default is 10 ohms). The 4 to 20 mA scale displayed as 0% (4 mA) to 100% (20 mA).

Table 1-3. Summary of 2640A/2645A Features

Feature	Description
Analog Channels	20 (channels 1 to 20)
Computed Channels	10 (channels 21 to 30)
Alarm Limits	Two per channel
Mx+B Scaling	Any configured channel (1 to 30)
Scan Triggering	Interval/External/Alarm Trigger
Channel Monitoring	Any configured channel, scanning or not scanning
Setup and Operation	Via host computer
Communications Ports	Ethernet 10BASE2 and 10BASE-T
Primary Power	AC - 107 to 264V ac, 50/60 Hz
	DC - 9 to 16V dc
Nonvolatile Memory (unaffected by cycling instrument power)	Instrument parameters: Base Channel Number, Line Frequency, Network Type, Socket Port, IP Address, Baud Rate. (See Chapter 2.)
Permanent Data Storage	Via host computer
Real-Time Trend Plotting	Via host computer

Options and Accessories   1-2.

Table 1-4 summarizes the available models, options and accessories, including measurement transducers, software, connector sets, Ethernet interfaces, cables, and components.

Table 1-4. Models, Options and Accessories

Model	Description
2640A	NetDAQ Instrument
2645A	NetDAQ Instrument
264XA-901	NetDAQ *Logger for Windows* (Isolated Network)
264XA-902	NetDAQ *Logger for Windows* (General Network)
264XA-902U	NetDAQ *Logger for Windows* Network (Upgrade Kit)
264XA-801	Ethernet Card
264XA-802	Parallel-to-LAN Adapter (10BASE2)
80i-410	Clamp-On DC/AC Current Probe
80i-1010	Clamp-On DC/AC Current Probe
2620A-100	I/O connector set, including Universal Input Module, DIGITAL I/O and ALARM/TRIGGER I/O connectors.
2620A-101	4-20 mA Current Shunt Strip
942615	NetDAQ Service Manual
Y2641	19-inch Rackmount Kit
Y2643	4-meter Cable Kit

Instrument Connector Set, 2620A-100   1-3.

The 2620A-100 is a complete set of input connectors: one Universal Input Module, one ALARM/TRIGGER I/O connector, and one DIGITAL I/O connector. Each instrument comes with a 2620A-100 Instrument Connector Set. The use of additional connector sets allows quick equipment interface to several wiring setups.

Host Computer Ethernet Interfaces   1-4.

The 264XA-801 is the recommended Ethernet card and the 264XA-802 is the recommended Parallel-to-LAN Adapter for host computer installations.

Interconnection Cables and Components   1-5.

Cables for equipment interconnection can be purchased as an option or fabricated. Ethernet interconnection components such as BNC "T" and 50-ohm terminations are available from any components supplier.

Operating Instructions 1-6.

Full operating instructions are provided in the *NetDAQ User Manual* (PN 942623). Refer to the User Manual as necessary during the maintenance and repair procedures presented in this Service Manual.

Organization of the Service Manual 1-7.

This manual focuses on performance tests, calibration procedures, and component-level repair of the 2640A and 2645A networked data acquisition units. To that end, manual chapters are often interdependent; effective troubleshooting may require not only reference to the troubleshooting procedures in Chapter 5, but also some understanding of the detailed Theory of Operation in Chapter 2 and some tracing of circuit operation in the Schematic Diagrams presented in Chapter 7.

Often, scanning the table of contents yields an appropriate place to start using the manual. A comprehensive table of contents is presented at the front of the manual; local tables of contents are also presented at the beginning of each chapter for ease of reference. If you know the topic name, the index at the end of the manual is probably a good place to start.

The following descriptions introduce the manual:

Chapter 1 - Introduction and Specifications Introduces the instrument, describing its features, options, and accessories. This chapter also discusses use of the Service Manual and the various conventions used in describing the circuitry. Finally, a complete set of specifications is presented.

Chapter 2 - Theory of Operation This chapter first categorizes the instrument's circuitry into functional blocks, with a description of each block's role in overall operation. A detailed circuit description is then given for each block. These descriptions explore operation to the component level and fully support troubleshooting procedures defined in Chapter 5.

Chapter 3 - General Maintenance Provides maintenance information covering handling, cleaning, and fuse replacement. Access and reassembly procedures are also explained in this chapter.

Chapter 4 - Performance Testing and Calibration This chapter provides performance verification procedures, which relate to the specifications presented in Chapter 1. To maintain these specifications, a full calibration procedure is also presented.

Chapter 5 - Diagnostic Testing and Troubleshooting The troubleshooting procedures presented in this chapter rely closely on both the Theory of Operation presented in Chapter 2, the Schematic Diagrams shown in Chapter 7, and the access information provided in Chapter 3.

Chapter 6 - List of Replaceable Parts Includes parts lists for all standard assemblies. Information on how and where to order parts is also provided.

Chapter 7 - Schematic Diagrams Includes schematic Diagrams for all standard and optional assemblies. A list of mnemonic definitions is also included to aid in identifying signal name abbreviations.

Conventions 1-8.

Throughout the manual set, certain notational conventions are used. A summary of these conventions follows:

- **Instrument Reference** The term "instrument" is used in this manual to refer to both the 2640A NetDAQ and 2645A NetDAQ networked data acquisition units. The model number (2640A or 2645A) is used when discussing characteristics unique to one instrument.
- **Printed Circuit Assembly** The term "pca" is used to represent a printed circuit board and its attached parts.
- **Signal Logic Polarity** On schematic Diagrams, a signal name followed by a "*" character is active (or asserted) low. Signals not so marked are active high.
- **Circuit Nodes** Individual pins or connections on a component are specified with a dash (-) following the assembly and component reference designators. For example, pin 19 of U30 on assembly A1 would be A1U30-19.
- **Front Panel Interface User Notation** For front panel operation, XXX, an uppercase word or symbol without parentheses indicates a button to be pressed by the user. Buttons can be pressed in four ways:
  1. Press a single button to select a function or operation.
  2. Press a combination of buttons, one after the other.
  3. Press and hold down a button; then press another button.
  4. Press multiple buttons simultaneously.
- **Computer Interface User Notation** For computer interface operation:

  XXX An uppercase word without parentheses identifies a command by name.

  <XXX> Angle brackets around all uppercase letters mean press the <XXX> key.

  (xxx) A lowercase word in parentheses indicates a keyboard input.

Specifications 1-9.

Specifications are divided into three sections. The first section contains the combined specifications that apply equally to both the 2640A and 2645A instruments. The second section contains specifications that apply only to the 2640A instrument. The third section contains specifications that apply only to the 2645A instrument.

2640A/2645A Combined Specifications 1-10.

The following specifications apply equally to both the 2640A and 2645A instruments. The topics include:

- 2640A/2645A General Specifications
- 2640A/2645A Environmental Specifications
- 2640A/2645A Digital I/O and Totalizer Interface

2640A/2645A General Specifications 1-11.

Table 1-5 provides the general specifications for the 2640A and 2645A instruments.

Table 1-5. 2640A/2645A General Specifications

Specification	Characteristic
Channel Capacity	20
I/O Lines Total	12
Size	9.3 cm (3.67 in) high, 21.6 cm (8.5 in) wide, 36.2 cm (14.28 in) deep
Weight	Net, 4 kg (8.8 lb.) Shipping, 6.0 kg (13.2 lb.)
Power	107 to 264V ac (no switching required), 45 to 65 Hz, 15 VA maximum 9V dc to 16V dc, 6W maximum. Specifications are for 50 or 60 Hz operation. If both sources are applied simultaneously, ac voltage is used if it exceeds approximately 8 times the dc voltage. Automatic switchover occurs between ac and dc without interruption.

Standards	Both instruments comply with:
	  IEC 1010-1
	  UL 1244
	  CSA Bulletin 556B
	  ANSI/ISA-S8201-1988
	  CSA C22.2 No. 101.1-92
	  Vfg. 243/1991 (when shielded cables are used)
	  FCC-15B, Class B level (when shielded cables are used)

Serial Interface (RS-232C)	Connector: 9 pin male (DB-9P) Signals: TX, RX, DTR, RTS, GND Modem Control: full duplex Baud rates: 4800, 9600, 19200, 38400 Data format: 8 data bits, no parity bit, one stop bit Flow control: XON/XOFF Echo: Off
Common Mode Voltage	2640A 150V (300V on channels 1 and 11) 2645A 50V dc or 30V ac rms.

Measurement Speed (Scanning Rates)	2640A
	  Slow - 6 readings per second
	  Medium - 48 readings per second (60 Hz)
	  Fast - 143 readings per second (20 configured channels)
	  Single Channel - 120 readings per second
	2645A
	  Slow - 54 readings per second (60 Hz)
	  Medium - 200 readings per second
	  Fast - 1000 readings per second (20 configured channels)
	  Single Channel - 400 readings per second

Accuracy of Medium Scanning Rate	Equal to (Fast Accuracy Rate + Slow Accuracy Rate)/2
Additional error if "Automatic drift correction" is turned off.	If the instrument is fully warmed-up at the time drift correction was disabled, i.e., turned on at least 1 hour earlier: 1/10 of the 90-day specification per °C change in ambient temperature from the temperature when drift correction was disabled. If the instrument was not fully warmed up at the time of drift correction was disabled: add an error equal to the 90-day specification for instrument warmup +1/10 of the 90-day specification per °C change in ambient temperature from the temperature when drift correction was disabled.

2640A/2645A Environmental Specifications 1-12.

Table 1-6 provides a summary of the environmental specifications for the 2640A/2645A.

Table 1-6. Environmental Specifications

Specification	Characteristic
Warmup Time	1 hour to rated specifications -or- 15 minutes if relative humidity (noncondensing) is 50% or less.
Operating Temperature	-10°C to 60°C (14°F to 140°F)
Storage Temperature	-40°C to +70°C (-40°F to +158F)
Relative Humidity	90% maximum for -10°C to 28°C (14°F to 82.4°F) 75% maximum for 28°C to 35°C (82.4°F to 95°F) 50% maximum for 35°C to 60°C (95°F to 140°F) (3 MΩ range, reduce humidity rating by 25% for 1 hour warmup. The 3 MΩ range meets full humidity ratings with 2-hour warmup.)
Altitude	Operating: 2,000m (6,561 ft) maximum Non-operating: 12,200m (40,000 ft) maximum
Vibration	0.7g at 15 Hz 1.3g at 25 Hz 3g at 55 Hz
Shock	30g half-sine per Mil-T-28800 Bench handling per Mil-T-28800

2640A/2645A Input/Output Capabilities 1-13.

The following specifications include the input/output functions, including the Digital I/O, Trigger Out, Trigger In, and Master Alarm output.

Digital I/O 1-14.

Table 1-7 provides a summary of the Digital I/O specifications for the 8 Digital I/O lines (0 to 7). Digital I/O is located on the DIGITAL I/O connector, terminals 0 to 7, and GND.

Table 1-7. 2640A/2645A DIGITAL I/O Specification

Specification	Characteristic
Maximum Input Voltage	30V
Minimum Input Voltage	-4V
Isolation	None (dc coupled)
Threshold	1.4V
Hysteresis	500 mV
Specification	Characteristic
Output Voltage - TTL Logical Zero	0.8V maximum for an Iout of -1.0 mA (1 LSTTL load)
Output Voltage - TTL Logical One	3.8V minimum for an Iout of 0.05 mA (1 LSTTL load)
Output Voltage - Non-TTL Load Zero	1.8V maximum for an Iout of -20 mA
Output Voltage - Non-TTL Load One	3.25V maximum for an Iout of -50 mA

Trigger In 1-15.

Table 1-8 provides a summary of the Trigger In specifications. The Trigger In input is located on the ALARM/TRIGGER I/O connector, terminals TI and GND.

Table 1-8. 2640A/2645A Trigger In (TI) Specification

Specification	Characteristic
Logical High - Trigger not set	Minimum: 2.0V Maximum: 7.0V
Logical Low - Trigger set	Minimum: -0.6V Maximum: +0.8V
Compatibility	TTL or Contact Closure
Isolation	None (dc coupled)
Minimum Pulse Width	5 µs
Maximum Frequency	Nominal 400 Hz
Repeatability	3 ms

Trigger Out 1-16.

Table 1-9 provides a summary of the Trigger Out specifications. The Trigger Out output is located on the ALARM/TRIGGER I/O connector, terminals TO and GND.

Table 1-9. 2640A/2645A Trigger Out (TO) Specification

Specification	Characteristic
TTL Logical Zero - Trigger Out Set	0.8V maximum for an Iout of -1.0 mA (1 LSTTL load)
TTL Logical One - Trigger Out Not Set	3.8V minimum for an Iout of 0.05 mA (1 LSTTL load)
Non-TTL Logical Zero - Trigger Out Set	1.8V maximum for an Iout of -20 mA
Non-TTL Logical One - Trigger Out Not Set	3.25V maximum for an Iout of -50 mA
Pulse Duration (Logic Low)	125 µs
Isolation	None

Master Alarm 1-17.

Table 1-10 provides a summary of the Master Alarm specifications. The Master Alarm output is located on the ALARM/TRIGGER I/O connector, terminals MA and GND.

Table 1-10. 2640A/2645A Master Alarm (MA) Specification

Specification	Characteristic
TTL Logical Zero - Master Alarm Set	0.8V maximum for an Iout of -1.0 mA (1 LSTTL load)
TTL Logical One - Master Alarm Not Set	3.8V minimum for an Iout of 0.05 mA (1 LSTTL load)
Non-TTL Logical Zero - Master Alarm Set	1.8V maximum for an Iout of -20 mA
Non-TTL Logical One - Master Alarm Not Set	3.25V maximum for an Iout of -50 mA
Isolation	None

2640A/2645A Totalizer 1-18.

Table 1-11 provides a summary of the Totalizer specifications. The Totalizer input is located on the DIGITAL I/O connector, terminals Σ and GND.

Table 1-11. 2640A/2645A Totalizer Specification

Specification	Characteristic
Maximum Input Voltage	30V
Minimum Input Voltage	-4V
Minimum Peak Voltage	2V
Isolation	None (dc coupled)
Threshold	1.4V
Hysteresis	500 mV
Input Debouncing	None or 1.75 ms (selectable)
Maximum Transition Rate	5 kHz (Debounce disabled) 500 Hz (Debounce enabled)
Maximum Count	4,294,967,295

2640A/2645A Real-Time Clock and Calendar 1-19.

Table 1-12 provides a summary of the battery powered real-time clock and calendar.

Table 1-12. 2640A/2645A Real-Time Clock and Calendar

Specification	Characteristic
Accuracy	1 minute per month for 0°C to 50°C range
Battery Life	>15 unpowered instrument years for 0°C to 28°C (32°F to 82.4°F). >6 unpowered instrument years for 0°C to 50°C (32°F to 122°F). >4 unpowered instrument years for 50°C to 70°C (122°F to 158°F).

2640A Specifications 1-20.

This section includes specifications specific to the 2640A instrument by measurement function.

2640A DC Voltage Measurement Specifications 1-21.

Tables 1-13 to 1-15 provide 2640A specifications for the dc voltage measurement function.

Table 1-13. 2640A DC Voltage General Specifications

Specification	Characteristic
Input Impedance	100 MΩ in parallel with 300 pF maximum for ranges <=3V 10 MΩ in parallel with 100 pF maximum for ranges >3V
Normal Mode Rejection	50 dB minimum at 50 Hz/60 Hz ±0.1%, Slow Rate
Common Mode Rejection	120 dB minimum at dc, 50 Hz/60 Hz ±0.1%, 1 kΩ imbalance, Slow Rate 80 dB minimum at dc, 50 Hz/60 Hz ±0.1%, 1 kΩ imbalance, Medium and Fast Rates
Channel-to-Channel Crosstalk	120 dB minimum Slow Rate (e.g., 30V dc on channel 1 may cause a 30 μV error on channel 2) 100 dB minimum Medium and Fast Rates (e.g., 1V dc on channel 1 may cause a 10 μV error on channel 2)
Temperature Coefficient	For % input: Add 1/10th the 90-day specification per °C above 28 °C or below 18 °C For floor error (V): Add 1/20th the 90-day specification per °C above 28 °C or below 18 °C
Maximum Input Voltage	The lesser voltage of: 300V from any terminal on channels 1 and 11 to earth; 150V from any terminal on channels 2 through 10, and 12 through 20 to earth; 300V from any terminal on channels 1 and 11 to any other terminal; 150V from any terminal on channels 2 through 10, and 12 through 20 to any other input terminal

Table 1-14. 2640A DC Voltage Range and Resolution Specifications

Range	Resolution	
	Slow	Fast
90 mV	0.3 μV	1 μV
300 mV	1 μV	3 μV
3V	10 μV	30 μV
30V	100 μV	300 μV
150V/300V	1 mV	3 mV
Note 300V range applies to channels 1 and 11 only.		

Table 1-15. 2640A DC Voltage Accuracy Specifications

Range	Accuracy, $3\sigma \pm$ (% input + V)					
	18°C to 28°C				-10°C to 60°C	
	90 Day		1 Year		1 Year	
	Slow	Fast	Slow	Fast	Slow	Fast
90 mV	.01%+7 µV	.01%+17 µV	.013%+8 µV	.013%+18 µV	.042%+18.2 µV	.042%+44.2 µV
300 mV	.01%+15 µV	.01%+30 µV	.013%+17 µV	.013%+35 µV	.042%+39 µV	.042%+78 µV
750 mV*	.01%+40 µV	.01%+70 µV	.013%+50 µV	.013%+80 µV	.042%+104 µV	.042%+182 µV
3V	.01%+0.1 mV	.01%+0.2 mV	.013%+0.15 mV	.013%+0.2 mV	.042%+0.26 mV	.042%+0.52 mV
30V	.01%+1.5 mV	.02%+3 mV	.013%+1.7 mV	.026%+3.5 mV	.042%+3.9 mV	.084%+7.8 mV
150/300V**	.01%+15 mV	.04%+30 mV	.013%+17 mV	.052%+35 mV	.042%+39 mV	.168%+78 mV

*   The 750 mV range is used internally to the instrument and not user selectable. ** 300V range applies to channels 1 and 11 only.

2640A AC Voltage Measurement Specifications 1-22.

Tables 1-16 to 1-18 provide 2640A specifications for the ac voltage measurement function.

Table 1-16. 2640A AC Voltage General Specifications

Specification	Characteristic
Input Impedance	1 MΩ in parallel with 100 pF
Maximum Crest Factor	3.0 Maximum 2.0 for rated accuracy
Crest Factor Error	For nonsinusoidal input signals with crest factors between 2 and 3 and pulse widths >=100 µs, add 0.2% to the accuracy specifications.
Common Mode Rejection	80 dB minimum at dc, 50 Hz/60 Hz ±0.1%, 1 kΩ imbalance, Slow Rate
Maximum Input Voltage	The lesser voltage of:
	300V ac rms from any terminal on channels 1 and 11 to earth.
	150V ac rms from any terminal on channels 2 through 10, and 12 through 20 to earth.
	300V ac rms from any terminal on channels 1 and 11 to any other terminal.
	150V ac rms from any terminal on channels 2 through 10 and 12 through 20 to any other input terminal.
Maximum Volt-Hertz Product	2×10^6 Volt-Hertz product on any range, normal mode input.
	1×10^6 Volt-Hertz product on any range, common mode input.
Temperature Coefficient	Linear interpolation between 2 applicable points for temperatures between 28°C and 60°C, or -10°C and 18°C, e.g., if the applicable specification at 28°C is 2% and the specification at 60°C is 3%, then the specification at 40°C is (3%-2%)x(40-28)/(60-28)+2%=2.375%.
DC Component Error	The presence of a dc voltage will cause an indeterminate error in the reading of the ac voltage on the input.

Table 1-17. 2640A AC Voltage Range and Resolution Specifications

Range	Resolution		Minimum Input for Rate Accuracy
	Slow	**Fast**	
Full Scale	±30,000	±3,000	
300 mV	10 µV	100 µV	20 mV
3V	100 µV	1 mV	200 mV
30V	1 mV	10 mV	2V
150/300V	10 mV	100 mV	20V
Note 300V range applies to channels 1 and 11 only.			

Table 1-18. 2640A AC Voltage Accuracy Specifications

Range	Frequency	1 Year Accuracy ± (%input + V) [1]			
		18°C to 28°C		**-10°C to 60°C**	
		Slow	**Fast**	**Slow**	**Fast**
300 mV	20 to 50 Hz	3%+.25 mV	6%+.5 mV	3.5%+.25 mV	7%+.5 mV
	50 to 150 Hz	0.4%+.25 mV	1%+.5 mV	0.5%+.25 mV	1.5%+.5 mV
	150 Hz to 10 kHz	0.3%+.25 mV	1%+.5 mV	0.4%+.25 mV	1.5%+.5 mV
	10 kHz to 20 kHz	0.4%+.25 mV	1%+.5 mV	0.7%+.25 mV	1.5%+.5 mV
	20 kHz to 50 kHz	2%+.3 mV	3%+.5 mV	3%+.3 mV	4%+.5 mV
	50 kHz to 100 kHz	5%+.5 mV	5%+1 mV	7%+.5 mV	8%+1 mV
3V	20 to 50 Hz	3%+2.5 mV	6%+5 mV	3.5%+2.5 mV	7%+5 mV
	50 to 150 Hz	0.4%+2.5 mV	1%+5 mV	0.5%+2.5 mV	1.2%+5 mV
	150 Hz to 10 kHz	0.3%+2.5 mV	1%+5 mV	0.4%+2.5 mV	1.2%+5 mV
	10 kHz to 20 kHz	0.4%+2.5 mV	1%+5 mV	0.5%+2.5 mV	1.2%+5 mV
	20 kHz to 50 kHz	1%+3 mV	1.5%+6 mV	1.5%+3 mV	2%+6 mV
	50 kHz to 100 kHz	2%+5 mV	3%+10 mV	3%+5 mV	4%+10 mV
30V	20 to 50 Hz	3%+25 mV	6%+50 mV	3.5%+25 mV	7%+50 mV
	50 to 150 Hz	0.4%+25 mV	1%+50 mV	0.5%+25 mV	1.2%+40 mV
	150 Hz to 10 kHz	0.3%+25 mV	1%+50 mV	0.5%+25 mV	1.2%+40 mV
	10 kHz to 20 kHz	0.4%+25 mV	1%+50 mV	0.5%+25 mV	1.2%+40 mV
	20 kHz to 50 kHz	1%+30 mV	1.5%+60 mV	1%+30 mV	2%+50 mV
	50 kHz to 100 kHz, V<20V	2%+50 mV	3%+100 mV	2.5%+50 mV	4%+100 mV
150/300V	20 to 50 Hz	3%+.25V	6%+.5V	3.5%+.25V	7%+.5V
	50 to 150 Hz	0.4%+.25V	1%+.5V	0.5%+.25V	1.2%+.4V
	150 Hz to 2 kHz Vx Hz<2 x10^6	0.3%+.25V	1.2%+.5V	0.5%+.25V	1.4%+.4V
	2 kHz to 20 kHz, V<100V	0.4%+.25V	1.6%+.5V	0.5%+.25V	1.8%+.4V
	20 kHz to 50 kHz, V<40V	1%+.30V	2.0%+.6V	1.2%+.30V	2.5%+.5V
[1] Sinewave inputs>6% of scale and signals with crest factors <2.					

2640A Four-Wire Resistance Measurement Specifications 1-23.

Tables 1-19 to 1-21 provide 2640A specifications for the four-wire resistance measurement function. The four-wire measurements use 2 input channels a decade apart, e.g., channels 4 and 14.

Table 1-19. 2640A Four-Wire Resistance Temperature Coefficient

Specification	Characteristic
Temperature Coefficient	Add 1/10th the 90 day specification per °C above 28°C or below 18°C.

Table 1-20. 2640A Four-Wire Resistance Range and Resolution Specifications

	Resolution		Current	Full Scale	Maximum Voltage
Range	Slow	Fast	Applied	Voltage	Applied by Instrument
300Ω	1 mΩ	3mΩ	1 mA	300 mV	3.5V
3 kΩ	10 mΩ	30 mΩ	100 µA	300 mV	3.5V
30 kΩ	100 mΩ	300 mΩ	10 µA	300 mV	3.5V
300 kΩ	1Ω	3Ω	10 µA	3.0V	3.5V
3 MΩ	10Ω	30Ω	1 µA	3.0V	3.5V

Table 1-21. 2640A Four-Wire Resistance Accuracy Specifications

	Accuracy, 3σ ± (% input + V)					
	18°C to 28°C				-10°C to 60°C	
Range	90 Day		1 Year		1 Year	
	Slow	Fast	Slow	Fast	Slow	Fast
300Ω	.015%+20 mΩ	.02%+80 mΩ	.02%+50 mΩ	.02%+120 mΩ	.084%+126 mΩ	.084%+336 mΩ
3 kΩ	.02%+.3Ω	.02%+.8Ω	.02%+.5Ω	.02%+1.2Ω	.084%+1.26Ω	.084%+3.36Ω
30 kΩ	.03%+3Ω	.04%+10Ω	.03%+5Ω	.04%+15Ω	.126%+12.6Ω	.168%+42Ω
300 kΩ	.1%+40Ω	.2%+100Ω	.1%+60Ω	.2%+150Ω	.42%+168Ω	.84%+420Ω
3 MΩ [1]	.25%+800Ω	.5%+10 kΩ	.25%+1 kΩ	.5%+1.5 kΩ	1.05%+3.36 kΩ	2.1%+4.2 kΩ

[1] The 3 MΩ range is susceptible to the absorption of humidity under extreme conditions. If the instrument is operated normally within its specified temperature-humidity range, the 3 MΩ range meets its accuracy specifications. However, if the instrument is "soaked" at 50°C, 90% relative humidity, the 3 MΩ range may require 1 hour of "dry-out" time at 25°C, <40% relative humidity for each hour of soak time in order to achieve its specified accuracy.

2640A Two-Wire Resistance Measurement Specifications 1-24.

The 2640A specifications for the two-wire resistance measurement function is based on the four-wire resistance measurement specification (above) except you add a nominal 5-ohm (10-ohm maximum) positive offset. This value varies for each channel and with temperature
(nominal +1%/ºC).

2640A Four-Wire RTD per ITS-1990 Measurement Specifications 1-25.

Tables 1-22 and 1-23 provide 2640A specifications for the four-wire Resistance-Temperature Detector (RTD) measurement function. The four-wire measurements use 2 input channels a decade apart, e.g., channels 4 and 14.

Table 1-22. 2640A Four-Wire RTD Temperature Coefficient

Specification	Characteristic
Temperature Coefficient	To calculate RTD accuracy for temperatures between 28°C and 60°C, or -10°C and 18°C, use a linear interpolation between the two applicable points. For example, if the applicable specification at 28°C is 0.2 and the specification at 60°C is 0.75, then the specification at 40°C is =(.75-.2)x(40-28)/(60-28)+.2=0.406.

Table 1-23. 2640A Four-Wire RTD Specifications

| Temperature | Resolution | | Accuracy, 3σ | | | | |
| | | | 90 Day 18°C to 28°C | | 1 Year 18°C to 28°C | 1 Year -10°C to 60°C | |
	Slow	Fast	Slow	Fast	Slow	Slow	Fast
-200°C	0.003°C	0.007°C	0.06°C	0.16°C	0.09°C	0.33°C	0.63°C
0°C	0.003°C	0.007°C	0.09°C	0.20°C	0.13°C	0.53°C	0.86°C
100°C	0.003°C	0.007°C	0.10°C	0.23°C	0.16°C	0.63°C	0.97°C
300°C	0.003°C	0.007°C	0.14°C	0.30°C	0.21°C	0.83°C	1.20°C
600°C	0.003°C	0.007°C	0.19°C	0.53°C	0.30°C	1.20°C	1.60°C

2640A Two-Wire RTD per ITS-1990 Measurement Specifications 1-26.

The 2640A specifications for the two-wire Resistance-Temperature Detector (RTD) measurement function is based on the four-wire RTD measurement specification (above) except you add a nominal 5-ohm (approximately 13°C) positive offset. This value varies for each channel and temperature gradient (nominal +1%/°C). Also note that the resistance of the RTD wiring adds directly to the error. After 100 million operations of a measurement channel, the offset will increase at an indeterminate rate.

2640A Thermocouple per ITS-1990 Measurement Specifications 1-27.

Tables 1-24 to 1-25 provide 2640A specifications for the thermocouple measurement function per ITS-1990.

Table 1-24. 2640A Thermocouple General Specifications

Specification	Characteristic
Input Impedance	100 MΩ minimum in parallel with 300 pF
Open Thermocouple Detect	Operates by injecting a small ac signal into the input after each measurement. A thermocouple resistance greater than 1k to 10k is detected as an open input.
Temperature Coefficient	To calculate Thermocouple accuracy for temperatures between 28°C and 60°C, or -10°C and 18°C, use a linear interpolation between the two applicable points. For example, if the applicable specification at 28°C is 0.6 and the specification at 60°C is 1.1, then the specification at 40°C is =(1.1-0.6)x(40-28)/(60-28)+0.6=0.7875.

Table 1-25. 2640A Thermocouple Specifications

Thermocouple		Resolution	Accuracy ± °C				
			18°C to 28°C			-10°C to 60°C	
			90 Day	1 Year		1 Year	
Type	Temperature °C		Slow	Slow	Fast	Slow	Fast
J	-100 to 80	.03	0.45	0.50	0.80	0.60	0.80
	80 to 230	.02	0.35	0.50	0.70	0.60	0.80
	230 to 760	.02	0.40	0.50	0.70	0.80	0.90
K	-100 to -25	.04	0.55	0.60	0.90	0.70	1.00
	-25 to 120	.03	0.40	0.50	0.80	0.60	0.90
	120 to 800	.03	0.50	0.65	0.90	1.00	1.20
	800 to 1372	.03	0.70	1.00	1.30	1.60	1.90
N	-100 to -25	.05	0.65	0.75	1.20	0.80	1.30
	-25 to 120	.05	0.55	0.60	1.00	0.70	1.10
	120 to 1000	.04	0.45	0.60	0.90	1.00	1.20
	1000 to 1300	.03	0.55	0.75	1.00	1.20	1.50
E	-100 to -25	.03	0.45	0.50	0.80	0.60	0.80
	-25 to 20	.02	0.35	0.40	0.60	0.50	0.70
	20 to 600	.02	0.30	0.40	0.60	0.50	0.80
	600 to 1000	.02	0.40	0.50	0.70	0.90	1.00
T	-100 to 0	.04	0.60	0.65	1.00	0.70	1.10
	0 to 150	.03	0.40	0.50	0.80	0.60	0.90
	150 to 400	.02	0.30	0.40	0.60	0.60	0.80

Table 1-25. 2640A Thermocouple Specifications (cont)

Thermocouple		Resolution	Accuracy ± °C				
			18°C to 28°C			-10°C to 60°C	
			90 Day	1 Year		1 Year	
Type	Temperature °C		Slow	Slow	Fast	Slow	Fast
R	250 to 600	0.1	0.90	1.00	2.10	1.20	2.20
	600 to 1500	0.1	0.80	0.90	1.80	1.30	2.00
	1500 to 1767	0.1	0.85	0.85	1.90	1.70	2.50
S	250 to 1000	0.1	0.95	1.10	2.30	1.30	2.40
	1000 to 1400	0.1	0.80	1.00	1.90	1.40	2.30
	1400 to 1767	0.1	1.00	1.30	2.20	1.80	2.80
B	600 to 900	0.2	1.20	1.40	3.10	1.50	3.20
	900 to 1200	0.2	0.90	1.00	2.20	1.20	2.40
	1200 to 1820	0.1	0.75	1.00	1.90	1.30	2.20
C	0 to 150	0.2	0.80	0.90	1.60	1.00	1.70
	150 to 650	0.1	0.65	0.75	1.40	1.00	1.50
	650 to 1000	.05	0.65	0.85	1.40	1.20	1.80
	1000 to 1800	.05	1.00	1.30	2.10	2.10	2.80
	1800 to 2316	.05	1.60	2.10	3.20	3.40	4.60

2640A Frequency Measurement Specifications 1-28.

Tables 1-26 to 1-27 provide 2640A specifications for the frequency measurement function.

Table 1-26. 2640A Frequency Accuracy Specifications

Range	Frequency Measurement Accuracy, 1 Year, -10°C to 60°C			
	Resolution		Accuracy ± (% input + Hz)	
	Slow	Fast	Slow	Fast
15 Hz to 900 Hz	0.01 Hz	0.1 Hz	0.05%+0.02 Hz	0.05%+0.2 Hz
900 Hz to 9 kHz	0.1 Hz	1 Hz	0.05%+0.1 Hz	0.05%+1 Hz
9 kHz to 90 kHz	1 Hz	10 Hz	0.05%+1 Hz	0.05%+10 Hz
90 kHz to 900 kHz	10 Hz	100 Hz	0.05%+10 Hz	0.05%+100 Hz
1 MHz	100 Hz	1 kHz	0.05%+100 Hz	0.05%+1 kHz

Table 1-27. 2640A Frequency Sensitivity Specifications

Frequency Measurement Sensitivity (Sinewave)		
Frequency Range	**Minimum Signal**	**Maximum Signal**
15 Hz to 70 kHz	100 mV ac rms	V<150/300Vrms [1] and Vx Hz<2×10^6)
70 kHz to 100 kHz	100 mV ac rms	20V ac rms
100 kHz to 200 kHz	150 mV ac rms	10V ac rms
200 kHz to 300 kHz	150 mV ac rms	7V ac rms
300 kHz to 1 MHz	Linearly increasing from 150 mV ac rms at 300 kHz to 2 V ac rms at 1 MHz	Linearly decreasing from 7 V ac rms at 300 kHz to 2 V ac rms at 1 MHz
[1] 300V range applies to channels 1 and 11 only.		

2645A Specifications   1-29.

This section includes specifications specific to the 2645A instrument by measurement function.

2645A DC Voltage Measurement Specifications   1-30.

Tables 1-28 to 1-30 provide 2645A specifications for the dc voltage measurement function.

Table 1-28. 2645A DC Voltage General Specifications

Specification	Characteristic
Input Impedance	100 MΩ in parallel with 300 pF maximum for ranges <=3V
	10 MΩ in parallel with 100 pF maximum for ranges >3V
Normal Mode Rejection	50 dB minimum at 50 Hz/60 Hz $\pm$0.1%, Slow Rate
Common Mode Rejection	120 dB minimum at dc, 50 Hz/60 Hz $\pm$0.1%, 1 kΩ imbalance, Slow Rate
	80 dB minimum at dc, 60 dB at 50 Hz/60 Hz $\pm$0.1%, 1 kΩ imbalance, Medium and Fast Rates
Channel-to-Channel Crosstalk	120 dB minimum Slow Rate (e.g., 30V dc on channel 1 may cause a 30 µV error on channel 2)
	80 dB minimum Medium and Fast Rates (e.g., 1V dc on channel 1 may cause a 10 µV error on channel 2)
Temperature Coefficient	For % input: Add 1/10th the 90-day specification per °C above 28°C or below 18°C.
	For floor error (V): Add 1/20th the 90-day specification per °C above 28°C or below 18°C.
Maximum Input Voltage	The lesser voltage of:
	50V dc or 30V ac rms from any input terminal to earth
	-or-
	50V dc or 30V ac rms from any input terminal to any other input terminal

Table 1-29. 2645A DC Voltage Resolution and Repeatability Specifications

Range	Resolution	
	Slow	Fast
90 mV	3 μV	6 μV
300 mV	1 μV	3 μV
3V	10 μV	30 μV
30V	100 μV	300 μV
50V	1 mV	3 mV

Table 1-30. 2645A DC Voltage Accuracy Specifications

Range	Accuracy, 3σ ± (% input + V)					
	18°C to 28°C				-10°C to 60°C	
	90 Day		1 Year		1 Year	
	Slow	Fast	Slow	Fast	Slow	Fast
90 mV	.01%+20 μV	.01%+50 μV	.013%+23 μV	.013%+50 μV	.042%+52 μV	.042%+130 μV
300 mV	.01%+40 μV	.01%+90 μV	.013%+49 μV	.013%+93 μV	.042%+104 μV	.042%+234 μV
750 mV*	.01%+90 μV	.01%+200 μV	.013%+105 μV	.013%+220 μV	.042%+273 μV	.042%+520 μV
3V	.01%+.3 mV	.01%+.6 mV	.013%+.38 mV	.013%+.64 mV	.042%+.78 mV	.042%+1.56 mV
30V	.01%+4 mV	.02%+8 mV	.013%+4.9 mV	.026%+9.5 mV	.042%+10.6 mV	.084%+20.3 mV
50V	.01%+30 mV	.04%+60 mV	.013%+40 mV	.052%+64 mV	.042%+78 mV	.168%+156 mV

* The 750 mV range is used internally to the instrument and not user selectable.

2645A AC Voltage Measurement Specifications 1-31.

Tables 1-31 to 1-33 provide 2645A specifications for the ac voltage function.

Table 1-31. 2645A AC Voltage General Specifications

Specification	Characteristic
Input Impedance	1 MΩ in parallel with 100 pF
Maximum Crest Factor	3.0 maximum; 2.0 for rated accuracy
Crest Factor Error	For nonsinusoidal input signals with crest factors between 2 and 3 and pulse widths >=100 μs, add 0.2% to the accuracy specifications.
Common Mode Rejection	80 dB minimum at dc, 50 Hz/60 Hz ±0.1%, 1 kΩ imbalance, Slow Rate
Maximum Input Voltage	The lesser voltage of: 30V ac rms from any input terminal to earth. 30V ac rms from any terminal input to any other input terminal.
Maximum Volt-Hertz Product	$2x10^6$ Volt-Hertz product on any range, normal mode input. $1x10^6$ Volt-Hertz product on any range, common mode input.
Temperature Coefficient	Linear interpolation between 2 applicable points for temperatures between 28°C and 60°C, or -10°C and 18°C, e.g., if the applicable specification at 28°C is 2% and the specification at 60°C is 3%, then the specification at 40°C is (3%-2%)x(40-28)/(60-28)+2%=2.375%.
DC Component Error	The presence of a dc voltage will cause an indeterminate error in the reading of the ac voltage on the input.

Table 1-32. 2645A AC Voltage Range and Resolution Specifications

Range	Resolution		Minimum Input for Rate Accuracy
	Slow	**Fast**	
Full Scale	±30,000	±3,000	
300 mV	10 μV	100 μV	20 mV
3V	100 μV	1 mV	200 mV
30V	1 mV	10 mV	2V

Table 1-33. 2645A AC Voltage Accuracy Specifications

Range	Frequency	1 Year Accuracy ± (%input + V) [1]			
		18°C to 28°C		**-10°C to 60°C**	
		Slow	**Fast**	**Slow**	**Fast**
300 mV	20 to 50 Hz	3%+.25 mV	6%+.5 mV	3.5%+.25 mV	7%+.5 mV
	50 to 150 Hz	0.4%+.25 mV	0.8%+.5 mV	0.5%+.25 mV	1%+.5 mV
	150 Hz to 10 kHz	0.3%+.25 mV	0.8%+.5 mV	0.4%+.25 mV	1%+.5 mV
	10 kHz to 20 kHz	0.4%+.25 mV	1%+.5 mV	0.7%+.25 mV	1.5%+.5 mV
	20 kHz to 50 kHz	2%+.3 mV	3%+.5 mV	3%+.3 mV	4%+.5 mV
	50 kHz to 100 kHz	5%+.5 mV	5%+1 mV	7%+.5 mV	8%+1 mV
3V	20 to 50 Hz	3%+2.5 mV	6%+5 mV	3.5%+2.5 mV	7%+5 mV
	50 to 150 Hz	0.4%+2.5 mV	0.8%+5 mV	0.5%+2.5 mV	1%+5 mV
	150 Hz to 10 kHz	0.3%+2.5 mV	0.6%+5 mV	0.4%+2.5 mV	1%+5 mV
	10 kHz to 20 kHz	0.4%+2.5 mV	0.8%+5 mV	0.5%+2.5 mV	1%+5 mV
	20 kHz to 50 kHz	1%+3 mV	1.5%+6 mV	1.5%+3 mV	2%+6 mV
	50 kHz to 100 kHz	2%+5 mV	3%+10 mV	3%+5 mV	4%+10 mV
30V	20 to 50 Hz	3%+25 mV	6%+50 mV	3.5%+25 mV	7%+50 mV
	50 to 150 Hz	0.4%+25 mV	0.8%+50 mV	1.2%+25 mV	1.3%+40 mV
	150 Hz to 10 kHz	0.4%+25 mV	0.8%+50 mV	1.2%+25 mV	1.3%+40 mV
	10 kHz to 20 kHz	0.4%+25 mV	0.8%+50 mV	1.2%+25 mV	1.3%+40 mV
	20 kHz to 50 kHz	1%+30 mV	1.5%+60 mV	1.2%+30 mV	2%+50 mV
	50 kHz to 100 kHz, V<20V	2%+50 mV	3%+100 mV	2.5%+50 mV	4%+100 mV
[1] Sinewave inputs>6% of scale and signals with crest factors <2.					

2645A Four-Wire Resistance Measurement Specifications 1-32.

Tables 1-34 to 1-36 provide 2645A specifications for the four-wire resistance measurement function. The four-wire measurements use 2 input channels a decade apart, e.g., channels 4 and 14.

Table 1-34. 2645A Four-Wire Resistance Temperature Coefficient

Specification	Characteristic
Temperature Coefficient	Add 1/10th the 90 day specification per °C above 28°C or below 18°C.

Table 1-35. 2645A Four-Wire Resistance Range and Resolution Specifications

Range	Resolution		Current Applied	Full Scale Voltage	Maximum Voltage Applied by Instrument
	Slow	Fast			
300Ω	10 mΩ	30 mΩ	1 mA	300 mV	3.5V
3 kΩ	100 mΩ	300 mΩ	100 μA	300 mV	3.5V
30 kΩ	1Ω	3Ω	10 μA	300 mV	3.5V
300 kΩ	10Ω	30Ω	10 μA	3.0V	3.5V
3 MΩ	100Ω	300Ω	1 μA	3.0V	3.5V

Table 1-36. 2645A Four-Wire Resistance Accuracy Specifications

Range	Accuracy, 3σ ± (% input + Ω)					
	18°C to 28°C				-10°C to 60°C	
	90 Day		1 Year		1 Year	
	Slow	Fast	Slow	Fast	Slow	Fast
300Ω	.02%+60 mΩ	.02%+.1Ω	.02%+.1Ω	.02%+.2Ω	.084%+.25Ω	.084%+.42Ω
3 kΩ	.02%+.6Ω	.02%+2Ω	.02%+1Ω	.02%+3Ω	.084%+2.5Ω	.084%+8.4Ω
30 kΩ	.02%+6Ω	.2%+200Ω	.02%+10Ω	.2%+300Ω	.084%+25Ω	.84%+840Ω
300 kΩ	.5%+80Ω	1%+2 kΩ	.5%+150Ω	1%+3 kΩ	2.1%+336Ω	4.2%+8.4 kΩ
3 MΩ	1.3%+1 kΩ	2%+120 kΩ	1.3%+2 kΩ	2%+200 kΩ	5.46%+4.2 kΩ	8.4%+200 kΩ

2645A Two-Wire Resistance Measurement Specifications 1-33.

The 2645A specifications for the two-wire resistance measurement function is based on the four-wire resistance measurement specification (above) except you add a 700 to 1000 ohm positive offset. This value varies for each channel and temperature gradient (nominal +1%/ºC).

2645A Four-Wire RTD per ITS-1990 Measurement Specifications 1-34.

Tables 1-37 and 1-38 provide 2645A specifications for the four-wire Resistance-Temperature Detector (RTD) measurement function. The four-wire measurements use 2 input channels a decade apart, e.g., channels 4 and 14. There is no two-wire RTD capability for the 2645A.

Table 1-37. 2645A Four-Wire RTD Temperature Coefficient

Specification	Characteristic
Temperature Coefficient	To calculate RTD accuracy for temperatures between 28°C and 60°C, or -10°C and 18°C, use a linear interpolation between the two applicable points. For example, if the applicable specification at 28°C is 0.2 and the specifications at 60°C is 0.75, then the specification at 40°C =(.75-.2)x(40-28)/(60-28)+.2=.406.

Table 1-38. 2645A Four-Wire RTD Specifications

Temperature	Resolution		Accuracy, 3σ				
			90 Day 18°C to 28°C		1 Year 18°C to 28°C	1 Year -10°C to 60°C	
	Slow	Fast	Slow	Fast	Slow	Slow	Fast
-200°C	0.03°C	0.06°C	0.16°C	0.25°C	0.25°C	0.62°C	1.10°C
0°C	0.03°C	0.06°C	0.20°C	0.31°C	0.31°C	0.85°C	1.30°C
100°C	0.03°C	0.06°C	0.23°C	0.34°C	0.34°C	0.95°C	1.40°C
300°C	0.03°C	0.06°C	0.30°C	0.41°C	0.41°C	1.18°C	1.70°C
600°C	0.03°C	0.06°C	0.53°C	0.63°C	0.63°C	1.62°C	2.12°C

2645A Thermocouple per ITS-1990 Measurement Specifications 1-35.

Tables 1-39 to 1-40 provide 2645A specifications for the thermocouple measurement function per ITS-1990.

Table 1-39. 2645A Thermocouple General Specifications

Specification	Characteristic
Input Impedance	100 MΩ minimum in parallel with 300 pF
Open Thermocouple Detect	Operates by injecting a small ac signal into the input after each measurement. A thermocouple resistance greater than 1 k to 10k is detected as an open input.
Temperature Coefficient	To calculate Thermocouple accuracy for temperatures between 28°C and 60°C, or -10°C and 18°C, use a linear interpolation between the two applicable points. For example, if the applicable specification at 28°C is 0.6 and the specification at 60°C is 1.1, then the specification at 40°C is =(1.1-0.6)x(40-28)/(60-28)+0.6=0.7875.

Table 1-40. 2645A Thermocouple Specifications

Thermocouple		Resolution	Accuracy ± °C				
			18°C to 28°C			-10°C to 60°C	
			90 Day	1 Year		1 Year	
Type	Temperature °C		Slow	Slow	Fast	Slow	Fast
J	-100 to 80	.3	0.8	0.9	1.6	0.9	1.7
	80 to 230	.2	0.7	0.8	1.4	0.9	1.5
	230 to 760	.2	0.7	0.8	1.3	1.0	1.5
K	-100 to -25	.4	1.0	1.1	2.0	1.2	2.1
	-25 to 120	.3	0.8	0.9	1.7	1.0	1.8
	120 to 1000	.3	0.9	1.1	1.8	1.5	2.2
	1000 to 1372	.3	1.2	1.5	2.3	2.0	2.9
N	-100 to -25	.5	1.4	1.5	2.8	1.5	2.9
	-25 to 120	.5	1.1	1.3	2.3	1.3	2.4
	120 to 1000	.4	1.0	1.1	2.0	1.2	2.1
	1000 to 1300	.3	1.0	1.2	1.9	1.6	2.4
E	-100 to -25	.3	0.8	0.9	1.5	1.0	1.6
	-25 to 20	.2	0.7	0.7	1.2	0.8	1.3
	20 to 600	.2	0.6	0.7	1.1	0.8	1.2
	600 to 1000	.2	0.6	0.8	1.2	1.1	1.5
T	-100 to 0	.4	1.1	1.2	2.2	1.3	2.3
	0 to 150	.3	0.9	1.0	1.7	1.0	1.8
	150 to 400	.2	0.7	0.8	1.4	0.8	1.5
R	250 to 600	1	2.4	2.7	5.6	2.8	5.7
	600 to 1500	1	2.0	2.3	4.6	2.4	4.8
	1500 to 1767	1	2.0	2.3	4.5	2.8	5.1
S	250 to 1000	1	2.6	2.8	5.9	2.9	6.0
	1000 to 1400	1	2.0	2.3	4.6	2.6	5.0
	1400 to 1767	1	2.3	2.7	5.3	3.3	5.9
B	600 to 1200	2	3.6	3.9	8.5	4.0	8.6
	1200 to 1550	2	2.1	2.4	5.0	2.6	5.2
	1550 to 1820	1	2.0	2.3	4.7	2.7	5.0
C	0 to 150	2	1.9	2.0	4.0	2.1	4.2
	150 to 650	1	1.6	1.7	3.5	1.8	3.6
	650 to 1000	.5	1.4	1.7	3.2	2.0	3.5
	1000 to 1800	.5	2.0	2.5	4.5	3.2	5.3
	1800 to 2316	.5	3.1	3.8	6.8	5.1	8.1

2645A Frequency Measurement Specifications *1-36.*

Tables 1-41 to 1-42 provide 2645A specifications for the frequency measurement function.

Table 1-41. 2645A Frequency Accuracy Specifications

Range	Frequency Measurement Accuracy, 1 Year, -10°C to 60°C			
	Resolution		Accuracy ± (% input + Hz)	
	Slow	**Fast**	**Slow**	**Fast**
15 Hz to 900 Hz	0.01 Hz	0.1 Hz	0.05%+0.02 Hz	0.05%+0.2 Hz
900 Hz to 9 kHz	0.1 Hz	1 Hz	0.05%+0.1 Hz	0.05%+1 Hz
9 kHz to 90 kHz	1 Hz	10 Hz	0.05%+1 Hz	0.05%+10 Hz
90 kHz to 900 kHz	10 Hz	100 Hz	0.05%+10 Hz	0.05%+100 Hz
1 MHz	100 Hz	1 kHz	0.05%+100 Hz	0.05%+1 kHz

Table 1-42. 2645A Frequency Sensitivity Specifications

Frequency Range	Minimum Signal	Maximum Signal
15 Hz to 70 kHz	100 mV ac rms	30V ac rms
70 kHz to 100 kHz	100 mV ac rms	20V ac rms
100 kHz to 200 kHz	150 mV ac rms	10V ac rms
200 kHz to 300 kHz	150 mV ac rms	7V ac rms
300 kHz to 1 MHz	Linearly increasing from 150 mV ac rms at 300 kHz to 2V ac rms at 1 MHz	Linearly decreasing from 7V ac rms at 300 kHz to 2V ac rms at 1 MHz

Chapter 2
Theory of Operation

Introduction 2-1.

The theory of operation begins with a general overview of the instrument and progresses to a detailed description of the circuits of each pca.

The instrument is first described in general terms with a Functional Block Description. Then, each block is detailed further with Detailed Circuit Descriptions. Refer to Chapter 7 of this manual for full schematic diagrams. The Interconnection Diagram (Figure 2-1) illustrates the physical connections between each pca.

In all discussions, signal names followed by a '*' character are active (asserted) low. All other signals are active high.

Functional Block Description 2-2.

Refer to Figure 2-2, Overall Functional Block Diagram, during the following functional block descriptions.
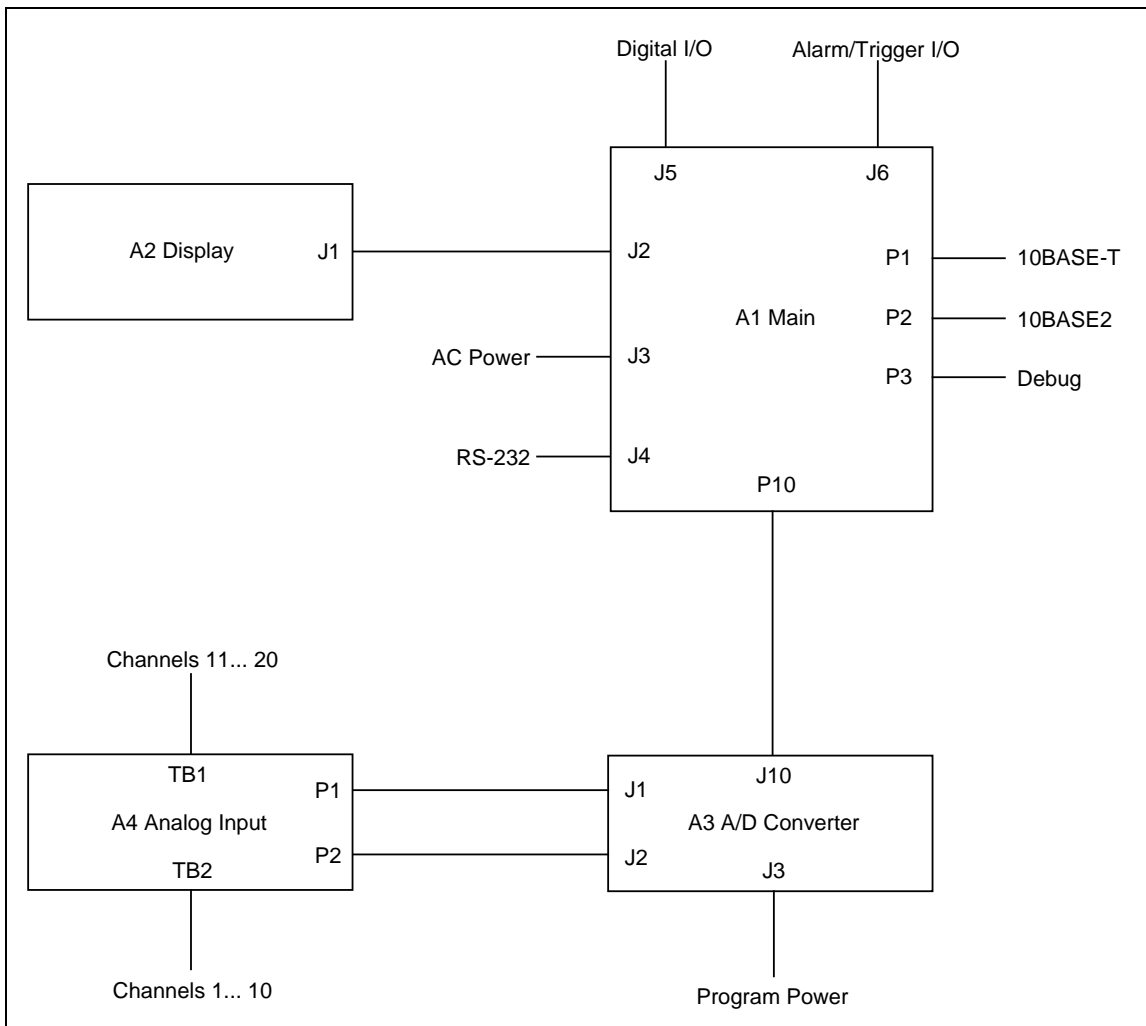
Figure 2-1. Interconnection Diagram
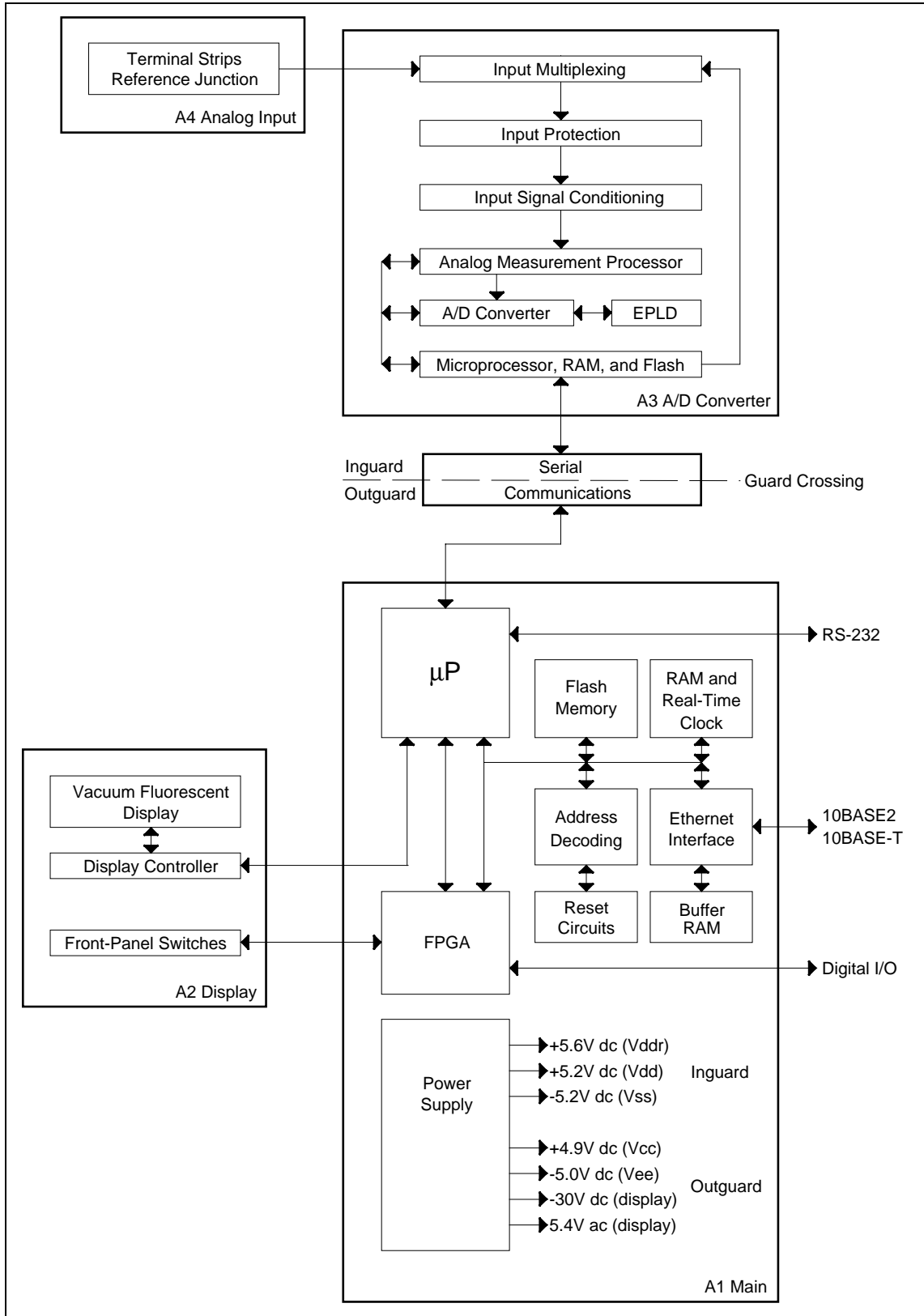
Figure 2-2. Overall Functional Block Diagram

A1 Main PCA Block Description   2-3.

The A1 Main pca description is divided into sections for each primary pca function as described below.

Power Supply   2-4.

The Power Supply functional block (Figure 2-3) provides voltages required by the outguard digital circuitry: +4.9V dc (Vcc); the vacuum-fluorescent display: -30V dc and filament voltage of 5.4V ac; the inguard circuitry: +5.2V dc (Vdd), +5.6V dc (Vddr), and -5.2V dc; and RS-232 interface voltage: -5.0V dc (Vee).

Within the power supply, the raw dc supply converts 107 to 264V ac line voltage into a dc level and applies it to the power switch, and/or the 9 to 16V dc input is applied to the power switch. The 5V Switcher (A1U9, A1U28) converts the dc from the power switch into 4.9V +/-0.05V dc, which is used by the Inverter (A1U22, A1U23) in generating the above-mentioned outputs. A Power Fail Detector provides a power supply status signal to the Microprocessor in the Digital Kernel.

Within the Ethernet interface (A1U16, A1U32) there is an inverter module that provides an isolated -9V dc supply for the 10BASE2 transceiver. The inverter module is powered from the 4.9V dc (Vcc) supply. There is also a small power supply that provides a programming voltage (Vpp) for the FLASH EPROM device on the outguard digital kernel.
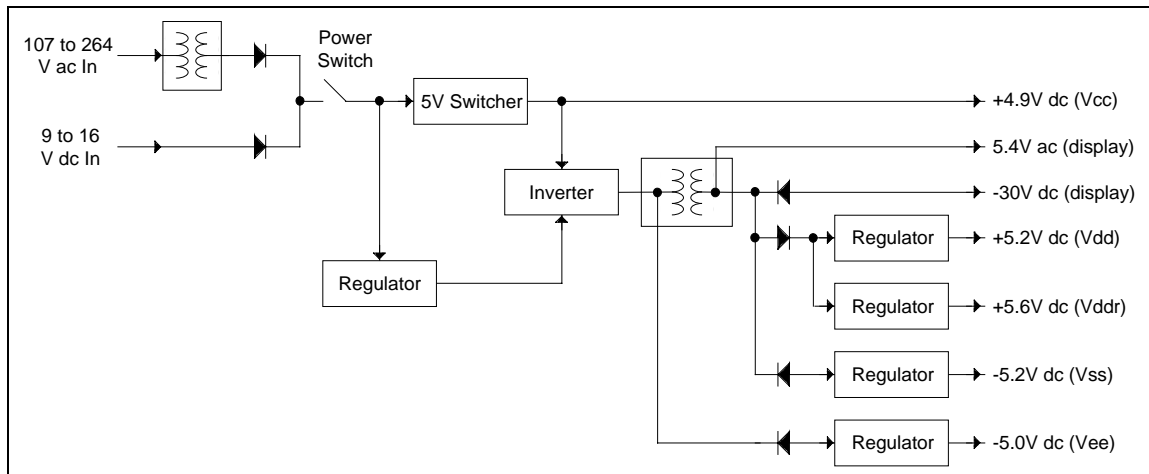
Figure 2-3. Power Supply Block Diagram

Digital Kernel   2-5.

The Digital Kernel functional block is responsible for the coordination of all activities within the instrument. This block requires voltages from the Power Supply and signals from the Power-on Reset circuit.

Specifically, the Digital Kernel microprocessor (A1U1) performs the following functions:

- Executes the instructions stored in FLASH EPROM (A1U21).
- Stores instrument calibration data in FLASH EPROM.

- Communicates with the microprocessor on the A/D Converter PCA via the Serial Communication (Guard Crossing) block (A1U5, A1U7).

- Communicates with the Display Controller to display readings and user interface information (A1U1, A1U31).

- Communicates with the Field Programmable Gate Array (A1U31), which scans the user interface keyboard found on the Display Assembly and interfaces with the Digital I/O hardware.

- Communicates with a host computer via the Ethernet interface (A1U32).

- Communicates with a host computer via the RS-232 interface (A1U1, A1U13).

- Reads the digital inputs and changes digital, alarm, and trigger outputs.

Serial Communication (Guard Crossing) 2-6.

This functional block provides a high isolation voltage communication path between the Digital Kernel of the Main PCA and the microprocessor on the A/D Converter PCA. This bidirectional communication circuit (A1U5, A1U7) requires power supply voltages from the Power Supply block.

Digital Inputs and Outputs 2-7.

This functional block contains the Totalizer and Trigger Input buffers, eight bidirectional Digital I/O channels (A1U3, A1U4, A1U17, A1U27), Master Alarm output, and a Trigger Output (A1U17). These circuits require power supply voltages from the Power Supply and signals from the Digital Kernel.

Ethernet Interface 2-8.

This functional block contains the Ethernet Controller (A1U32), used for both 10BASE2 and 10BASE-T. When 10BASE2 is selected by the Ethernet interface, an additional Ethernet Transceiver device (A1U32) is used. These circuits require power supply voltages from the Power Supply and signals from the Digital Kernel.

A2 Display PCA Block Description 2-9.

The Display Assembly controller communicates with the A1 Main PCA microprocessor (A1U1) over a three-wire communication channel. Commands from the microprocessor inform the Display Controller how to modify its internal display memory. The Display Controller (A2U1) then drives the grid and anode signals to illuminate the required segments on the Display. The A2 Display PCA requires power supply voltages from the A1 Main PCA power supply voltages and a clock signal from the A1U4 microprocessor.

A3 A/D Converter PCA Block Description 2-10.

The following paragraphs describe the major blocks of circuitry on the A/D Converter PCA.

Analog Measurement Processor 2-11.

The Analog Measurement Processor (A3U30) provides input signal conditioning, ranging, and frequency measurement. This custom chip is controlled by the A/D Microprocessor (A3U5). The A/D Microprocessor communicates with the Main PCA Microprocessor (A1U1) over a serial interface.

Input Protection 2-12.

This circuitry protects the instrument measurement circuits during overvoltage conditions.

Input Signal Conditioning 2-13.

Here, each input is conditioned and/or scaled to a dc voltage for measurement by the a/d converter. DC voltage levels greater than 3V are attenuated. To measure resistance, a dc current is applied across a series connection of the input resistance and a reference resistance to develop dc voltages that can be ratioed. DC volts and ohms measurements are filtered by a passive filter. AC voltages are first scaled by an ac buffer, converted to a representative dc voltage by an rms converter, and then filtered by an active filter.

Analog-to-Digital (a/d) Converter 2-14.

The dc voltage output from the signal conditioning circuits is applied to a multi-slope A/D converter.

The input voltage is applied to a buffer/integrator that charges a capacitor for an exact amount of time. During this time, positive and negative reference voltages are alternately applied to the integrator. The references are switched in a sequence controlled by the A/D Electrically Programmed Logic Device (EPLD) (A3U18), which prevents the integrator from saturating.

The amount of time that each reference is applied to the integrator, and the amount of time required to discharge the capacitor, are measured by digital counter circuits in the A/D EPLD (A3U18). These times are used by the inguard microprocessor (A3U5) to calculate the level of the unknown input signal.

Inguard Microcontroller 2-15.

This microprocessor (A3U5) and associated circuitry controls all functions on the A/D Converter PCA and communicates with the digital kernel on the Main PCA. Upon request by the Main PCA, the inguard microprocessor selects the input channel to be measured through the channel selection circuitry, sets up the input signal conditioning, commands the A/D EPLD (A3U18) to begin a conversion, stops the measurement, and then fetches the measurement result. The inguard microprocessor manipulates the result mathematically and transmits the reading to the digital kernel.

Channel Selection 2-16.

This circuitry consists of a set of relays and relay-control drivers. The relays form a tree that routes the input channels to the measurement circuitry. Two of the relays are also used to switch between two-wire and four-wire operation. For signal switching and selection, the 2640A uses reed relays, while the 2645A uses solid-state relays.

Open Thermocouple Check 2-17.

Under control of the Inguard Microprocessor, the open thermocouple check circuit applies a small ac signal to a thermocouple input before each measurement. If an excessive resistance is encountered, an open thermocouple input condition is reported.

A4 Analog Input PCA Block Description 2-18.

The following paragraphs briefly describe the major sections of the Input Connector PCA, which is the "Universal Input Module" used for connecting the analog inputs to the instrument.

20-Channel Terminals 2-19.

Twenty HI and LO terminal blocks are provided in two rows, one for channels 1 through 10 and one for channels 11 through 20. The terminals can accommodate a wide range of wire sizes, starting with 12 gauge as the largest size. The two rows of terminal blocks are maintained very close to the same temperature for accurate thermocouple measurements.

Reference Junction Temperature 2-20.

A semiconductor junction is used to sense the temperature of the thermocouple input terminals. The resulting dc output voltage is proportional to the block temperature and is sent to the A/D Converter PCA for measurement.

Detailed Circuit Description 2-21.

The following circuit descriptions describe the theory of operation for each Instrument pca. For these descriptions, refer to the associated schematic diagram in Chapter 7.

A1 Main PCA Circuit Description 2-22.

The following paragraphs describe the operation of the circuits on the A1 Main PCA. The schematic for this pca is located in Chapter 7.

Power Supply Circuit Description 2-23.

The power supply portion of the A1 Main pca consists of three major sections:

- **Raw DC Supply** The raw dc supply converts line voltage (107V to 264V ac) into a dc output of 8V to 35V.

- **5V Switcher Supply** The 5V switcher supply regulates the 8V to 35V dc input into the 4.9V +/-0.05V dc (Vcc) source.

- **Inverter** Using the 5V switching supply output, the inverter generates the -30V dc and 5.4V ac supply levels needed for the vacuum-fluorescent display and the -5V dc supply for the RS-232 Interface. The inverter also provides isolated +5.6V (Vddr), +5.2V (Vdd), and -5.2V (Vss) outputs for the inguard circuitry.

Raw DC Supply 2-24.

The raw dc supply circuitry receives input from power transformer T401, which operates from an ac source of 107V to 264V ac. The power transformer is energized whenever the power cord is plugged into the ac line; there is no on/off switch on the primary side of the transformer. The transformer has an internal 275V ac metal-oxide varistor (MOV) to clamp line transients. The MOV normally acts as an open circuit. When the peak voltage exceeds approximately 400V, the line impedance in series with the line fuse limits transients to approximately 450V. All line voltages use a time-delay 0.15 A, 250V fuse.

On the secondary side of the transformer, rectifiers A1CR2, A1CR3, and capacitor A1C7 rectify and filter the output. When ON, switch A1S1 (the rear panel POWER switch) connects the output of the rectifiers to the filter capacitor and the rest of the instrument. Depending on line voltage, the output of the rectifiers is between 8.0 and 35V dc. Capacitor A1C2 is used for electromagnetic interference (EMI) and electromagnetic compatibility (EMC) requirements. Capacitor A1C1 helps supply the high frequency ripple current drawn by the switching regulator (described below).

When external dc power is used, the power switch connects the external dc source to power the instrument. The external dc input uses thermistor A1RT1 for overcurrent protection and diode A1CR1 for reverse input voltage protection. Capacitor A1C59 is used for EMI/EMC requirements. Resistor A1R48, and capacitors A1C102 and A1C39 are also used for EMI/EMC performance requirements. If both ac power and dc power are connected to the instrument, the instrument uses ac power when it exceeds approximately eight times the value of the dc voltage. Automatic switchover occurs between ac and dc power without interrupting instrument operation.

Auxiliary 6V Supply 2-25.

Three-terminal regulator A1U19, voltage-setting resistors A1R44 and A1R46, and capacitor A1C34, make up the auxiliary 6-volt supply. This supply is used to power the inverter oscillator and inverter driver.

5V Switcher 2-26.

The 5V switcher supply uses a controller/switch device A1U9 and related circuitry to produce the 4.9V dc (Vcc) output.

4.9V dc (Vcc) The 8V to 35V dc input is regulated to 4.9V dc (Vcc) through pulse-width modulation at a nominal switching frequency of 100 kHz. The output voltage of the switcher supply is controlled by varying the duty cycle (ON time) of the switching transistor in the controller/switch device A1U9. A1U9 contains the supply reference, oscillator, switch transistor, pulse-width modulator comparator, switch drive circuit, current-limit comparator, current-limit reference, and thermal limit. Dual inductor A1T2 regulates the current that flows from the raw supply to the load as the switching transistor in A1U9 is turned on and off. Complementary switch A1CR10 conducts when switching is turned off.

The pulse-width modulator comparator in A1U9 compares the output to an internal reference and sets the ON-time/OFF-time ratio to regulate the output to 4.9V dc. A1C1 is the input filter capacitor, and A1C14 and A1C18 are the output filter capacitors. Proper inductor and capacitor values set the filter frequency response to ensure best overall system stability. A1R26 and A1C21 ensure that the switcher supply remains stable and operating in the continuous mode. The power supply current is internally limited by A1U9 to 5 amps.

Resistors A1R5, A1R6, A1R27, A1R29, A1R30 and A1R31 form a voltage divider that operates in conjunction with amplifier A1U28, which is configured as a voltage follower. A1U28-3 samples the 4.9V dc output, while A1U28-2 is the voltage divider input. The effect is to maintain the junction of R30 and R31 at 4.9V dc, resulting in an A1U28-1 output level of 6.14V dc, or 1.24V dc above the output This feedback voltage is applied to A1U9-2, which A1U9 interprets as 1.24V dc because A1U9-3 (ground) is connected to the 4.9V dc output. A1U9 maintains the feedback and reference voltages at 1.24V dc and thus regulates the 4.9V dc source.

Inverter   2-27.

The inverter supply uses a two transistor-driven push-pull configuration. The center tap of transformer A1T1 primary is connected to the 4.9V dc Vcc supply, and each side is alternately connected to common through transistors A1Q7 and A1Q8. A1R38 may be removed to disable the inverter supply for troubleshooting purposes. A1Q7 and A1Q8 are driven by the outputs of D flip-flop A1U22. Resistors A1R34 and A1R28, and diodes A1CR11 and A1CR12 shape the input drive signals to properly drive the gate of the transistors. D flip-flop A1U22 is wired as a divide-by-two counter driven by a 110-kHz square wave. The 110-kHz square wave is generated by hex inverter A1U23, which is connected as an oscillator with a frequency determined by the values of resistors A1R40 and A1R47, and capacitor A1C35. The resulting ac voltage produced across the secondary of A1T1 is rectified to provide the input to the inverter inguard and outguard supplies.

Inverter Outguard Supply   2-28.

The inverter outguard supply provides three outputs: -30V dc and 5.4V ac for the display, and -5.0V dc (Vee) for the RS-232 drivers and receiver.

-30V dc Dual diodes A1CR8 and A1CR9 provide full-wave rectification of A1T1 outputs (pins 4, 5, and 8), creating the -30V dc supply. Output filtering for the -30V dc supply is provided by capacitor A1C17.

5.4V ac The 5.4V ac supply is sourced from a secondary winding on transformer T1 (pins 6 and 7), and is biased at -24V dc with zener diode A1VR3 and resistor A1R22.

-5.0V dc (Vee) Dual-diode A1CR13 rectifies an input from the inverter circuit, with the diode and capacitors A1C30 and A1C31 configured as a voltage doubler, generating -12V dc. This voltage is applied to the three-terminal regulator A1U18, which regulates the output for the -5.0V dc (Vee) source. Capacitor A1C32 is used for transient response performance of the three-terminal regulator.

Inverter Inguard Supply 2-29.

The inverter inguard supply provides three outputs: +5.2V dc (Vdd) and -5.2V dc (Vss) for the inguard analog and digital circuitry, and +5.6V dc (Vddr) for the relays. Diodes A1CR5 and A1CR6, and capacitor A1C12 create a +6.8V dc source, while diodes A1CR7 and capacitor A1C13 create a -9.5V dc source.

+5.2V dc (Vdd) The +5.2V dc (Vdd) source is regulated from a +6.8V dc input to A1U24 with resistors A1R9 and A1R10 setting the output voltage, and A1C4 handling transient loads. Resistors A1R4, A1R130, A1R128 and A1R13, along with transistor A1Q1, comprise a current-limiting circuit, which prevents A1U24 from supplying more than 60 mA of load current.

-5.2V dc (Vss) The -5.2V dc (Vss) source is regulated from a -9.5V dc input to A1U25 with resistors A1R11 and A1R12 setting the output voltage, and A1C5 handling transient loads. Resistors A1R14, A1R15, A1R129, A1R122, along with transistors A1Q5 and A1Q6, comprise a current-limiting circuit, which prevents A1U25 from supplying more than 40 mA of load current. Capacitor A1C9 enables the regulator to start up.

+5.6V dc (Vddr) The +5.6V dc (Vddr) source is regulated from a +6.8V dc input to A1U6 with resistors A1R131 and A1R132 setting the output voltage, and A1C6 handling transient loads.

Power Fail Detection 2-30.

The power fail detection circuit generates a signal to warn the Microprocessor that the power supply is going down. Microprocessor supervisor A1U10 compares the divided-down raw supply voltage, via voltage divider A1R19 and A1R20. When the raw supply voltage falls below approximately 8V dc, A1U10-5 output is low. Resistor A1R99 is a pull up resistor for the A1U10-7 reset line, and A1C81 provides filtering of high frequency noise. The reference voltage internal to the A1U10 is nominally 1.3V dc.

Digital Kernel *2-31.*

The Digital Kernel is composed of the following 10 functional circuit blocks:

- Reset Circuits
- Microprocessor
- Address Decoding
- Flash Memory
- Static RAM
- Real-Time Clock
- FPGA (Field Programmable Gate Array)
- Serial Communication (Guard Crossing)
- RS-232 Interface
- Ethernet Interface

Each of the 10 topics is discussed below.

Reset Circuits   2-32.

The Power-On Reset signal (POR*, A1U10-7) is generated by the Microprocessor Supervisor, which monitors the voltage of Vcc at A1U10-2. If Vcc is less than +4.65 volts, then A1U10-7 is driven low. POR* drives the enable inputs of the four tri-state buffers in A1U2, causing the HALT*, RESET*, and DRST* signals to be driven low when POR* is low. When POR* goes high, the tri-state buffer outputs (A1U2) go to their high-impedance state and the pull-up resistors pull the outputs to a high level.

When HALT* and RESET* are both driven low, the Microprocessor (A1U1) is reset and is in execution when they both go high. The Microprocessor may execute a "reset" instruction during normal operation to drive A1U1-92 low for approximately 10 microseconds to reset all system hardware connected to the RESET* signal.

The Display Reset signal (DRST*) is driven low by A1U2-6 when POR* is low, or it may be driven low by the Microprocessor (A1U1-56) if the instrument firmware needs to reset only the display hardware. For example, the firmware resets the display hardware after the FPGA is loaded at power-up and the Display Clock (DCLK) signal from the FPGA begins normal operation. This ensures that the Display Processor is properly reset while DCLK is active.

Microprocessor   2-33.

The Microprocessor uses a 16-bit data bus and a 20-bit address bus to access locations in the Flash Memory (A1U21), the Static RAM (A1U20, A1U30, A1U34 and A1U35), the Real-Time Clock (A1U11), the FPGA (A1U31), and the Ethernet Interface (A1U32). All of the data bus lines and the lowest 12 address lines have series termination resistors located near the Microprocessor (A1U1) to ensure that the instrument meets EMI/EMC performance requirements. When a memory access is done to the upper half of the data bus (D15 through D8), the upper data strobe (UDS*) goes low. When a memory access is done to the lower half of the data bus (D7 through D0), the lower data strobe (LDS*) goes low. When a memory access is a read cycle, R/W* must be high. Conversely for any write cycle, R/W* must be low.

The Microprocessor is a variant of the popular Motorola 68000 processor and is enhanced by including hardware support for clock generation, address decoding, timers, parallel ports, synchronous and asynchronous serial communications, interrupt controller, DMA (Direct Memory Access) controllers, and a watchdog timer.

The 15.36-MHz system clock signal (A1TP11) is generated by the oscillator circuit composed of A1U1, A1Y1, A1R2, A1C3, and A1C8. This clock goes through a series termination resistor (A1R17) to the FPGA (A1U31). This resistor is necessary to ensure that the instrument meets EMI/EMC performance requirements.

The Microprocessor has four software programmed address decoders that include wait state control logic. These four outputs are used to enable external memory and I/O components during read and write bus cycles. See "Address Decoding" for a complete description.

One sixteen-bit timer in the Microprocessor is used to keep track of the time to the nearest millisecond. The timer counter runs off the 15.36 MHz clock at a rate of 1/64th millisecond. The CINT* signal from the Real Time Clock chip (A1U11) causes the timer counter to be sampled every 1/64th of a second. The CINT* signal also interrupts the Microprocessor to provide a timing reference for the software. The combination of the counter and the interrupt are used by the software to keep track of the time to the nearest millisecond, referenced to the Real Time Clock Chip.

A second sixteen-bit timer in the Microprocessor is used for an interval timer. It is also clocked at a rate of 1/64th millisecond. This timer interrupts the Microprocessor at a rate determined by the application.

The Microprocessor has two parallel ports. Many of the parallel port pins are either used as software controlled signals or as inputs or outputs of timers and serial communication channels. Port A has 16 bits and Port B has 12 bits.

The Microprocessor communicates to the Display Controller using a synchronous, three-wire communication interface controlled by hardware in the Microprocessor. Information is communicated to the Display Controller to display user interface menus and measurement data. Details of this communication are described in the Display Controller Theory of Operation in this chapter.

The Microprocessor communicates to the A/D Microprocessor on the A/D Converter PCA (via the Serial Communication circuit) using an asynchronous communication channel at 120,000 baud. Communication to the A/D Microprocessor (A3U5) originates at A1U1-80. Communication from the A/D's Microprocessor to the Microprocessor appears at A1U1-52. When there is no communication in progress between the Microprocessor and the A/D Microprocessor, both of these signals are high.

The Microprocessor uses another asynchronous communication channel to communicate to external computing or modem equipment through the RS-232 interface. This interface is described in detail in the RS-232 Interface Theory of Operation in this chapter.

The third asynchronous communication channel in the Microprocessor is connected to the Debug Interface (P3). This connector is not installed in production assemblies.

The interrupt controller in the Microprocessor prioritizes interrupts received from hardware devices both internal and external to the Microprocessor. Table 2-1 lists interrupt sources from highest to lowest priority.

Table 2-1. Microprocessor Interrupt Sources

Microprocessor Pin	Signal Name	Description
A1U1-96	CINT*	Real-Time Clock Interrupt; 64 per second.
A1U1-121	XTINT*	External Trigger Interrupt.
A1U1-120	KINT*	Keyboard Interrupt; interrupts on each debounced change of keyboard conditions.
n/a	n/a	A/D Communication Interrupt; internal to the microprocessor.
n/a	n/a	RS-232 Interface Interrupt; internal to the microprocessor.
n/a	n/a	Timer Interrupt; internal to the microprocessor.
n/a	n/a	Debug Serial Interface Interrupt; internal to the microprocessor.
A1U1-119	EINT*	Ethernet Interface.
n/a	n/a	Timer Interrupt; internal to the microprocessor.
n/a	n/a	Display Serial Interface Interrupt; internal to the microprocessor.
n/a	n/a	Watchdog Timer; internal to the microprocessor.
A1U1-118	DISRX	Display Interrupt..
A1U1-97	TOTINT*	Totalizer Interrupt; interrupts on totalizer overflow from a count of 4,294,967,295 to 0.

The Microprocessor also has several internal DMA (Direct Memory Access) controllers that are used by the serial communication channels. Each serial communication channel has a DMA channel that handles character reception and another that handles character transmission. The use of these DMA controllers is transparent to the external operation of the Microprocessor, but it is important to understand that communication is handled at hardware speeds without the need for an interrupt for each character being transferred.

A watchdog timer internal to the Microprocessor is programmed to have a 10-second timeout interval. If the code executed by the Microprocessor fails to reinitialize the watchdog timer every 10 seconds or less, then A1U1-117 (POR*) is driven low for 16 cycles of SCLK (approximately 1 microsecond). This results in a complete hardware reset of the instrument, which restarts operation.

Address Decoding   2-34.

The four chip-select outputs on the Microprocessor are individual software programmed elements that allow the Microprocessor to select the base address, the size, and the number of wait states for the memory accessed by each output.

The FLSH* signal (A1U1-128) enables accesses to 512 kilobytes of Flash Memory (A1U21). The FLSH* signal goes through jumper W3, which must always be installed during normal instrument operation. W3 is removed only during the initial programming of the Flash Memory during production at the factory.

The RAM* signal (A1U1-127) enables access to the Static RAM (A1U20, A1U30, A1U34, or A1U35). There are two banks of static RAM. The SRAM decoding circuit (A1U14, A1U15, A1R125, and A1R126) selects one of the two banks. The RAM1* signal selects one bank (A1U20 and A1U30) and RAM2* selects the other bank (A1U34 and A1U35). A1R125 is installed for 128Kx8 SRAMs, or A1R126 is installed for 512Kx8 SRAMs. The I/O* and ENET* signals go to the I/O Decoder (A1U29), which decodes small areas of address space for I/O devices like the FPGA, the Real-Time Clock, and the Ethernet Interface.

There are no wait states for accesses to FLSH* and SRAM*, but two wait states are used for any access to I/O*. Each wait state adds approximately 65 nanoseconds to the length of a memory read or write cycle. The Ethernet Interface (A1U32) handles wait state timing for any accesses to ENET*. When the Microprocessor is starting up (also referred to as "booting"), the address decoding maps the address space as shown in Table 2-2.

Table 2-2. Booting Microprocessor Memory Map

Hexadecimal Address	Device Selected
000000 - 07FFFF	Flash (A1U21)
200000 - 27FFFF	SRAM (A1U20, A1U30, A1U34, and A1U35)
400000 - 401000	Microprocessor Internal
500000 - 50000F	Ethernet Interface (A1U32)
600000 - 60007F	FPGA Configuration (A1U31)
600080 - 6000FF	Real-Time Clock (A1U11)

Just before beginning execution of the instrument code, the address decoding is changed to map the address space as shown in Table 2-3. This change switches the positions of Flash Memory and Static RAM within the address space of the Microprocessor. Note that the Flash Memory is duplicated at two address ranges. When the instrument code begins executing, it runs out of the address range beginning at 088000 Hex.

Table 2-3. Instrument Microprocessor Memory Map

Hexadecimal Address	Device Selected
000000 - 07FFFF	SRAM (A1U20, A1U30, A1U34, and A1U35)
080000 - 87FFFF	Flash (A1U21)
088000 - 8FFFFF	Flash (A1U21)
400000 - 401000	Microprocessor Internal
500000 - 50000F	Ethernet Interface (A1U32)
600000 - 600007	FPGA Control / Status (A1U31)
600008 - 60000F	Alarm Outputs (A1U31)
600010 - 600017	Digital Outputs (A1U31)
600018 - 60001F (Read Only)	Digital Inputs (A1U31)
600020 - 600027 (Read Only)	Keyboard Input (A1U31)
600028 - 60002F (Read Only)	Totalizer LSB Input (A1U31)
600030 - 600037 (Read Only)	Totalizer MSB Input (A1U31)
600080 - 6000FF	Real-Time Clock (A1U11)

Flash Memory   2-35.

The Flash EPROM is an electrically erasable and programmable memory that provides storage of instructions for the Microprocessor and measurement calibration data.

A switching power supply composed of A1U12, A1L3, A1CR16, A1C11, A1C15, A1C86, and A1C97 generates a nominal +12 volt programming power supply (Vpp) when the Microprocessor drives VPPEN high (A1U12-2). Resistor A1R119 pulls A1U12-2 to near ground during power-up to ensure that A1U12 is not enabled while the Microprocessor is being reset. When the power supply is not enabled, the output voltage (Vpp) should be about 0.1 volt less than the input voltage of the power supply (Vcc).

The only time that the programming power supply is active is when new firmware is being loaded or new calibration constants are being stored into the Flash EPROM. The code executed immediately after power-up is stored in an area of the Flash EPROM (known as the Boot Block) that is only erasable and reprogrammable if BBVPP (A1U21-44) is at a nominal +12 volts. This may be accomplished by installing jumper A1W2, but this should only be done by a trained technician, and A1W2 should never be installed unless it is necessary to update the Boot firmware. In normal operation, resistor A1R124 and diode A1CR20 pull BBVPP up to about 0.25 volts less than Vcc.

The FLSH* chip select (A1U1-128) for this device goes low for any memory access to A1U21. The FLSH* signal goes through jumper W3, which must always be installed during normal instrument operation. W3 is removed only during the initial programming of the Flash Memory during production at the factory.

Static RAM   2-36.

The Static RAM (SRAM) provides 512K bytes of data storage for the instrument using 128Kx8 SRAM devices. The board may also be configured for 2M bytes of data storage using 512Kx8 SRAM devices.

The RAM* address decode output (A1U1-127) for the SRAM goes low for any memory access to A1U20, A1U30, A1U34, or A1U35. Two OR gates in A1U15 are used to select two of the memory chips. RAM1* selects A1U20 and A1U30, and RAM2* selects A1U34 and A1U35. A1R125 or A1R126 is installed depending on the size of the memory chips. A1R125 is installed for 128Kx8 SRAMs, or A1R126 is installed for 512Kx8 SRAMS. Address bit 18 (A18) is inverted to A1U20-30 and A1U30-30 to provide an active high chip select when 128Kx8 SRAM chips are used.

A1U30 and A1U35 are connected to the high 8 bits of the data bus, so read accesses are enabled by the Read Upper (RD1*;A1U30-24;A1U35-24) signal going low, and write accesses are enabled by the Write Upper (WRU*;A1U30-29;A1U35-29) signal going low. A1U20 and A1U34 are connected to the low 8 bits of the data bus, so read accesses are enabled by the Read Lower (RD2*;A1U20-24;A1U34-24) signal going low, and write accesses are enabled by the Write Lower (WRL*;A1U20-29;A1U34-29) signal going low.

Real-Time Clock 2-37.

The Real-Time Clock maintains time and calendar date information for use by the instrument.

A nonvolatile power supply (Vbb) biases A1U11. The Microprocessor Supervisor (A1U10) monitors the voltage on Vcc (A1U10-2). If Vcc is greater than the voltage of the lithium battery (A1U10-8), A1U10 switches Vcc from A1U10-2 to A1U10-1 (Vbb). If Vcc drops below the voltage of the lithium battery (A1U10-8), A1U10 switches voltage from lithium battery A1BT1 through current-limiting resistor A1R84 to A1U10-1 (Vbb). The nominal current required from the lithium battery (A1BT1) at room temperature with the instrument powered down is approximately 2 microamperes. This can be easily measured by checking the voltage across A1R98.

Memory accesses to the Real-Time Clock (A1U11) are enabled by the RTC address decode output (A1U29-16). This signal must go through a NAND gate in A1U36 to the Real-Time Clock chip select input (A1U11-18). This ensures that when the instrument is powered down and A1U10-7 is driven low, A1U11-18 is driven high so that the contents of the Real-Time Clock cannot be changed, and the power dissipated by the Real-Time Clock is minimized. A1U11 is connected to the high 8 bits of the data bus, so read accesses are enabled by the Read Lower (RD1*;A1U11-19) signal going low, and write accesses are enabled by the Write Upper (WRU*;A1U11-20) signal going low. When the instrument is powered up, the accuracy of the timebase generated by the internal crystal may be tested by measuring the frequency of the 1-Hz square wave output (A1U11-4). The Real-Time Clock also has an interrupt output (A1U11-3) that is used by the Microprocessor to synchronize its internal millisecond timer to the real-time clock. There should be 64 interrupts per second from the real-time clock.

FPGA (Field Programmable Gate Array) 2-38.

When the instrument is powered up, the FPGA, a complex programmable logic device, clears its configuration memory and waits until RESET* (A1U31-78) goes high. The FPGA then tests its mode pins and should determine that it is in "peripheral" configuration mode (A1U31-54 high; A1U31-52 low; A1U31-56 high). In this mode the Microprocessor must load the configuration information into the FPGA before the FPGA logic can begin operation.

The Microprocessor first makes sure that the FPGA is ready to be configured by driving XD/P* (A1U31-80) low and then pulsing the RESET* (A1U31-78) input low for about 10 microseconds. The Microprocessor then waits until the XINIT* (A1U31-65) output goes high, indicating that the FPGA has been initialized and is ready for configuration. The Microprocessor then writes a byte of configuration data to the FPGA by driving PGA* (A1U31-88) low and latching the data on the data inputs (D<0> through D<7>) by pulsing WRL* (A1U31-5) low and then back high. The XRDY (A1U31-99) output then goes low to indicate that the FPGA is busy loading that configuration byte. The Microprocessor then waits until XRDY goes high again before loading the next configuration byte, and the sequence is repeated until the last byte is loaded. While the configuration data is being loaded, the FPGA drives the XD/P* signal (A1U31-80) low. When the FPGA has been completely configured, the XD/P* signal is released and pulled high by resistor A1R64. The Microprocessor repeats the configuration sequence if XD/P* (A1U31-80) does not go high when it is expected to.

The FPGA contains the following eight functional elements after the Microprocessor has loaded the configuration into the FPGA:

- Clock Dividers
- Internal Register Address Decoding
- Keyboard Scanner
- Digital I/O Buffers
- Latches
- Totalizer Debouncing and Mode Selection
- Totalizer Counter
- External Trigger Logic

Clock Dividers The 15.36-MHz system clock (A1U31-30) is divided down by the Clock Dividers to create the 1.024-MHz Display Clock (DCLK; A1U31-19). The Display Clock is not a square wave; it is low for 2/3 of a cycle and high for the other 1/3. The Display Clock is also used internal to the FPGA to create the 128-kHz Totalizer Debouncer Clock and the 4-kHz Keyboard Scanner Clock.

Internal Register Address Decoding The FPGA logic decodes four bits of the address bus (A<3> through A<6>), the PGA* chip select signal (A1U31-88), RD2* (A1U31-95), and WRL* (A1U31-5) to allow the Microprocessor to read five registers and write to three registers implemented in the FPGA logic. The absolute addresses are listed in Table 2-3.

Keyboard Scanner The Keyboard Scanner sequences through the array of switches on the Display Assembly to detect and debounce switch closures. After a switch closure is detected, it must remain closed for at least 16 milliseconds before the Microprocessor is interrupted and the Keyboard Input register is read from the FPGA. When the keyboard interrupt (KINT*, A1U31-62) goes low, the Keyboard Scanner stops scanning until the Microprocessor reads the Keyboard Input register, which automatically clears the interrupt by driving KINT* high again. The FPGA interrupts the Microprocessor again when the switch on the Display Assembly is detected as open again. Actually the Microprocessor is interrupted once for each debounced change in the contents of the Keyboard Input register. See also the information on "Front Panel Switches" in the "Display PCA" section for this instrument.

The Microprocessor can enable or disable the Keyboard Scanner by changing the state of a bit in the Control/Status register that is in the FPGA. The Keyboard Scanner is disabled if the instrument is in either the RWLS or LWLS state (see Users Manual; RWLS, and LWLS Computer Interface Commands).

Digital I/O Buffers and Latches The FPGA logic implements internal registers for the eight Digital Outputs (DO<0> through DO<7>), Master Alarm Output (AO<2>), and Trigger Output (AO<3>). The two Alarm Outputs (AO<0> and ADO<1>) are not supported. These registers are both written and read by the Microprocessor. The FPGA logic also implements an eight-bit input buffer so that the Microprocessor can read the eight Digital Input lines (DI<0> through DI<7>). See also "Digital Input Buffers" and "Digital and Alarm Output Drivers."

Totalizer Debouncing and Mode Selection Logic internal to the FPGA lets the Microprocessor enable a debouncer in the Totalizer input signal path. You can find the detailed description of the Totalizer Debouncer and Mode Selection later in this chapter under the heading "Totalizer Input."

Totalizer Counter There is a 16 bit counter internal to the FPGA to count the totalizer inputs. When the 16 bit counter overflows, the microprocessor is interrupted and a software counter is incremented.

External Trigger Logic Logic internal to the FPGA allows the Microprocessor to set up the External Trigger Logic to interrupt on rising or falling edges of the XTI input to the FPGA. The FPGA also allows the Microprocessor to pulse an external trigger output from the FPGA. The detailed description of the External Trigger operation may be found later in this chapter in the "External Trigger Circuits" section.

Serial Communication (Guard Crossing)   2-39.

The transmission of information from the Microprocessor (A1U1) to the A/D Microprocessor (A3U5) is accomplished via the circuit made up of A1U5, A1R8, A1R16, and A1CR22. The transmit output from the Microprocessor (A1U1-80) switches current through optocoupler LED (A1U5-3). Resistor A1R8 limits the current through the LED.

The photodiode in A1U5 responds to the light emitted by the LED when A1U1-80 is driven low. The open collector output (A1U5-6) is pulled high by A1R16 and A1CR22. This output is connected to a serial port input on the A/D Microprocessor (A3U5-53).

The transmission of data from the A/D Microprocessor (A3U5) to the Microprocessor (A1U1) is accomplished via the circuit made up of A1U7, A1R7, and A1R3. The transmit output from the A/D Microprocessor (A3U5-54) drives the optocoupler LED (A1U7-3). The current through the LED is limited by resistor A1R7. The photodiode in A1U7 responds to the light emitted by the LED when A1U7-3 is driven low.

The photodiode in A1U7 responds to the light emitted by the LED when A3U5-54 is driven low. The open collector output (A1U7-6) is pulled high by A1R3. This output is connected to a serial port input on the Microprocessor (A1U1-52).

RS-232 Interface   2-40.

The RS-232 interface is composed of connector A1J4, RS-232 Driver/Receiver A1U13, and the serial communication hardware in Microprocessor A1U1.

The serial communication transmit signal (A1U1-54) goes to the RS-232 driver (A1U13-14), where it is inverted and level shifted so that the RS-232 transmit signal transitions between approximately +5.0 and -5.0V dc. When the instrument is not transmitting, the driver output (TP13;A1U13-3) is approximately -5.0V dc. The RS-232 receive signal from A1J4 goes to the RS-232 receiver A1U13-4, which inverts and level shifts the signal so that the input to the serial communication hardware transitions between 0 and +5.0V dc. When nothing is being transmitted to the instrument, the receiver output (TP12;A1U13-13) is +5.0V dc.

Data Terminal Ready (DTR) and Request To Send (RTS) are modem control signals controlled by the Microprocessor. When the instrument is powered up, the Microprocessor initially sets DTR and RTS false by setting A1U1-61 and A1U1-59 high, which results in the RS-232 driver outputs (A1U13-7 and A1U13-5 respectively) going to -5.0V dc. When the instrument has initialized the RS-232 interface and is ready to receive and transmit, A1U1-61 and A1U1-59 goes low, resulting in the RS-232 DTR and RTS signals going to +5.0V dc. The RS-232 DTR and RTS signals remain at +5.0V dc until the instrument is powered down except for a short period of time when the user changes RS-232 communication parameters from the front panel of the instrument.

Clear To Send (CTS) and Data Set Ready (DSR) are modem control inputs from the connected RS-232 equipment. Of these signals, only CTS is used when CTS flow control is enabled via the RS-232 communication setup menu. The CTS modem control signal from A1J4 goes to the RS-232 receiver A1U13-6, which inverts and level shifts the signal so that the input to the Microprocessor (A1U1-58) transitions between 0 and +5.0V dc. When the instrument is cleared to send characters to the RS-232 interface, the receiver output (A1U13-11) is +5.0V dc. If the RS-232 CTS signal is not driven by the attached RS-232 equipment, the receiver output (A1U13-11) is near 0V dc.

Ethernet Interface   2-41.

The Ethernet Interface is the primary means the instrument uses to communicate with a host computer. The interface is comprised of an Ethernet chip, a buffer memory, two physical connectors, and electrically isolated interfaces between the Ethernet chip and the connectors. Only one of the two connectors are used at a time.

Ethernet Chip and Buffer Memory The Ethernet chip (A1U32) is directly connected to the Microprocessor's address and data bus. Three address lines are used to select registers within the Ethernet Chip, and data is transferred over 16 data lines. The chip select is performed by read and write strobe signals EIOR* and EIOW* (A1U32-154 and A1U32-155). EIOR* is driven low when the Microprocessor is reading from the Ethernet Chip, and EIOW* is driven low when the Microprocessor is writing to the Ethernet Chip. The Ethernet chip signals the end of a read or write cycle by driving its RDY output (A1U32-151) low. This enables the output of tri-state buffer A1U2-3, driving the DTACK* signal low to the Microprocessor (A1U1-85). When the Microprocessor sees DTACK* go low, it ends the read or write cycle to the Ethernet chip. The Ethernet Chip may also interrupt the Microprocessor by driving EINT* low (A1U32-133.) A1R133 is used to pull EINT* high.

Unlike RS-232 and other serial interfaces, Ethernet transfers data as packets of several K bytes of data, instead of as single bytes. The buffer memory is used to store packets while they are being received, or while being transmitted. The Ethernet Chip (A1U32) is connected directly to the buffer memory (A1U33). Packets being received or transmitted are stored to or retrieved from the buffer memory by the Ethernet Chip. The buffer memory (A1U33) provides 32K bytes of storage for data packets.

Packets stored in the buffer memory (A1U33) are transferred to or from the Static RAM (A1U20, A1U30, A1U34, or A1U35) by a DMA controller in the Microprocessor (A1U1). This transfer is done with read or write cycles to the Ethernet Chip (A1U32).

The clock for the Ethernet Chip is provided by A1Y2, A1C38, and A1C89, which are connected directly to A1U32-17 and A1U32-18. This provides a 20 MHz clock to the Ethernet Chip. The clock allows the Ethernet Interface to send and receive data at 10 M-bits per second.

A1R107 sets internal bias currents in the Ethernet Chip (A1U32). The voltage drop across this resistor is normally around 1.25 volts.

The Ethernet Chip also drives three LEDs. A1DS2 indicates that a packet is being received. A1DS3 indicates that the Ethernet Chip is transmitting a packet. A1DS1 indicates two different things depending on the type of physical interface being used. If 10BASE-2 (Coax) is being used, A1DS1 indicates when collisions were detected on the Ethernet. If 10BASE-T (Twisted Pair) is being used, A1DS1 indicates whether the link to the host computer is intact. A1DS1 is driven by the Ethernet Chip (A1U32) through a dual diode (A1CR4), which ORs together two outputs (A1U32-59 and A1U32-60). A1DS2 and A1DS3 are driven directly by A1U32-57 and A1U32-58. Resistors A1R37, A1R122, and A1R121 limit current to LEDs A1DS1, A1DS2, and A1DS3.

Ethernet Connectors The instrument is connected to the Ethernet by either a 10BASE-2 interface (A1P2) or a 10BASE-T interface (A1P1). 10BASE-2 uses coaxial cable to attach instrument to a host computer. Other instruments and possibly other equipment may be attached to the same coaxial cable when a 10BASE-2 interface is used. 10BASE-T uses twisted pair cable to attach instrument to some kind of hub. A host computer, other instruments, and other equipment are connected to a 10BASE-T hub using separate twisted pair cables.

10BASE-T Ethernet Connector Pulse transformer A1T4 provides electrical isolation between the Ethernet Chip (A1U32) and the 10BASE-T connector (A1P1). Two twisted pairs are used in a 10BASE-T cable. One pair is used to transmit data (A1P1-1 and A1P1-2), and the other is used to receive data (A1P1-3 and A1P1-6). Resistors A1R86, A1R95, and capacitor A1C60 provide a termination network for data received through the pulse transformer (A1T4). Resistors A1R32, A1R76, A1R92, A1R100, and A1R120 provide a termination network for data transmitted through the pulse transformer (A1T4). Connector A1P1 provides chassis potential on pins 9 and 10 to shield the cable and provide a system ground. Capacitor A1C28 helps the instrument meet EMI requirements.

10BASE2 Ethernet Connector Ethernet transceiver chip A1U16 drives and receives data on the 10BASE-2 (Coaxial) interface connector (A1P2). In addition, A1U16 detects collisions on the Ethernet. Data and collision detect signals are transferred between the transceiver chip (A1U16) and the Ethernet Interface (A1U32) through pulse transformer A1T3. Power supply module A1U38 provides a -9V isolated power supply to the 10BASE-2 transceiver chip A1U16. The power supply module can be powered down by a signal from the Ethernet Chip (A1U32-64) when the 10BASE-2 interface is not being used. The transceiver chip (A1U16) is protected from electrostatic discharge (ESD) by resistors A1R136, A1R77, capacitors A1C23, A1C61, and MOV A1RV2. A1R18 sets internal bias currents in A1U16.

Pulse transformer A1T3 provides electrical isolation between the Ethernet Chip (A1U32) and the 10BASE-2 transceiver chip (A1U16). Data is transmitted from the Ethernet Chip (A1U32) to the transceiver chip (A1U16) through pins 1, 2, 15, and 16 of pulse transformer A1T3. Resistor A1R24 terminates the outputs from the Ethernet Chip (A1U32). Data is received from the transceiver chip (A1U16) through pins 4, 5, 12, and 13 of pulse transformer A1T3. Resistors A1R42, A1R65, and capacitor A1C33 provide a termination network for data received through the pulse transformer (A1T4). The transceiver chip indicates a collision was detected on the Ethernet through pins 7, 8, 9, and 10 of pulse transformer A1T3. Resistors A1R85, A1R87, and capacitor A1C69 provide a termination network for the collision detected signal received through the pulse transformer (A1T4).

Digital Inputs and Outputs   2-42.

The following paragraphs describe the digital input/output as follows:

- Digital Input Threshold
- Digital Input Buffers
- Digital and Alarm Output Drivers
- Totalizer Input
- External Trigger Circuits

Digital Input Threshold   2-43.

The Digital Input Threshold circuit sets the input threshold level for the Digital Input Buffers and the Totalizer Input. A fixed value voltage divider (A1R36, A1R37) and a unity gain buffer amplifier (A1U8) are the main components in this circuit. The voltage from the divider (approximately +1.4V dc) is then buffered by A1U8, which sets the input threshold. Capacitor A1C29 filters the divider voltage at the input of A1U8.

Digital Input Buffers   2-44.

Since the eight Digital Input Buffers are identical in design, only components used for Digital Input 0 are referenced in this description. If the Digital Output Driver (A1U17-12) is off, the input to the Digital Input Buffer is determined by the voltage level at A1J5-10. If the Digital Output Driver is on, the input of the Digital Input Buffer is the voltage at the output of the Digital Output Driver.

The Digital Input Threshold circuit and resistor network A1Z1 determine the input threshold voltage and Hysteresis for inverting comparator A1U3. The inverting input of the comparator (A1U3-2) is protected by a series resistor (A1Z3) and diode A1CR14. A negative input clamp circuit (A1Q9, A1Z2, and A1CR17) sets a clamp voltage of approximately +0.7V dc for the protection diodes of all Digital Input Buffers. A negative input voltage at A1J5-10 causes A1CR14 to conduct current, clamping the comparator input A1U3-2 at approximately 0V dc.

The input threshold of +1.4V dc and a hysteresis of +0.5V dc are used for all Digital Input Buffers. When the input of the Digital Input Buffer is greater than approximately +1.65V dc, the output of the inverting comparator is low. When the input then drops below about +1.15V dc, the output of the inverting comparator goes high.

Digital and Alarm Output Drivers 2-45.

Since the 11 Digital Output and Alarm Output Drivers are identical in design, the following example description references only the components that are used for the Master Alarm Output (AO<2>).

The Microprocessor controls the state of the Master Alarm Output Driver by writing to the Alarm Output register in the FPGA (A1U31) to set the level of output A1U31-61. When A1U31-61 is set high, the output of the open-collector Darlington driver (A1U17-14) sinks current through current-limiting resistor A1R60. When A1U31-61 is set low, the driver output turns off and is pulled up by A1Z2 and/or the voltage of the external device that the output is driving. If the driver output is driving an external inductive load, the internal flyback diode (A1U17-9) conducts the energy into MOV A1RV1 to keep the driver output from being damaged by excessive voltage. Capacitor A1C56 ensures that the instrument meets electromagnetic interference (EMI) and electromagnetic compatibility (EMC) performance requirements.

Totalizer Input 2-46.

The Totalizer Input circuit consists of Input Protection, a Digital Input Buffer circuit, and a Totalizer Debouncing circuit. The Digital Input Buffer for the totalizer is protected from electrostatic discharge (ESD) damage by A1R49 and A1C43. Refer to the detailed description of the Digital Input Buffer circuit for more information.

The Totalizer Debounce circuit in the FPGA (A1U31) allows the Microprocessor to select totalizing of either the input signal or the debounced input signal. The buffered Totalizer Input signal (TOTI*) goes into the FPGA at A1U31-12. Inside the FPGA, the totalizer signal is routed to a 16-bit counter in the FPGA. The counter can be read at any time by the microprocessor. When the 16-bit counter overflows, the microprocessor is interrupted by the Totalizer Interrupt signal (TOTINT*) that comes from A1U31-8. The microprocessor uses this interrupt (A1U1-97) to increment a software counter.

The actual debouncing of the input signal is accomplished by A1U31. Counters divide the 15.36-MHz system clock down to 128 kHz for the debouncing circuit. An EXOR gate compares the input signal (TOTI*) and the latched output of the debouncer. If these signals differ, the EXOR gate output goes high, enabling the debouncer. If the input remains stable for 1.75 milliseconds, the debouncer output changes state. If the input does not remain stable for 1.75 milliseconds, the debouncer output does not change state. If the Microprocessor selected totalizing of the debounced input signal, the debouncer output is connected to the 16-bit counter inside the FPGA.

External Trigger Circuits 2-47.

The External Trigger Input circuit can be configured by the Microprocessor to interrupt on a rising or falling edge of the TGIN* input (A1J6-2) or to not interrupt on any transitions of the TGIN* input. The falling edge of the TGIN* input is used by the instrument firmware as an indication to start scanning, and the rising edge is used as an indication to stop scanning.

The External Trigger Input is pulled up to +5V dc by A1Z2 and is protected from electrostatic discharge (ESD) damage by A1R58, A1C54, A1Z3, and A1CR15. Capacitor A1C54 helps ensure that the instrument meets EMI/EMC performance requirements.

The input (XTI) is then routed to the FPGA (A1U31), that contains the External Trigger control circuitry. The Microprocessor sets control register bits in the FPGA (A1U31) to control the external trigger circuit. The External Trigger control circuit output (A1U31-9) drives an interrupt input on the Microprocessor (A1U1-121).

If External Triggering is enabled (see User Manual), the Microprocessor sets FPGA control register bits to allow a low level on the TGIN* input to cause the External Trigger Interrupt (XTINT*; A1U31-9) to go low. The Microprocessor then changes the FPGA control register bits to allow a high level on the TGIN* input to cause XTINT* (A1U31-9) to go low. Thus the Microprocessor can detect both rising and falling edges on the TGIN* input. Normally, the XTINT* output of the FPGA (A1U31-9) should be low only for a few microseconds at any time. If it is held low constantly, the instrument does not operate. Resistor A1R39 pulls the XTINT* output high to ensure that it is high during power-up.

The instrument has a trigger output line that is pulsed low when the Microprocessor writes a bit to a register in the FPGA (A1U31). The trigger output line (TGOUT* A1J6-3) is pulsed low for 250 to 500 microseconds at the beginning of the first measurement of each acquisition scan. The pulse width is set by circuitry within the FPGA. The output circuitry for the trigger output is the same as for the digital and alarm output buffers, except for transistor A1Q10. This transistor is used to increase the amount of current the trigger output can sink. This allows the trigger output to drive the trigger inputs of up to 19 instruments.

A2 Display PCA Circuit Description   2-48.

Display Assembly operation is classified into six functional circuit blocks as follows:

- Main PCA Connector
- Front Panel Switches
- Display
- Beeper Drive Circuit
- Watchdog Timer/Reset Circuit
- Display Controller

Each circuit block is described in the following paragraphs.

Main PCA Connector   2-49.

The 20-pin Main PCA Connector (A2J1) provides the interface between the Main PCA and the other functional blocks on the Display PCA. Seven of the connector pins provide the necessary connections to the four power supply voltages: -30V dc, -5V dc (Vee), +4.9V dc (Vcc), and 5.4V ac filament voltage (see Table 2-4). Six pins are used to provide the interface to the Front Panel Switches (A2SWR1 through A2SWR6). The other seven signals interface the Microprocessor (A1U4) to the Display Controller (A2U1) and pass the reset signals between the assemblies.

Table 2-4. A2 Display Power Supply Connections

Power Supply	A2J1 Pins	Nominal Voltage
Vcc	8	+4.9V dc
Vee	6	-5.0V dc
Vload	7	-30V dc
FIL1/FIL2	2/3	5.4V ac

Front Panel Switches 2-50.

The FPGA monitors the front panel switches (see below) using six interface signals SWR1 through SWR6. The ground connection is already available from the power supply.

Switch Designation	Switch Function
S11	COMM
S12	Left Arrow
S13	DIO
S14	Right Arrow
S15	MON
S16	ENTER
S17	Up Arrow
S18	Down Arrow
S21	CAL Enable

The six Switch Interface Signals (SWR1 though SWR6) are connected to bidirectional I/O pins on the FPGA. Each successive column has one less switch. This arrangement allows the unused interface signals to function as strobe signals when their respective column is driven by the FPGA. The FPGA cycles through six steps to scan the complete front panel switch matrix. Table 2-5 shows the interface signal state and, if the signal state is an output, the switches that may be detected as closed.

In step 1, six I/O pins are set to input, and the interface signal values are read. In steps 2 through 6, the pin listed as O is set to output zero, the other pins are read, and pins indicated by a Z are ignored.

Each of the interface signals is pulled up to the +5V dc supply by a 10 kΩ resistor in network A2Z1. Normally, the resistance between any two of the interface signals is approximately 20 kΩ. Checking resistances between any two signals (SWR1 through SWR6) verifies proper termination by resistor network A2Z1.

Table 2-5. Front Panel Switch Scanning

Interface Signal States or Key Sensed						
Step	**SWR6**	**SWR5**	**SWR4**	**SWR3**	**SWR2**	**SWR1**
1		A2S17	A2S10	A2S12	A2S18	A2S13
2					A2S11	0
3					0	Z
4	A2S14	A2S15	A2S16	0	Z	Z
5	n/a	n/a	0	Z	Z	Z
6	A2S21	0	Z	Z	Z	Z
A2Sn indicates switch closure sensed.						
0 indicates strobe driven to logic 0.						
Z indicates high impedance input state ignored.						

Display   2-51.

The custom vacuum-fluorescent display (A2DS1) consists of a filament, 11 grids (numbered 0 through 10 from right to left on the display), and up to 14 anodes under each grid. The anodes make up the digits and annunciators for their respective area of the display. The grids are positioned between the filament and the anodes.

A 5.4V ac signal, biased at a -24V dc level, drives the filament. When a grid is driven to +5V dc, the electrons from the filament are accelerated toward the anodes that are under that grid. Anodes under that grid that are also driven to +5V dc are illuminated, but the anodes that are driven to -30V dc are not. Grids are driven to +5V dc one at a time, sequencing from GRID(10) to GRID(0) (left to right, as the display is viewed.)

Beeper Drive Circuit   2-52.

The Beeper Drive circuit drives the speaker (A2LS1) to provide an audible response to a button press. A valid entry yields a short beep; an incorrect entry yields a longer beep.

The circuitry consists of a dual four-bit binary counter (A2U4) and a NAND gate (A2U6) used as an inverter. One four-bit free-running counter (A2U4) divides the 1.024-MHz clock signal (E) from the FPGA (DSCLK) by 2 to generate the 512-kHz clock (CLK1) used by the Display Controller. This counter also divides the 1.024-MHz clock by 16, generating the 64-kHz clock that drives the second four-bit binary counter (A2U4).

The second four-bit counter is controlled by an open-drain output on the Display Controller (A2U1-17) and pull-down resistor A2R1. When the beeper (A2LS1) is off, A2U1-17 is pulled to ground by A2R1. This signal is then inverted by A2U6, with A2U6-6 driving the CLR input high to hold the four-bit counter reset. Output A2U4-8 of the four-bit counter drives the parallel combination of the beeper (A2LS1) and A2R10 to ground to keep the beeper silent. When commanded by the Microprocessor, the Display Controller drives A2U1-17 high, enabling the beeper and driving the CLR input of the four-bit counter (A2U4-12) low. A 4-kHz square wave then appears at counter output A2U4-8 and across the parallel combination of A2LS1 and A2R10, causing the beeper to resonate.

Watchdog Timer and Reset Circuit 2-53.

The Watchdog Timer and Reset circuit has been defeated by the insertion of the jumper between TP1 and TP3 on the Display Assembly. In this instrument, the reset circuitry is on the Main Assembly and the Watchdog Timer is part of the Microprocessor (A1U1).

The Display Reset signal (DRST*) drives the RESET2* signal on the Display Assembly low when the instrument is being reset. This discharges capacitor A2C3, and NAND gate output A2U6-11 provides an active high reset signal to the Display Processor. The Watchdog Timer on the Display Assembly (A2U5, A2U6 and various resistive and capacitive timing components) is held "cleared" by TP1 being held at 0V dc by a jumper, and output A2U5-12 is high.

Display Controller 2-54.

The Display Controller is a four-bit, single-chip microcomputer with high-voltage outputs that are capable of driving a vacuum-fluorescent display directly. The controller receives commands over a three-wire communication channel from the Microprocessor on the Main Assembly. Each command is transferred serially to the Display Controller on the display transmit (DISTX) signal, with bits being clocked into the Display Controller on the rising edges of the display clock signal (DSCLK). Responses from the Display Controller are sent to the Microprocessor on the display receive signal (DISRX) and are clocked out of the Display Controller on the falling edge of DSCLK.

Series resistor A2R11 isolates DSCLK from A2U1-40, preventing this output from trying to drive A1U4-16 directly. Figure 2-4 shows the waveforms during a single command byte transfer. Note that a high DISRX signal is used to hold off further transfers until the Display Controller has processed the previously received byte of the command.
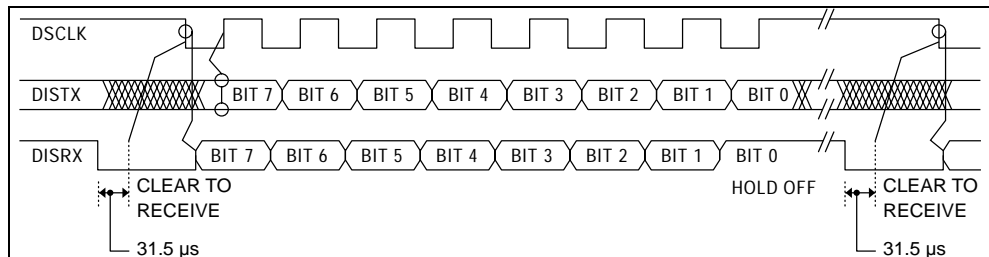
Figure 2-4. Command Byte Transfer Waveforms

Once reset, the Display Controller performs a series of self-tests, initializing display memory and holding the DISRX signal high. After DISRX goes low, the Display Controller is ready for communication; on the first command byte from the Microprocessor, the Display Controller responds with a self-test results response. If all self-tests pass, a response of 00000001 (binary) is returned. If any self-test fails, a response of 01010101 (binary) is returned. The Display Controller initializes its display memory to one of four display patterns depending on the states of the DTEST* (A2U1-41) and LTE* (A2U1-13) inputs. The DTEST* input is pulled up by A2Z1, but may be pulled down by jumpering A2TP4 to A2TP3 (GND). The LTE* input is pulled down by A2R12, but may be pulled up by jumpering A2TP5 to A2TP6 (Vcc). The default conditions of DTEST* and LTE* cause the Display Controller to turn all segments on bright at power-up.

Table 2-6 defines the logic and the selection process for the four display initialization modes.

Table 2-6. Display Initialization Modes

A2TP4 DTEST*	A2TP5 LTE*	Power-Up Display Initialization
1	1	All Segments OFF
1	0	All Segments ON (default)
0	1	Display Test Pattern #1
0	0	Display Test Pattern #2

The two display test patterns are a mixture of on and off segments forming a recognizable pattern that allows for simple testing of display operation. Test patterns #1 and #2 are shown in Chapter 5 of this manual.

The Display Controller provides 11 grid control outputs and 15 anode control outputs (only 14 anode control outputs are used). Each of these 26 high-voltage outputs provides an active driver to the +5V dc supply and a passive 220-k\Q (nominal) pull-down to the -30V dc supply. These pull-down resistances are internal to the Display Controller.

The Display Controller provides multiplexed drive to the vacuum-fluorescent display by strobing each grid while the segment data for that display area is present on the anode outputs. Each grid is strobed for approximately 1.14 milliseconds every 13.8 milliseconds, resulting in each grid on the display being strobed about 72 times per second. The grid strobing sequence is from GRID(10) to GRID(0), that results in left-to-right strobing of grid areas on the display. Figure 2-5 shows grid control signal timing.
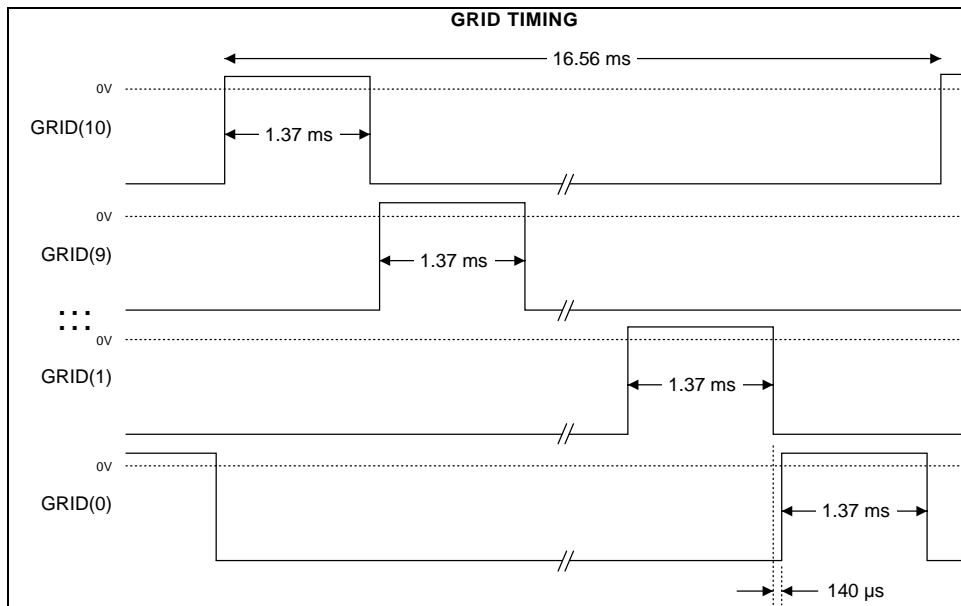
Figure 2-5. Grid Control Signal Timing

The single grid strobing process involves turning off the previously enabled grid, outputting the anode data for the next grid, and then enabling the next grid. This procedure ensures that there is some time between grid strobes so that no shadowing occurs on the display. A grid is enabled only if one or more anodes are also enabled. Thus, if all anodes under a grid are to be off, the grid is not turned on. Figure 2-6 describes the timing relationship between an individual grid control signal and the anode control signals.
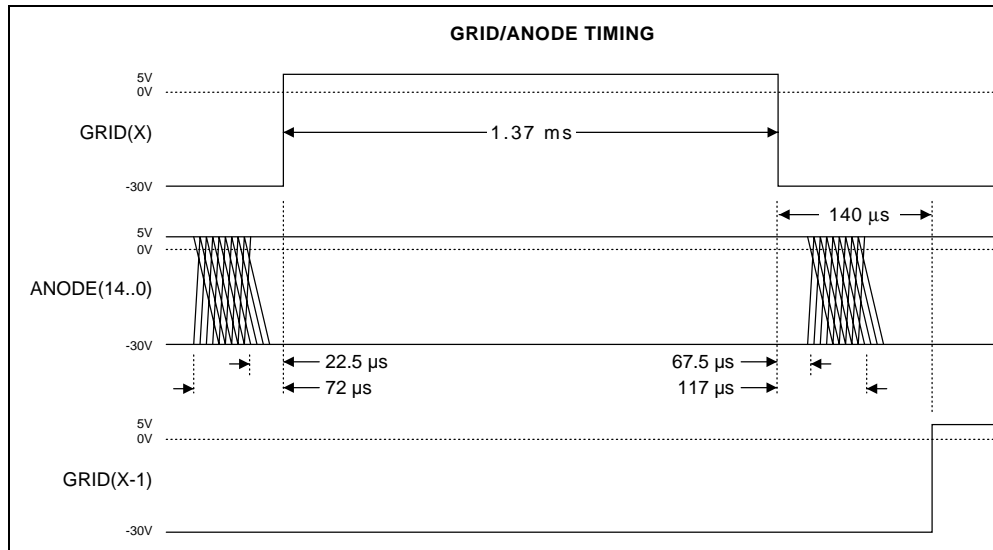
Figure 2-6. Grid-Anode Timing Relationships

A3 A/D Converter PCA Circuit Description 2-55.

The following paragraphs describe the operation of the circuits on the A3 A/D Converter PCA. See Figure 2-7 for a block diagram and Chapter 7 for a schematic diagram. The 2640A and 2645A A/D Converter PCAs are identical, except for signal switching, and both use the following:

- Motorola 68302 microprocessor.
- Flash ROM
- RAM
- Serial Interface to the Main Board.
- A Fluke manufactured Stallion IC (U30) for range selection and frequency measurements.
- Muli-Slope A/D converter comprised of discrete components and an FPGA (Field Programmable Gate Array) (U18).

The difference between the A/D boards is that the 2640A uses reed relays, while the 2645A uses optically coupled solid state relays.
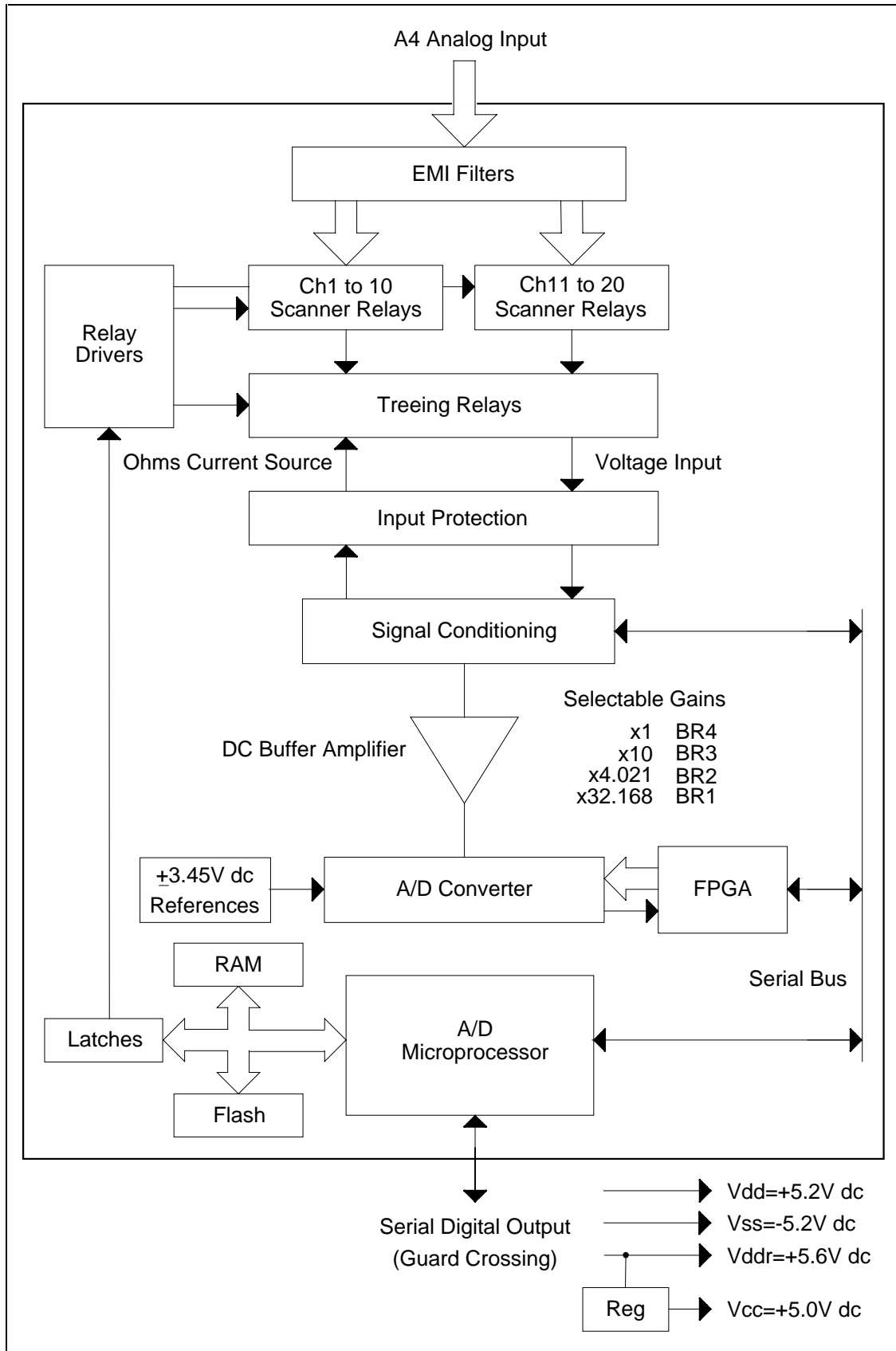
Figure 2-7. A3 A/D Converter Block Diagram

Stallion Chip 2-56.

The Stallion IC (A3U30) is a Fluke-designed 100-pin CMOS device that performs the following functions under control of the A/D Microprocessor (A3U5):

- Input signal routing
- Input signal conditioning
- A/D buffer amplifier range switching
- Frequency measurements
- Active filtering of ac voltage measurements

The Stallion IC design is based on the Mercury A/D Chip used in Fluke 45 and Hydra, except it does not contain the A/D conversion function, that is now done using discrete components using a multi-slope technique.

Two separate signal paths are used. One path is for the functions dcv/ohms/temperature, and other path is used for ac voltages/frequency.

Input Protection 2-57.

Input protection is provided by series hold-off resistors A3R111, A3R110, A3R138 and A3R132, and related transistor switches used as clamp devices. Excessive voltages develop a current through the resistors that is sensed by the corresponding transistor, which turns on to provide a signal path to ground. For example, an excessive input on the LO SENSE line is sensed by A3R132 (100 kΩ, 3w) and clamped to ground by A3Q17.

Input Signal Conditioning 2-58.

Each analog input is conditioned and/or scaled to a dc voltage (3 volts or less) for input to the buffer amplifier (A3U27, A3U28 and related devices), which scales the voltage to approximately 3V Full Scale for measurement by the multi-slope A/D converter circuitry. The scalings of the buffer amplifier are x1, x4.021, x10, and x32.168. Accuracy is derived by software calibration constants.

AC volts signal conditioning consists of conversion of an ac level to a scaled and corresponding dc level. The ac level is scaled by resistor network A3Z6 and switches A3Q10 to A3Q16, and is processed by A3U29. Input protection is via A3Z6 and A3CR5.

DC voltages below 3V can be applied directly to the Stallion IC, while higher dc input voltages are scaled by A3Z7. Ohms inputs are converted to a dc voltage, and ac inputs are first scaled then converted to a dc voltage. Noise rejection is provided by the A/D for dc inputs and an active filter for ac inputs.

Function Relays 2-59.

For both the 2640A and 2645A, the function relays A3K25, A3K26, and A3K27 route the input signal to the correct measurement path. They are latching relays and switched when a 6 ms pulse is applied to the set or reset coils. The A/D Microprocessor (A3U5) controls the relay drive pulses by putting a data word on the bus and latching it into F/F A3U10. The drive pulses are sent by A3U10 to the appropriate coils.

Channel Selection Circuitry   2-60.

Channel selection is done using reed relays on the 2640A and by optically coupled solid-state relay on the 2645A. Channel selection is done by a set of 24 relays organized in a tree structure. Relays A3K1 through K20 select the specific channel 1-20. The selection of relays A3K21 through K24 (Treeing Relays) depends on which bank of 10 channels is being used (both banks are selected for four-wire ohms) and the channel function and range being used.

DC Volts and Thermocouples Measurement Circuitry   2-61.

For 3 volts and lower ranges, the input to Stallion (A3U30) are as follows for signal HI and signal LO inputs:

- HI is a direct input via the HI SENSE line A3R11, A3K26, A3R130, and pin 50 (HI1) input of A3U30.

- LO is an input to LO SENSE via A3R132 to pin 80 (LO2) of A3U30.

For the 30 and 300 volt range, the input to Stallion (A3U30) are as follows for the HI and LO signal inputs:

- The HI signal is scaled by A3Z7. The input is applied to pin 1 of A3Z7 and a 101:1 divider is formed by the 10 MΩ 100 kΩ resistors when switches S3 and S13 are closed. The attenuated HI input is then sent via S24, S64, and S44 to the Buffer Amplifier and then to A/D Converter.

- The LO signal is sensed through A3L52, A3R146, A3K27, A3R119, and S33 and S37.

The outputs from Stallion (A3U30) are as follows:

- HI (pin 20) is to Buffer Amplifier circuitry (A3U27 and A3U28).

- LO (pin 100) is to Buffer Amplifier circuitry (A3U27 and A3U28).

The ranges for the buffer amplifier are shown in Table 2-7 and measurement matrix in Table 2-8. Figure 2-8 shows a simplified signal path for the 300V dc range.

Table 2-7. Range of Buffer Amplifier

Range	Buffer Range Control Signals (Gain)
90mV Range	BR1 (x32.168 gain)
300mV Range	BR3 (x10 gain)
750mV Range	BR2 (x4.021 gain)
3V Range	BR4 (x1 gain)
30V Range	BR3 (x10 gain)
300V Range	BR4 (x1 gain)

Table 2-8. Measurement Matrix for DC Volts

DC Volt Range	Input to Stallion	Full-Scale Output of Stallion	Gain of DC Buffer Amplifier	Full-Scale DC Volts Input to Multislope A/D	Buffer Range Control Signal
90 mV	Direct	90 mV	32.168	3V	BR1
300 mV	Direct	300 mV	10.00	3V	BR3
750 mV	Direct	750 mV	4.021	3V	BR2
3V	Direct	3V	1.000	3V	BR4
30V	Divide by 101	300 mV	10.000	3V	BR3
150/300V	Divide by 101	3V	1.000	3V	BR4
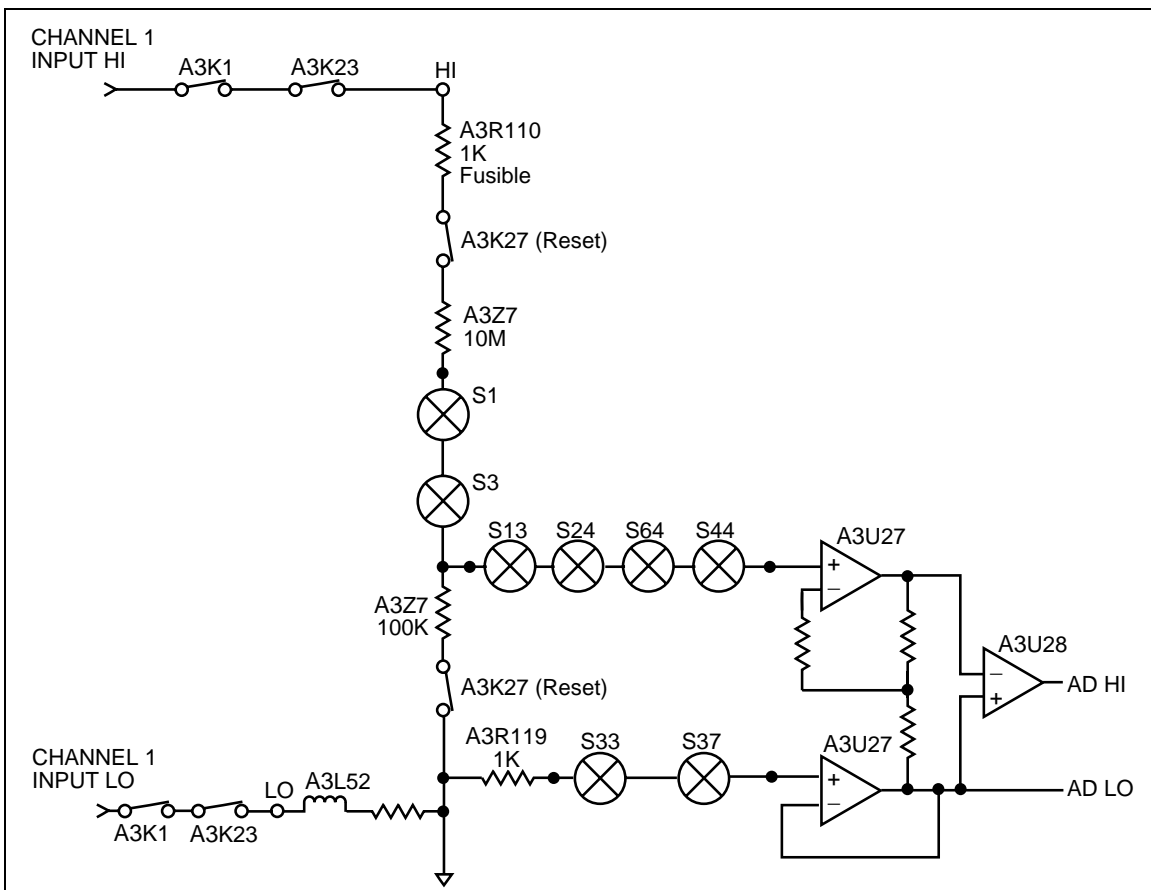
Figure 2-8. DC Volts 300V Range Simplified Schematic

Ohms and RTD Measurement Circuitry 2-62.

Resistance measurements are made by sourcing dc current through the unknown resistor and measuring the resultant dc voltage (see Table 2-9). The current source consists of operational amplifier A1U31, FET A3Q19, and switches internal to the Stallion. four-wire measurements use separate source and sense signal paths to the point of the unknown resistance. This technique eliminates lead wire resistance errors. Figure 2-9 shows a simplified signal path for an RTD four-wire measurement.

Table 2-9. Measurement Matrix for Ohms

Ohms Range	Current Used	Full-Scale Input to Stallion (dc volts)	Full-Scale Output of Stallion (dc volts)	Gain of DC Buffer Amplifier	Full-Scale DC Volts input to Multislope A/D	Buffer Range Control Signal
300 Ohm	1 mA	300 mV	300 mV	10	3V	BR3
3k Ohm	100 μA	300 mV	300 mV	10	3V	BR3
30k Ohm	10 μA	300 mV	300 mV	10	3V	BR3
300k Ohm	10 μA	3V	3V	1	3V	BR3
3M Ohm	1 μA	3V	3V	1	3V	BR3
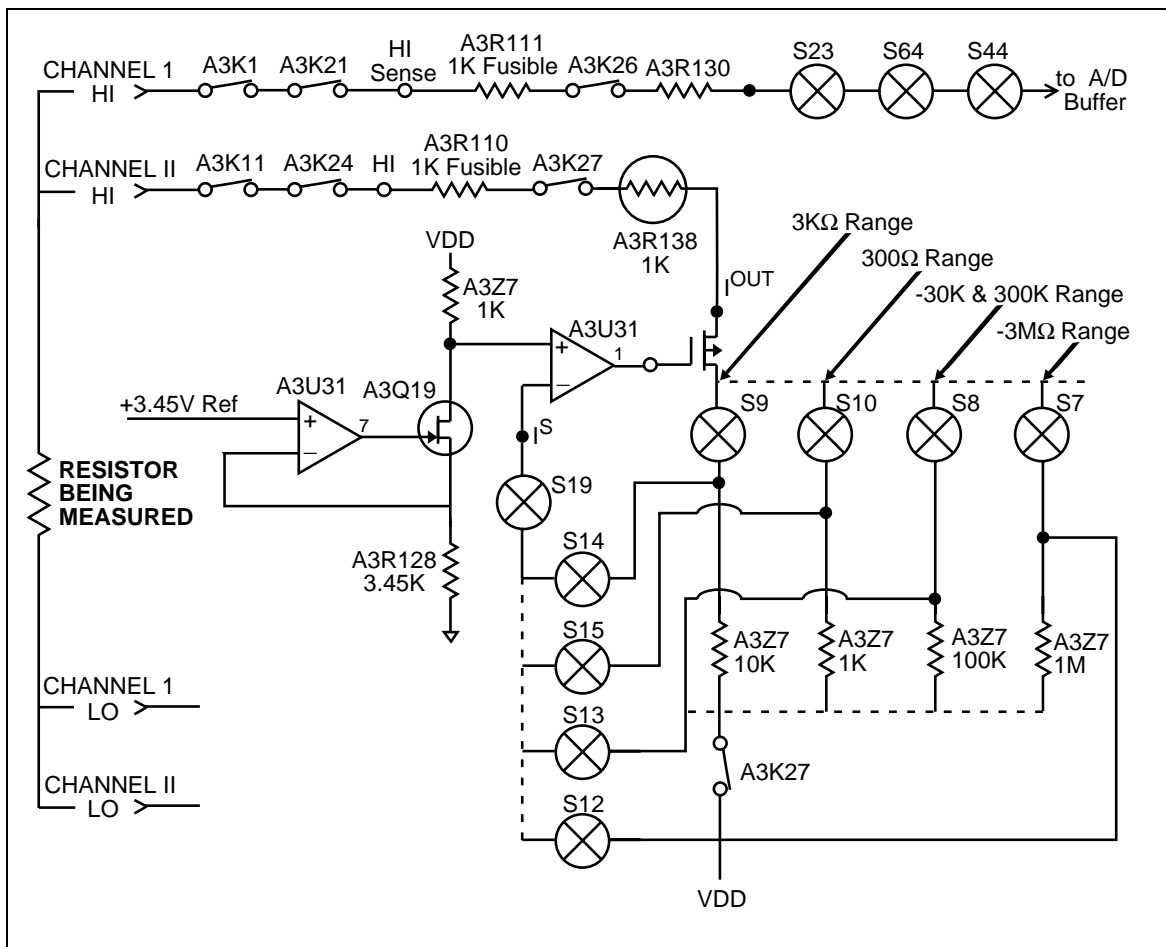
Figure 2-9. RTD Measurement Simplified Schematic

AC Volts Measurement Circuitry   *2-63.*

AC-coupled voltage inputs are scaled by an ac buffer (A3U29), converted to dc by a true rms ac-to-dc converter (A3U26), filtered by an active ac volt filter, then sent to the Stallion IC, the Buffer Amplifier, and the A/D Conversion Circuitry (see Table 2-10). The HI input is switched to the ac buffer through dc blocking capacitor A3C80. The LO input is sensed through A3L52, A3R146, A3K27, A3R119, and S33 and S37. The gain or attenuation of the ac buffer is selected by A3U30's ACR1-ACR4 outputs. 0V turns JFETS A3Q10 to A3Q16 ON, while -5V (VAC) turns the JFETS OFF. Only one line at a time is set at 0V.

The ac voltage input signal is routed through and scaled by the buffer to obtain a full scale buffer output of 0.75V RMS at A3U29-6. A3R120 and A3C76 provides high frequency compensation on the 300 mV range. The output of the buffer is ac coupled to the input of the ac-to-dc rms converter. The output of the rms converter (0.75VDC) is divided by 2.5 by A3Z2 and sent to the acv filter. The filtered output is sent to pin 31 (ACFO) of the Stallion chip via S41. Full scale input to Stallion is 300 mV dc. Figure 2-10 shows a simplified signal path for the 3V ac range.

Table 2-10. Measurement Matrix for AC Volts

AC Volt Range	Gain of AC Volts Buffer Amplifier	Full-Scale Output of AC Volts Buffer Amplifier	Full-Scale Output of RMS Converter	Full-Scale Input to Stallion (dc volts)	Full-Scale Output of Stallion (dc volts)	Gain of DC Buffer Amplifier	Full-Scale DC Volts Input to Multislope A/D	Buffer Range Control Signal
300 mV	2.5	0.75V rms	0.75V	300 mV	300 mV	10	3V	BR3
3V	0.25	0.75V rms	0.75V	300 mV	300 mV	10	3V	BR3
30V	0.025	0.75V rms	0.75V	300 mV	300 mV	10	3V	BR3
150/300V	0.0025	0.75V rms	0.75V	300 mV	300 mV	10	3V	BR3

Frequency Measurements   *2-64.*

The ac input follows the same path as ac volt measurements except the output of the buffer (A3U29) is sent to the Stallion Chip pin 35 (C+). Internal to the Stallion Chip switch S38 sends the C+ input to a frequency comparator and counter.

Active Filter (ACV Filter)   *2-65.*

The active filter is used only for ac volt measurements to filter out the ac ripple and noise present on the output of the rms converter. The filter uses an op-amp internal to the Stallion Chip, resistors A3R102, A3R103, and A3R104, capacitors A3C57, A3C58, and A3C59. A3Q6 turns on to discharge the capacitors between measurements.

Voltage Reference Circuit 2-66.

The voltage reference circuit creates a well-regulated +3.45/-3.45V dc source for use by the A/D converter, and as a source for ohms and current measurements. The circuit is formed around two dual op-amps A3U12 and A3U20. A3U12 controls balance between +3.45V dc and -3.45V dc by adjusting the +3.45V dc through A3Q2 as the divider between these voltages in zener diode A3Z1 reads above or below zero. The other half of A3U12 adjusts the absolute voltage difference between the two outputs by regulating the -3.45V dc so as to produce zero collector-base volts on A3Q5. If the collector voltage rises, then A3Q5 needs more current, which is produced by lowering the -3.45V dc through A3Q3. Resistor A3R101 and capacitor A3C48 stabilize the loop.
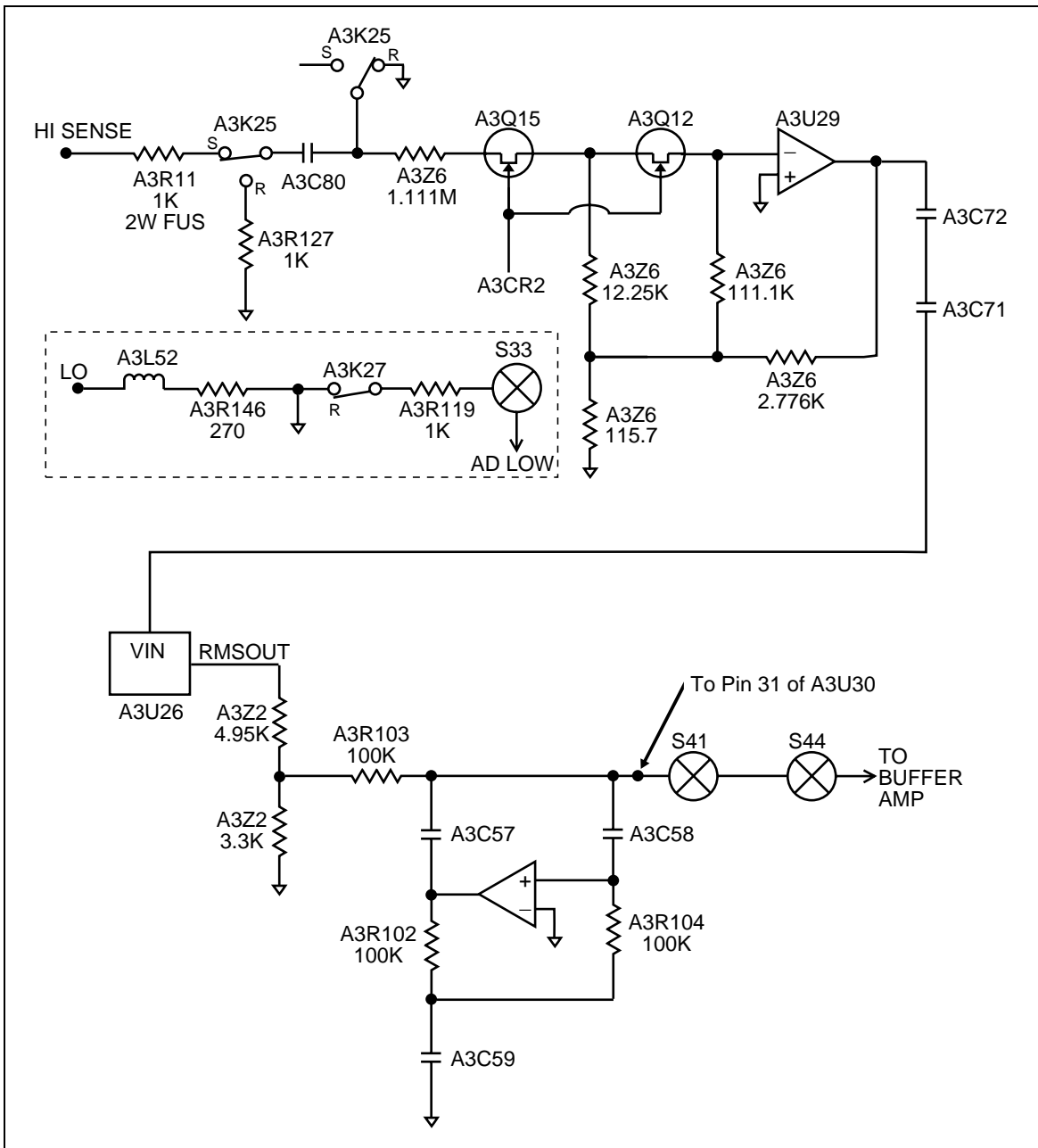
Figure 2-10. AC Volts 3V Range Simplified Schematic

A3U20 is also a dual op-amp. One half provides the regulated 3 mA required to flow into the cathode of the zener diode within A3Q5 by forming a current source with A3Q4. If not supplied from a current source, the current would change with the emitter base voltage of A3Q5. The current source is best visualized as a differential amp sensing both sides of A3R83 and nulling this against the reference voltage. The other side of A3Q20 establishes a reference voltage of 0.493V dc above the collector of A3Q5 so that the selected resistors A3R64 and A3R65 provide the required current. When A3Q5 is tested, it has a collector current specified for zero tc. This current is converted into resistor values, but requires a known voltage differential to operate properly.

Analog/Digital Converter Circuit 2-67.

The A/D converter consists of a gate array for control, switches for directing currents, and a reference circuit and reference resistors for providing the currents. The various currents are integrated across capacitor A3C44, and the zero crossing is detected by comparator A3U11 and a logic signal returned to the FPGA (Field Programmable Gate Array). The FPGA contains counters that count the amount of time that the reference currents are applied to the integrator. The input voltage is proportional to the difference in the time required of positive and negative reference currents to null the applied input. The a/d produces about $\pm35,000$ counts for ±3V dc. It has linear behavior up to 3.4V dc. This gives a resolution of about 88 µV in the fast measurement mode.

The measurement cycle consists of four basic periods as shown in Table 2-11. This gives a total measurement time of 833.533 µs. A brief explanation of each state follows. For additional information, refer to "A1 Main to A3 A/D Converter Communications" later in this chapter.

Table 2-11. Analog/Digital Converter Measurement Cycle

State	Counts	Time
Autozero	125	200.0 µs
Integrate	307	491.4 µs
Deintegrate1	64	102.4 µs
Deintegrate2	24	38.4 µs
Overhead	n/a	1.333 µs
	Total	833.533 µs

Autozero 2-68.

Autozero is the state the a/d idles in when not in use. In this state, the signals PREF, NREF, DREF, and INT are all low. The purpose of the state is to remove any remaining charge on A3C44, to charge A3C60 to a voltage so that pin 6 of A3U19 is at zero, and to provide time to return data to the microprocessor. In this state, the input is not connected, A3R94 and A3R95 ground the input, A3U19 produces an error signal, which is amplified by the other halve of A3U19, providing feedback to produce a nulling voltage at A3C60. A3C60 stays charged to this voltage until another cycle is initiated.

Integrate 2-69.

The integrate state is when the input voltage is actually connected to the integrator. PREF and NREF are each switched off and on 10 to 20 times during this state and DREF is still off, INT is on, AZ is off, and the CMP signal is switching off and on. The primary signal is pin 7 of A3U19, which looks approximately like a triangular wave with 51.2 μs slope when the input voltage is zero. The triangular wave is very irregular at other voltages, moving on an upward or downward slope and reversing direction within the integrate time period. The actual behavior is determined by the algorithm in the FPGA.

This tests the CMP signal at defined times spaced 51.2 μs apart. If the CMP signal is turned off, then NREF is turned on. PREF and NREF are never on at the same time during integrate. First, the existing reference is turned off and a 1-count (1.6 us) period is entered where only the input signal is integrated. Next, a reference of a polarity such as to keep the total number of NREF pulses so far equal to the number of PREF pulses is turned on for 1-count (1.6 μs).

Finally, the reference with a polarity determined by the comparator (CMP) test at the very first of the interval is turned on for the remaining 30 counts (48 μs) of the interval. The beginning first interval is only 16 counts instead of 32 counts. The last state is 35 counts to allow for completing the PREF and NREF pulse count equalization. There are 8 normal intervals of 32 counts. The purpose is to bound the waveform to prevent amplifier saturation, prevent charge injection from being a variable with waveform changes and prevent logic signals themselves from injecting unwanted signals into the summing node.

The integrate state is the primary measuring interval, and during this time the FPGA accumulates counts of how long PREF and NREF have been applied. The count is completed during deintegrate. Typical integrator output waveforms for different inputs are shown in Figure 2-11, Figure 2-12, and Figure 2-13.
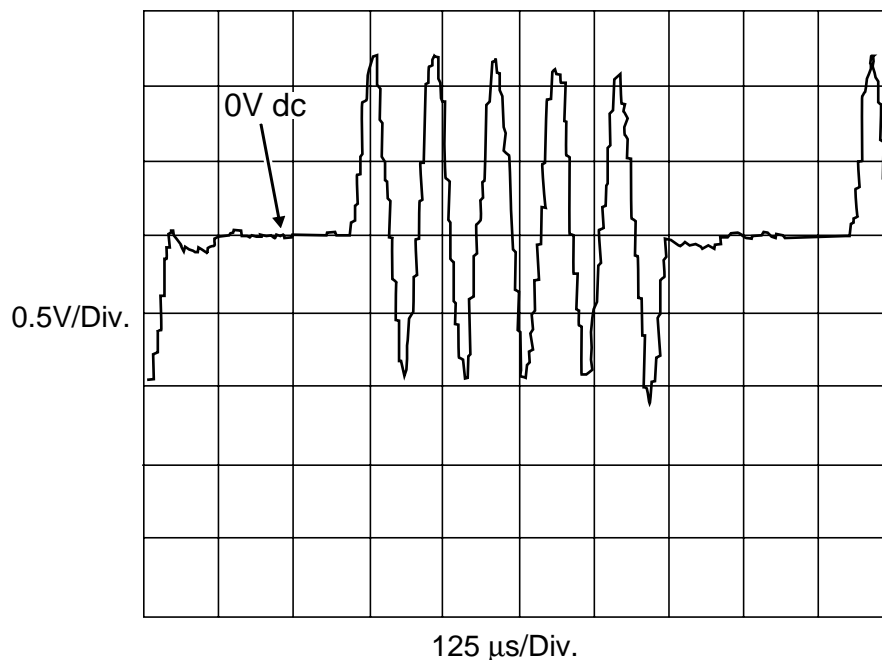
Figure 2-11. Integrator Output Waveform for Input Near 0

0.5V/Div.

0V dc

125 µs/Div.
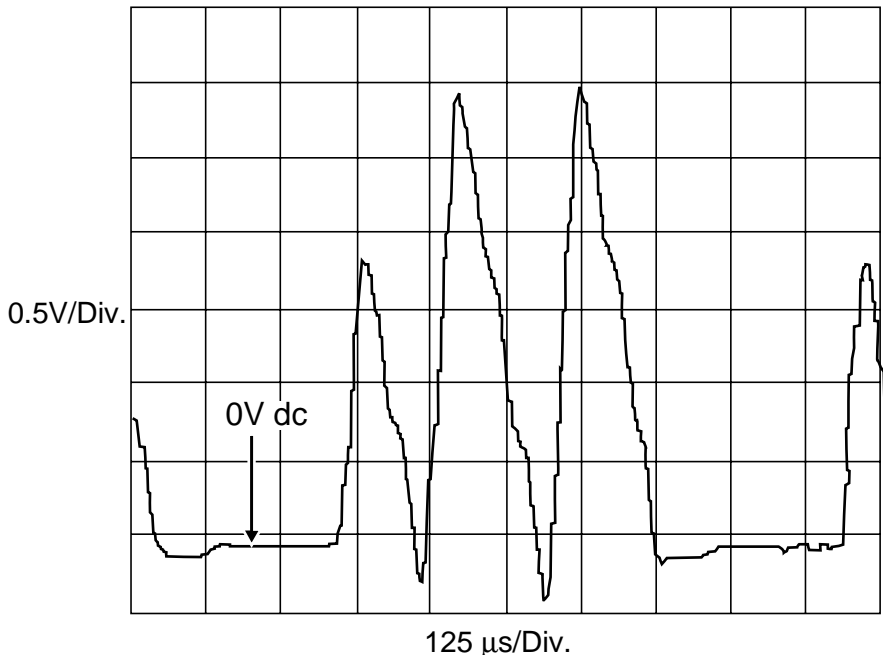
Figure 2-12. Integrator Output Waveform for Input Near + Full Scale

0v dc

0.5V/Div.

125 µs/Div.
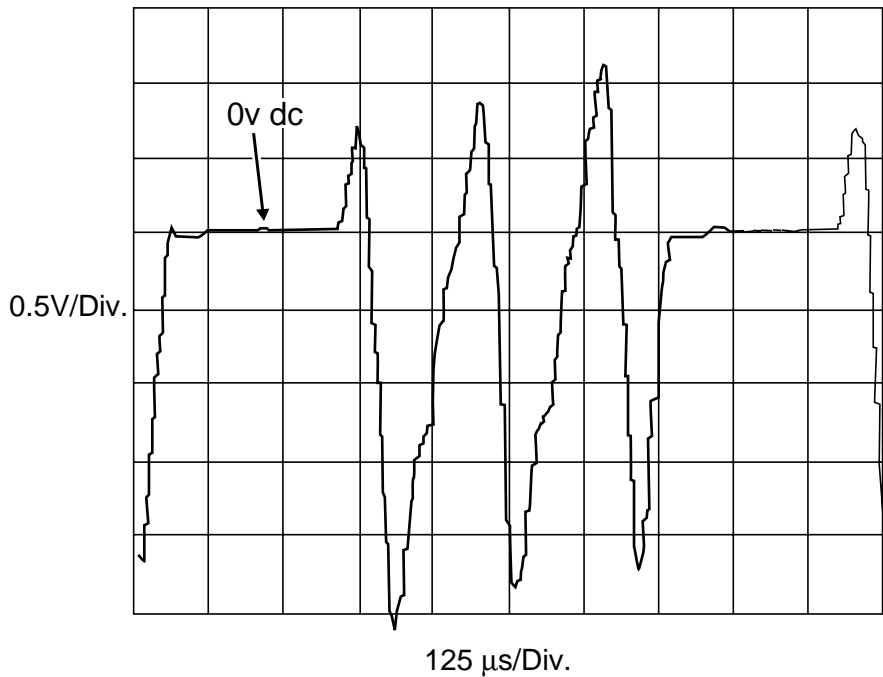
Figure 2-13. Integrator Output Waveform for Input Near - Full Scale

Deintegrate1 2-70.

Deintegrate1 is when the remaining charge of the capacitor is removed and the major count is completed. The input is turned off and no longer affects the reading. INT is off, PREF, and NREF continue to switch a few more times, and the signal is brought very close to zero. The previous integrate state ended in a hold (both references off) and this state begins with the PREF signal on. The comparator is examined after each count and as soon as CMP goes low, a hold state begins with both references off. Depending of the level of the signal at the beginning of deintegrate, this can result in PREF being on from 1 to 60 counts. At the end of the hold count NREF, is turned on until CMP drops low.

This can also be anywhere from 1 to 60 counts, but at this point, the output should be within 1 count of reaching zero volts. Next, another hold state is entered into for 1 count, followed by PREF until CMP goes high. This sets up the final DREF to always approach zero from the same direction. A hold state with both references off begins until a total of 64 counts have occurred since deintegrate began. If the magnitude of the signal as it ends integrate is large, this final hold is short. If the signal at the end of integrate is small, the hold is as long as 60 counts.

Deintegrate2 2-71.

Deintegrate begins with the turning on of DREF. This reference applies 1/16th of the current of NREF so the approach to zero is slower and more accurate. Correspondingly, the internal FPGA counter counts this time at 1/16th the value of NREF time. The count ends as the final state of the comparator (CMP) goes low, indicating that the charge has been removed from the capacitor. This also ends the count accumulation in the FPGA counters. The deintegrate2 state always takes 24 counts even though the data has already been accumulated. This guarantees the entire measurement cycle is of fixed length so that line cycle rejection is maintained. The data is sent to the microprocessor during the following autozero state. It is sent with 20 bits each for the PREF and NREF times. In the microprocessor, the voltage is computed based on the difference between p-counts and n-counts.

Overhead 2-72.

Overhead is a fixed amount of time required for signal settling and processing.

Inguard Digital Kernel Circuitry *2-73.*

The inguard digital kernel circuitry consists of devices A3U2, A3U5, A3U6, A3U7, and A3U10. The memory consists of Flash ROM (A3U6) that contains the internal A/D program and RAM (A3U2) . The 68302 Microprocessor is A3U5, which communicates with the main processor A1U1, and the Stallion device via the serial lines SB CLK, SB XMIT, and SB RECV. Kernel communications are via the A/D State Machine (FPGA IC, A3U18) using serial lines SB CLK, SB XMIT, and SB RECV (sends measurement commands and reads measurement data).

To start a measurement, A/D TRIGGER* is asserted by the A/D microprocessor A3U5-113. Communication is with Stallion if the processor sets STAL SELECT* low (A3U5 pin 115). The DISCHARGE signal at A3U5-59 is asserted to discharge the filter capacitors, and a data word sent out on the D0-D7 bus controls channel, treeing, and function relays.

Communication with the main processor is done using the IGDR line to receive and the IGDS line to send serial data. On the A/D side, these signals are called RECV DATA and XMIT DATA (pins A3U5-53 and A3U5-54 respectively). The RESET* signal is asserted on power-up for reset and during operation when a break signal is received from A1U4.

The A/D microprocessor guard crossing is bidirectional. When the user finishes defining the channels and intervals and starts scanning, the A1 Main PCA downloads all the channel information to the A3 A/D Converter PCA. The A1 Main PCA uses the guard crossing to advise the A3 A/D Converter PCA when to start scans, and then return the readings to the A1 Main PCA. The arrangement keeps the guard-crossing traffic to a minimum when scanning is taking place allowing peak performance during short scan intervals.

Open Thermocouple Detect Circuitry 2-74.

The open thermocouple detect circuitry uses devices A3U23 and A3U32. Before every thermocouple measurement the open T/C check is done by sending a small ac-coupled signal to the thermocouple input. The A/D Microcomputer (A3U5) initiates the open T/C test by asserting OTC_EN and turning ON A3Q20. A 19.2 kHz square wave is sent out the OTCCLK line through A3Q20 and A3C82 to the thermocouple.

The resulting waveform is detected by A3U32 pin 3 and a proportional level is stored on A3C79. If the level is above a threshold level of about 2.7V (Vth) the resistance at the input is too large (greater than 4 kohm to 10 kohm) and open T/C check is asserted by A3U32 pin 7. After a short delay the A/D Microcontroller reads the signal and determines if the thermocouple should be reported to the main processor as open.

A4 Analog Input PCA Circuit Description 2-75.

The Input Connector assembly, which plugs into the A/D Converter PCA from the rear of the instrument, provides 20 pairs of channel terminals for connecting measurement sensors. This assembly also provides the reference junction temperature sensor circuitry used when making thermocouple measurements.

Circuit connections between the Input Connector and A/D Converter PCAs are made via connectors A4P1 and A4P2. Input channel and earth ground connections are made via A4P1, while temperature sensor connections are made through A4P2.

Input connections to channels 1 through 20 are made through terminal blocks TB1 and TB2. Channel 1 and 11 HI and LO terminals incorporate larger creepage and clearance distances and each have a metal oxide varistor (MOV) to earth ground to clamp voltage transients. MOVs A4RV1 through A4RV4 limit transient impulses to the more reasonable level of approximately 1800V peak instead of the 2500V peak that can be expected on 240V ac, IEC 664 Installation Category II, ac mains. In this way, higher voltage ratings can be applied to channels 1 and 11 than can be applied to the other rear channels.

Strain relief for the user's sensor wiring is provided both by the Connector PCA housing and the two round pin headers. Each pin of the strain relief headers is electrically isolated from all other pins and circuitry.

Temperature sensor transistor A4Q1 outputs a voltage inversely proportional to the temperature of the input channel terminals. This voltage is 0.6V dc at 25 °C, increasing 2 mV with each degree decrease in temperature, or decreasing 2 mV with each degree increase in temperature. For high accuracy, A4Q1 is physically centered within and thermally linked to the 20 input terminals. Local voltage reference A4VR1 and resistors A4R1 through A4R3 set the calibrated operating current of the temperature sensor. Capacitor A4C1 shunts noise and EMI to ground.

A1 Main to A3 A/D Converter Communications 2-76.

The exclusive means of communication between the inguard and outguard is a bidirectional, asynchronous, optically-isolated serial link. This link operates at a rate of 120,000 baud. The individual bytes are transmitted with eight data bits, one stop bit, and one even parity bit.

The outguard can send either a reset or a command to the inguard. A reset consists of a number of consecutive break characters, and causes a complete reset of the inguard hardware and software. The inguard returns no response to a reset. A command is a six-byte packet (hereafter referred to as a 'command packet') that causes the inguard to perform some action and return one or more six-byte response packets. Transactions between the outguard and inguard are always initiated by the outguard. The inguard never sends data across the guard without being asked to do so.

There are two modes of communication between the inguard and outguard: non-pipelined and pipelined. In the non-pipelined mode, commands and responses are synchronous, i.e., the outguard waits for the response to a command before sending another command. In the pipelined mode, the outguard may send a second command before the first command has completed. The outguard must wait for the response from the first command before sending a third command.

Special Codes 2-77.

An ACK response packet is arbitrarily defined as the sequence of bytes (42,0,0,0,0,x) where x is the checksum byte. A NAK response packet is defined as (255,255,255,255,255,x) where x is the checksum byte. A break is an all-zeros character without stop bits.

Resets 2-78.

A reset consists of 5 ms of consecutive break characters sent to the inguard. A hardware circuit on the inguard detects this condition and causes a complete reset of the inguard subsystem. The inguard sends no response to a reset. After sending a reset, the outguard must wait a predefined amount of time before attempting further communication with the inguard. This is the same amount of time it waits after a power-up, approximately 3.5 seconds.

Commands 2-79.

A command consists of a six-byte packet sent from the outguard to the inguard. The most-significant four bits of the first bytes define the following command types:

- Perform Scan.
- Perform a Self-Test.
- Return A/D Main Firmware Version.
- Return A/D Boot Firmware Version.
- Set Global Configuration.
- Set Channel Configuration.
- Do Houskeeping.

The sixth byte is a checksum. The meanings of the remainder of the bits in the command packet vary depending on the command type. The response to all commands is one or more six-byte response packets. The sixth byte in a packet is always the checksum byte; the meaning of the remainder of the bits depends on the command. The only restriction is that a response packet should always be distinguishable from a NAK, i.e., it should never have all bits 1.

Perform Scan 2-80.

The Perform Command Packet tells the A/D Converter Assembly to do the following:

- Measure Channel Number if set.
- Return BR1 Zero Offset if set.
- Return BR2 Zero Offset if set.
- Return BR3 Zero Offset if set.
- Return BR4 Zero Offset if set.
- Return Reference Junction Reading if set.
- Return Reference Balance (both references off) reading if set.
- Return Reference Balance (both references on) reading if set.
- Return Checksum.

Action Performed The Perform Scan command causes the inguard to measure each channel indicated. These channels must have been previously defined using the Set Channel Configuration command. One response packet is sent to the outguard for each channel measured. If any thermocouple channels are requested in this scan, the first response packet is the reference junction reading. If a requested channel has not been defined, its value is returned as NaN.

There are several bits in the command that exist for debugging purposes only. These bits indicate that the current stored value for the corresponding housekeeping reading should be returned. The actual value returned for these bits depend on the current measurement rate, since a different value is stored for each measurement rate. Note that these bits do not cause any physical measurement to take place, they simply cause the latest values to be returned.

Response Packets Returned The inguard returns one response packet for the reference junction reading if any of the measured channels is a thermocouple channel, followed by a response packet for each channel measured, returned in ascending channel order, followed by a response packet for each housekeeping reading specified by the scan command.

Response Packet Format Each response packet for a Perform Scan command consists of a floating-point number representing the measurement value, the range used to take the measurement, the channel number, and the checksum. The floating-point format used is ANSI/IEEE Std 754-1975 single-precision. Positive and negative overload conditions cause a value of PLUS_OVLD_VAL (0x7f800000) and MINUS_OVLD_VAL (0xff800000), respectively, to be returned. A frequency channel whose input frequency is too low to measure returns 0 Hz. A channel with an open-thermocouple condition causes the value of OTC_VAL (0x7fc00000) to be returned. The inguard waits until it has completed all measurement activity associated with a particular scan before beginning the transmission of the response packets for that scan to the outguard.

The floating-point value returned has a nominal range of -3.0 to +3.0. The outguard must scale this according to the channel function and range to produce the correct volts or ohms. For most ranges, a full-range value is returned as +3.0. For example, on the 300 ohm range, +3.0 represents 300 ohms. For the 90 mV and 750 mV ranges, however, +3.0 represents 93.26 mV and 0.746083V, respectively. Also, frequency readings always return the actual frequency measured and do not require range-scaling by the outguard.

Perform Self-Test   2-81.

The Command Packet tells the A/D to perform all self tests. Response Packets Returned always returns a single response packet. The Response Packet Format provides the following:

- A/D self-test result, pass or fail.
- Zero Offset self-test result, pass or fail.
- Reference Balance self-test result, pass or fail.
- Ohms Overload self-test result, pass or fail.
- Open Thermocouple self-test result, pass or fail.
- Checksum

Return Main Firmware Version   2-82.

This Command Packet requests version number of the inguard main firmware and always returns a single response packet.

Response Packet Format The response consists of five ASCII characters (plus the checksum byte), in the form txxyy, where t is "F" for FFE (2645A) software and "P" for the PFE (2640A); xx are the two digits of the major version number, and yy are the two digits of the minor version number (there is an implicit decimal point between the two). Note that constraining the bytes to be ASCII characters causes the most significant bit of each character to be a 0, making the response packet always distinguishable from a NAK.

Return Boot Firmware Version 2-83.

This Command Packet Format requests version number of the inguard boot firmware and always returns a single response packet.

Response Packet Format The response consists of five ASCII characters (plus the checksum byte), in the form Bxxyy, where B indicates boot software, xx are the two digits of the major version number, and yy are the two digits of the minor version number (there is an implicit decimal point between the two). Note that constraining the bytes to be ASCII characters causes the most significant bit of each character to be a 0, making the response packet always distinguishable from a NAK.

Set Global Configuration 2-84.

The Command Packet tells the A/D the following:

* Measurement Rate, fast, medium, or slow

* Power Line Frequency, 50 Hz or 60 Hz

* Scheduled Housekeeping Measurements, Enable or Disable

Action Performed Sets global configuration parameters (instrument measurement rate, AC power line frequency, and enable or disable housekeeping measurements). The default state for the inguard is to measure on the fast rate, assuming 60 Hz, and with scheduled housekeeping measurements enabled. The meaning of "scheduled housekeeping measurements" depends on the current measurement rate.

Response Packets Returned Always returns a single response packet.

Response Packet Format Returns either an ACK packet or a NAK if the command arguments are not recognized.

Set Channel Configuration 2-85.

The Command Packet tells the A/D the following:

Measurement Function VDC, VAC, 2-Wire Ohms, 4-Wire Ohms, Frequency, Thermocouple, OFF.

Range 90 mV or 300 ohm, 300 mV or 3 kΩ, 3V or 30 kohm, 30V or 300 kΩ, 50V (2645A), 150/300V (2640A), or 3 MΩ, 750 mV (reference junction calibration).

The range field is ignored for frequency and thermocouple channels.

Channel Number 0 to 19 (though user sees channel 1 to 20)

Enable Autorange if bit set (ignored for frequency and thermocouple).

Enable Open Thermocouple Detect if bit set.

Checksum Action Performed is configuration of a single channel to the parameters given. The Response Packets Returned always returns a single response packet. The Response Packet Format returns an ACK response packet if the channel was successfully configured; otherwise, it returns a NAK.

Do Housekeeping 2-86.

The Command Packet tells the A/D to do the following:

- Do all housekeeping readings if bit set.
- Do the next housekeeping reading in the schedule if bit set.
- Prescan: preset the function relays.

Checksum Action Performed is as follows:

- If the Housekeeping bit is 1, the inguard takes a complete set of housekeeping readings for the current measurement rate (there is one set for each rate).
- If the Next bit is 1, the inguard does the next housekeeping reading indicated by its internal schedule. This is the same schedule used for a housekeeping timeout.
- If the Do2 bit is 1, the inguard does the two reference balance readings.
- If the PS bit is 1, the inguard presets the function relays for the first defined channel.

These bits may be set or cleared independently. Note that the actions described above are carried out regardless of whether scheduled housekeeping is "enabled" by the global configuration command.

Response Packets Returned Always returns a single response packet. This packet is not returned until the inguard completes all indicated housekeeping measurements.

Response Packet Format Returns a single ACK packet.

Checksums 2-87.

The last byte of each command and response packet is its checksum.

Any time a packet that fails its checksum test is received, it is treated as a communication error. The inguard transmits a break and waits to be reset. The outguard resets the inguard.

Errors 2-88.

Whenever the inguard encounters an unrecoverable error or a guard-crossing communications error (e.g., parity error, overrun), it attempts to send a break character to the outguard and then goes into a loop, ignoring all subsequent commands from the outguard, and waits to be reset by the outguard. This insures that all measurement hardware is properly reset. This type of error could be caused by a glitch in the inguard hardware, which is conceivable but rare.

The inguard returns a NAK whenever it receives an illegal command or a command with illegal parameters. Such an error should never occur and probably indicates a software defect. The exception to this is that an error in a scan command returns a break (instead of a NAK).

Power-Up Protocol   2-89.

The inguard powers up silently, without sending any kind of unsolicited information to the outguard. The outguard, after powering up, waits 3.5 seconds before attempting to communicate with the inguard, to allow it to complete its initialization procedure and power-on self-tests. The inguard performs only limited self-tests automatically on power-up. The full set of self-tests is performed only in response to a self-test command from the outguard.

Inguard Unresponsive   2-90.

The inguard does not contain any kind of watchdog timer. If, for whatever reason, the inguard fails to respond after the expected length of time, the outguard should reset the inguard by sending a series of break characters. The "expected length of time" for a scan command is variable depending on the number and types of channels defined, and is calculated by the outguard at run-time.

Inguard Software Description   2-91.

The major functional blocks of the inguard are given in Figure 2-7. The arrows show the flow of measurement information. There is a control interface (not shown) between the A3U5 A/D microprocessor and every other functional block.

The channel scanner relays select the desired channel to be measured and route it to the function relays. The function relays route the signal to the appropriate portion of the Signal Conditioning circuitry, depending on the function being measured (VAC, VDC, ohms, etc.). The Signal Conditioning circuitry converts the signal into a form that can be measured by the A/D (i.e., a DC voltage with a range of -3 to 3V).

The A/D converts the analog voltage to a digital value, which is then read by the A3U5 A/D microprocessor. The box labeled A/D microprocessor represents the microcontroller and its associated memory and glue logic, upon which the inguard software runs. It controls all of the other hardware elements on the inguard and handles communication with the outguard.

The primary task of the inguard software is to interpret configuration information and scan requests from the outguard, manipulate the hardware in the appropriate way to obtain the requested measurements, and return the measurement data to the outguard.

Hardware Elements   2-92.

This section contains information about the various hardware subsystems on the inguard board.

Channel MUX   2-93.

The channel multiplexing consists of treeing and channel switches, implemented with either FET switches (2645A) or reed relays (2640A). There are two sets of bits associated with these switches. The tree bits must be set to indicate which bank of channels is being used where bank 0 is channels 1 to 10, and bank 1 is channels 11-20. For four-wire ohms measurements, both banks are selected. The position of the tree switches is also a function of the channel function and range being measured.

The channel bits are set to indicate which of the 10 channels within a bank is being selected. To deselect a channel (so that no channels are selected), write 1111 to the channel bits. The tree bits should not be deselected, since this would result in excessive wear of these switches (for the 2640A). Table 2-12: Tree Bits gives the bit patterns for the tree bits and Table 2-13: Channel Bits gives the bit patterns for the channel bits.

Table 2-12. Tree Bits

Signal	TR2	TR1	TR0	Switches
2W Ohms, VAC, Frequency, VDC, <=3V, OTC, TC (CH1-10)	1	0	1	K21, K23
2W Ohms, VAC, Frequency, VDC, <=3V, OTC, TC (CH11-20)	1	1	0	K22, K24
VDC >3V (CH1-10)	0	0	1	K23
VDC >3V (CH11-20)	0	1	0	K24
4W Ohms	1	1	1	K21, K24

Table 2-13. Channel Bits

Channels Enabled	CH3	CH2	CH1	CH0
1, 11	0	0	0	0
2, 12	0	0	0	1
3, 13	0	0	1	0
4, 14	0	0	1	1
5, 15	0	1	0	0
6, 16	0	1	0	1
7, 17	0	1	1	0
8, 18	0	1	1	1
9, 19	1	0	0	0
10, 20	1	0	0	1

The time required for the channel switches to settle is given in Table 2-14: Tree and Channel Switch Settling Times. Note that for both the 2645A and the 2640A, the switches are guaranteed to have a select time that is longer than their deselect time. This means that you can select a new channel at the same time as you deselect the previous channel, without worrying about shorting together the two channels.

Table 2-14. Tree and Channel Switch Settling Times

Description	2640A	2645A
Select	1 ms	150 μs
Deselect	1 ms	120 μs

Function Relays 2-94.

There are three relays (K25, K26, and K27) that route the signal to different portions of signal-conditioning circuitry on the A/D board. These are relatively slow relays, requiring 6 ms to change position. Each relay has a SET and RESET position, which are configured by pulsing the SET and RESET coils, respectively. Each change of state of the function relays requires two writes by the A3U5 A/D microprocessor: one to set the appropriate bits and energize the relays and another to reset all the bits and de-energize the coils once the relays have switched (after 6 ms).

Table 2-15: Function Relays gives the required relay states and bit patterns for the various measurement functions. Note that after the indicated bit pattern is written and 6 ms have elapsed, a pattern of 000000 should be written. Also note that the two bits associated with any given relay, corresponding to SET and RST, are never set to 1 at the same time. Table 2-16: Function Relay Settling Time gives the required time for the relays to settle for a given function.

Table 2-15. Function Relays

Function	K26	K25	K27	F0	F1	F2	F3	F4	F5
VDC, TC, OTC	S	R	R	0	1	1	0	1	0
Ohms	S	R	S	0	1	1	0	0	1
VAC, Frequency	R	S	R	1	0	0	1	1	0

Table 2-16. Function Relay Settling Time

2640A	2645A
6 ms	6 ms

Stallion Chip and Signal Conditioning 2-95.

The Stallion Chip (A3U30) is a Fluke-custom IC that contains assorted switches, amplifiers, and the frequency counter. The chip contains registers that the A3U5 A/D microprocessor may read and write to configure the chip and obtain frequency readings. Its interface to the A3U5 A/D microprocessor consists of a synchronous serial port. The SCP port of the A3U5 A/D microprocessor is used to program the Stallion, with a clock rate of 3.072 MHz. When reading information from the Stallion (the only time this needs to be done is for frequency readings), the clock rate is reduced to 960 kHz. Due to a limitation of the Stallion chip, the fastest that data may be reliably read from the chip is 1 MHz.

The Stallion switch settings for the various function/range combinations are given in Table 2-17: Stallion Switch Settings.

Table 2-17. Stallion Switch Settings

Function	Stallion Settings															
	S Switches											Other Switches				
VDC 90 mV	17	23	35	37	39	44	50	64				BR1	ACR4	FPWR	RPCTL	
VDC 300 mV	17	23	35	37	39	44	50	64				BR3	ACR4	FPWR	RPCTL	
VDC 750 mV	17	23	35	37	39	44	50	64				BR2	ACR4	FPWR	RPCTL	
VDC 3V	17	23	35	37	39	44	50	64				BR4	ACR4	FPWR	RPCTL	
VDC 30V	1	3	13	17	24	33	37	39	44	50	64	BR3	ACR4	FPWR	RPCTL	
VDC HIV	1	3	13	17	24	33	37	39	44	50	64	BR4	ACR4	FPWR	RPCTL	
VAC 300 mV	1	17	18	34	37	39	41	44				BR3	ACR1	FPWR	RPCTL	
VAC 3V	1	17	18	34	37	39	41	44				BR3	ACR2	FPWR	RPCTL	
VAC 30V	1	17	18	34	37	39	41	44				BR3	ACR3	FPWR	RPCTL	
VAC HIV	1	17	18	34	37	39	41	44				BR3	ACR4	FPWR	RPCTL	
2W 300Ω	10	15	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
2W 3 kΩ	9	14	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
2W 30 kΩ	8	13	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
2W 300 kΩ	8	12	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
2W 3 MΩ	7	11	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
4W 300Ω	10	15	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
4W 3 kΩ	9	14	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
4W 30 kΩ	8	13	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
4W 300 kΩ	8	12	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
4W 3 MΩ	7	11	19	23	35	37	39	44	64			BR3	ACR4	FPWR	RPCTL	
Freq. 300 mV	1	17	18	26	32	34	38	44	64			ACR1	FPWR	FHYST0	FHYST1	RPCTL
Freq. 3V	1	17	18	26	32	34	38	44	64			ACR2	FPWR	FHYST0	FHYST1	RPCTL
Freq. 30V	1	17	18	26	32	34	38	44	64			ACR3	FPWR	FHYST0	FHYST1	RPCTL
Freq. HIV	1	17	18	26	32	34	38	44	64			ACR4	FPWR	FHYST0	FHYST1	RPCTL
TC	(same as VDC 90 mV)															
Zero BR1	23	35	37	39	44	64						BR1	ACR4	ACR5	FPWR	RPCTL
Zero BR2	23	35	37	39	44	64						BR2	ACR4	ACR5	FPWR	RPCTL
Zero BR3	23	35	37	39	44	64						BR3	ACR4	ACR5	FPWR	RPCTL
Zero BR4	23	35	37	39	44	64						BR4	ACR4	ACR5	FPWR	RPCTL
REFBAL2	26	34	37	39	44	64						BR4	ACR4	FPWR	RPCTL	
REFBAL0	26	34	37	39	44	64						BR4	ACR4	FPWR	RPCTL	
REFJUNC	17	21	34	37	39	44	64					BR2	ACR4	FPWR	RPCTL	
OTC Dischg	17	23	34	37	42	43	44	46	64	65		BR1	ACR4	FPWR	RPCTL	

After the input channel has been selected and the Stallion chip programmed appropriately, there is a minimum time required for the signal conditioning circuitry to settle. This settling time varies depending on the function and range being measured, and is given in Table 2-18: Signal Conditioning Settling Time.

Table 2-18. Signal Conditioning Settling Time

Function	Time
VDC	30 µs
VAC, fast	100 ms
VAC, medium	150 ms
VAC, slow	200 ms
300Ω	20 µs
3 kΩ	100 µs
30 kΩ	400 µs
300 kΩ	2 ms
3 MΩ	10 ms
Frequency, fast	100 ms
Frequency, medium	150 ms
Frequency, slow	200 µs
Zero, BR1	30 µs
Zero, BR2	30 µs
Zero, BR3	30 µs
Zero, BR4	30 µs
Reference Balance, both references on	30 µs
Reference Balance, both references off	30 µs
Reference Junction	30 µs

A/D   *2-96.*

The multi-slope A/D converter in the instrument uses a hardware state machine (A3U18) to control the switching of the voltage references during the A/D conversion. This state machine also contains the counters that measure how long each reference is switched in, and provides the A3U5 A/D microprocessor with its interface to the A/D. A synchronous serial port is used to transfer the counter contents from the state machine to the A3U5 A/D microprocessor. These counter values can then be manipulated to form an A/D reading. There are two counters, NCOUNT and PCOUNT, which measure how long the negative and positive references, respectively, are switched in.

Timing 2-97.

The timing for the 2645A and 2640A A/Ds is shown in Figures 2-14 and 2-15. These figures apply to normal readings. For Reference Balance readings, the timing for both 2645A and 2640A is given by Figure 2-15.
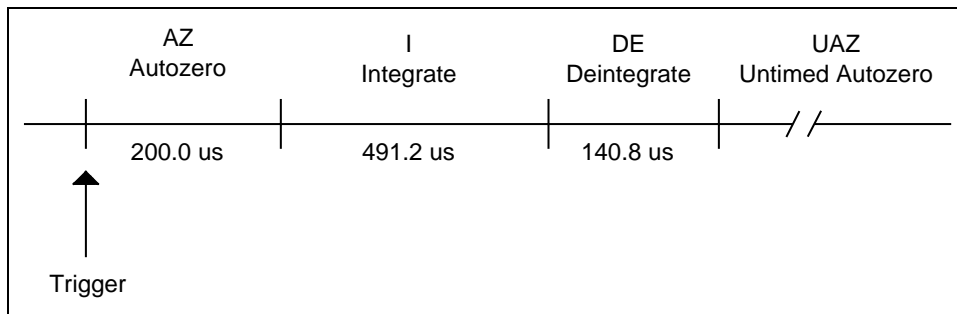
Figure 2-14. A/D Timing (2645A Normal Reading)
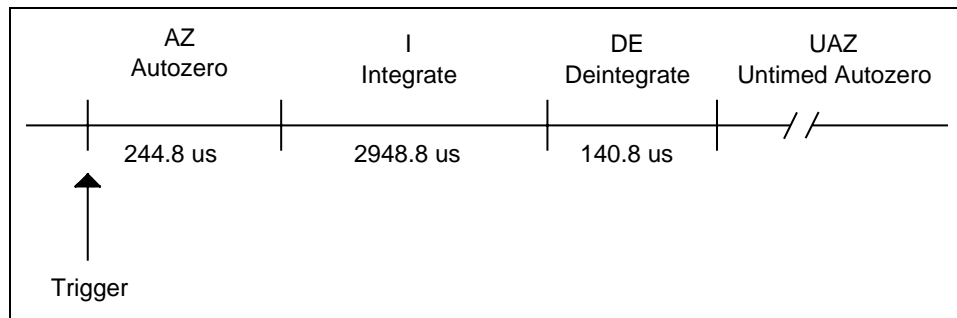
Figure 2-15. A/D Timing (2640A Normal Reading, 2640A and 2645A Reference Balance)

After the Trigger signal from the A3U5 A/D microprocessor is recognized, the A/D goes into the Autozero period. Immediately following this are the Integrate and Deintegrate periods. The only time that the input signal is actually being measured by the A/D is during the Integrate period. Therefore, the channel can be deselected and the Stallion programming for the next channel begun during the Deintegrate period. Also, the signal conditioning does not need to be settled until the beginning of integrate. At the end of Deintegrate, if the Trigger signal is still asserted, the A/D immediately begins the Autozero period for the next reading. Otherwise, it enters the Untimed Autozero period, which lasts until the Trigger signal is once again asserted. To take higher resolution measurements, the Trigger signal is left asserted until the required number of readings are obtained. This is also done for VDC readings on the fast rate (2645A only).

Control Signals 2-98.

Several signals are used by the A3U5 A/D microprocessor to control and receive state information from the A/D state machine (A3U18). The Trigger line, used to indicate to the A/D when to begin a reading, was discussed previously.

The A/D state machine has several modes of operation: perform conversion (measure input); do a reference balance reading with both references on; or do a reference balance reading with both references off. These modes are selected by the A3U5 A/D microprocessor through a two-bit parallel port, which consists of two data lines and a strobe line. The codes for the commands are given in Table 2-19: A/D Command Codes. To send a command to the A/D state machine, the data lines are set to the values shown, and then latched with a rising edge on the strobe line.

Table 2-19. A/D Command Codes

Command	C1	C0
Measure Signal	0	0
Reference Balance Reading, Both References	0	1
Reference Balance Reading, Neither Reference	1	0

There are two lines from the A/D state machine (A3U18) that indicate its state. These are connected as interrupt request signals to the A3U5 A/D microprocessor. The falling edge of the A/D Interrupt* signal indicates that a reading is complete and the counters are ready to be read. The A/D Interrupt* signal goes high at the beginning of the Integrate period, when the counters are cleared, and the signal is read by the A3U5 A/D microprocessor reads the counters to make sure that they were read in time. The DE_INT* signal indicates the beginning of the Deintegrate period. See Figure 2-16 A/D Status Signals.
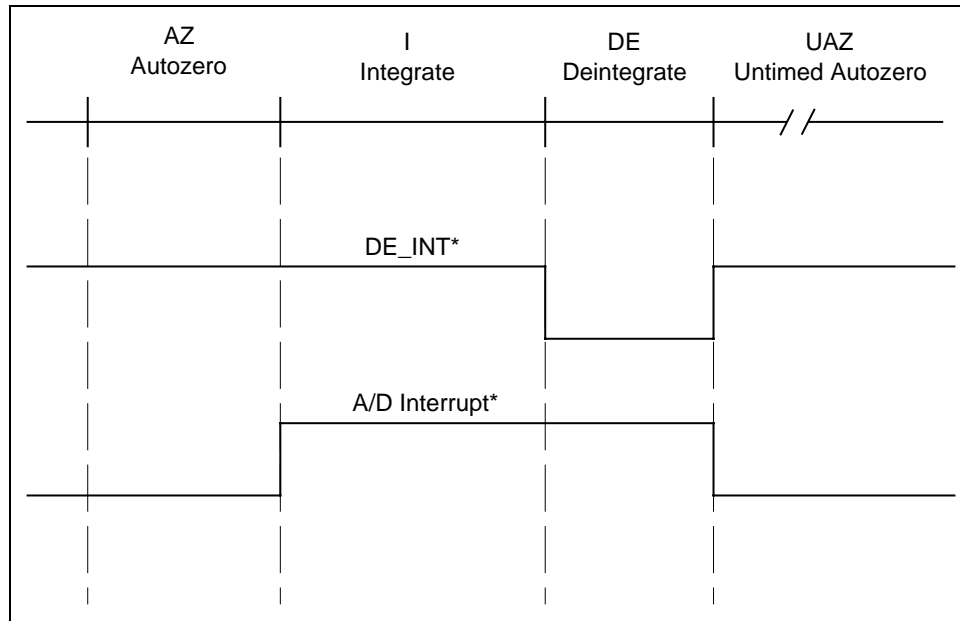
Figure 2-16. A/D Status Signals

Counters   2-99.

The counters in the A/D state machine (A3U18) are accessed through a synchronous serial interface. This interface is connected to the SCP port of the A3U5 A/D microprocessor, which is also connected to the Stallion chip. Chip-select lines are used to indicate the device the A3U5 A/D microprocessor is communicating. The counter values from the A/D are transmitted in five bytes. The hardware state machine transmits bytes most-significant bit first. There is no hardware detection of overload. An overload condition is detected by a software check of the PCOUNT and NCOUNT values. The hardware is designed so that there are sufficient guard bits on the A/D counters to avoid overflow.

The counters are cleared at the beginning of the Integrate period. This means that when taking continuous readings, the A3U5 A/D microprocessor has only the length of the Autozero period to read the counters.

Converting Counts to Volts   2-100.

If we assume perfect voltage references and no offsets, the basic formula for obtaining volts from N and P counts is as follows:

$V = (16P - N)K$

where

V = volts

P = P counts

N = N counts

$K = (0.1)(2)(3.45) / (16) / (307) / (1.6)$ (2645A)

$K = (0.1)(2)(3.45) / (16) / (1843) / (1.6)$ (2640A)

For higher resolution measurements, P and N counts are accumulated for the total number of A/D readings in the measurement and then used in the above formula. We call these Ptot and Ntot. The final voltage is then divided by the number of A/D readings in the measurement.

In reality, we do not have perfect references, so we must apply a scale factor. The scale factor is applied to P counts in the above formula, giving:

$V = (16PS - N)K$

where

S = scale factor

The scale factor is derived from the reference balance readings. See Reference Balance Readings. The scale factor has a nominal value of 1.0, and a typical value between 0.99 and 1.01.

We also must subtract the correct zero offset from the measurement. There are four zero offsets, one for each DC buffer amplifier gain setting (BR1, BR2, BR3, or BR4). The gain setting used for a particular function and range can be determined from the Stallion switch settings (Table 2-17: Stallion Switch Settings). The final formula is therefore

$V = (16PtotS - Ntot)K - Z$

where

Ptot = P counts (total)

Ntot = N counts (total)

Z = zero offset.

Zero offsets are also covered in "Zero Offset Readings" later in this chapter.

DISCHARGE Signal 2-101.

The signal DISCHARGE is driven by the A3U5 A/D microprocessor (pin 59) through one of its parallel port pins and controls the discharge of certain filter capacitors. This line is normally left low. It is driven high during the VAC discharge mode. See "VAC Discharge Mode" later in this chapter for more information.

Open-Thermocouple Detector 2-102.

To check for an open thermocouple input, the appropriate channel is selected with the function relays also set to the appropriate position, and the OTC circuitry is enabled. This is done by setting the OTC_EN bit high and turning on the OTC_CLK signal, with a frequency of 19.2 kHz. OTC_CLK is supplied by the A3U5 A/D microprocessor in the form of the SCC3 baud rate generator (BRG3 pin). After 1.7 ms, the OTC bit is read to determine the status of the channel. A 1 represents an open thermocouple.

After the reading, the OTC_CLK signal is turned off by setting it high. Then the OTC_EN bit is set low.

After deselecting the channel, the measurement circuitry that has been charged by the OTC test must be discharged. This is done by programming Stallion to apply a short between its HI1 pin and ground, setting OTC_CLK low, and setting OTC_EN high. This short is maintained for 500 us. After this, OTC_CLK is set high again, and OTC_EN is set low.

Channel Measurements 2-103.

The following paragraphs describe the Channel Measurement characteristics.

Reading Rates 2-104.

The instrument has three reading rates: fast, medium, and slow. These measurement rates allow you to obtain higher resolution and accuracy at the expense of slower measurements. The instrument obtains higher resolution measurements by averaging multiple A/D readings and/or waiting longer for signal conditioning to settle. The number of A/D readings averaged together to obtain a single measurement is given below in Table 2-20: A/D Readings to Average to Obtain a Measurement. Multiple A/D readings taken to average to obtain a measurement must be taken back-to-back, without interruption, in order to obtain AC line-frequency rejection.

Note that these numbers do not apply to measurement types that do not use the A/D converter. They also do not apply to reference balance readings (see Reference Balance Readings).

Table 2-20. A/D Readings to Average to Obtain a Measurement

Instrument	Reading Rate Fast	Reading Rate Medium	Reading Rate Slow
2640A	1	5 (60 Hz) 6 (50 Hz)	45 (60 Hz) 48 (50 Hz)
2645A	1	4	20 (60 Hz) 24 (50 Hz)

Measurement Types *2-105.*

There are several steps that you must perform at the beginning of any channel measurement:

- Set function relays. See "Function Relays" earlier in this chapter. This is a relatively slow operation and should be done only if the relay positions actually need to change.

- Set tree and channel switches. See "Channel MUX" earlier in this chapter.

- Program Stallion. See "Stallion Chip and Signal Conditioning" earlier in this chapter.

- Wait for channel switches to settle. See Table 2-14: Tree and Channel Switch Settling Times.

- Wait for signal conditioning circuitry to settle. See Table2-18: Signal Conditioning Settling Time.

After these steps have been carried out, the sequence of operations depends on the measurement function.

VDC, VAC, Ohms 2-106.

These types of measurements all use the A/D converter. After selecting the channel and configuring the signal conditioning circuitry, the A/D is triggered and, depending on the reading rate, one or more readings taken. The A/D counts are converted to a floating-point value and stored in a buffer for later transmission to the outguard. The channel and tree switches are then deselected.

VDC Fast Rate, 2645A 2-107.

Volts DC on the 2645A, fast rate represent a special case. To attain the required throughput, you cannot perform the sequence of steps given above for each channel. Instead, certain characteristics of VDC readings are exploited in order to allow the A/D to be triggered continuously for all the channels in a VDC block. A VDC block consists of a series of channels that are all defined as VDC, with "similar" ranges. Similar range means either the low ranges (90 mV, 300 mV, 750 mV, and 3V) or the high ranges (30V and HIV).

For the channels within such a block, we can assume the following:

- No function relay switches are required.
- There is only one Stallion register, that must be written to between channels.
- A channel can be selected at the beginning of the deintegrate period of the previous channel, at the same time that the previous channel is deselected.
- There is sufficient time during the deintegrate period to configure the Stallion for the next channel.
- There is sufficient time during the autozero period of a channel for signal conditioning settling.
- The N and P counters for a channel can be read during the autozero period of the next channel.

Thermocouples   2-108.

A thermocouple channel is measured in the same way as a volts DC channel, on the 90 mV range. However, before deselecting the channel at the end of the measurement, an open-thermocouple check may be done, if the channel is so configured. An "open" indication from this check causes a value of OTC_VAL to be returned for the channel measurement, regardless of the voltage measured. See Open-Thermocouple Detector.

Thermocouple readings also require an isothermal block reference junction reading to be taken. If any thermocouple channels are measured in a scan, a reference junction measurement is taken first, before any channel measurements.

Reference Junction   2-109.

The reference junction reading is similar to a VDC reading. However, no channel selection or function relay switching is required; however, the Stallion must be configured. The reference junction reading is converted to a floating-point value and returned to the outguard.

Frequency   2-110.

There are actually two parts to a frequency measurement. First, a normal VAC measurement is taken using the highest range. You must do this to determine the amplitude of the input signal, and thus the most appropriate gain setting to use for the actual frequency measurement. The frequency measurement circuitry works best with a large amplitude input signal.

Therefore, the gain setting used is one higher than would be used for a normal VAC measurement. For example, if the autosensitivity reading indicates that the input amplitude is 3V, you take the frequency measurement is taken with the AC buffer amplifier set to the 300 mV range. See Table 2-21: Frequency Sensitivity. For input signals whose measured amplitude is very low, a frequency reading is still attempted, since the frequency response of the VAC measurement circuitry rolls off more quickly at higher frequencies than that of the frequency measurement circuitry.

Table 2-21. Frequency Sensitivity

Measured Amplitude	Range Used for Frequency Measurement
Less than 3V	ACR1 (300 mV)
Between 3V and 30V	ACR2 (3V)
Greater than 30V (2640A only)	ACR3 (30V)

The frequency measurement itself does not use the A/D. Frequency measurements are taken using the Stallion chip. To reduce noise in frequency measurements, the instrument takes eight frequency readings and averages them together to obtain a single frequency measurement.

There is only one frequency range (this is different from sensitivity), and therefore the range field of the channel configuration is ignored for a frequency channel.

The only difference between the three measurement rates for a frequency reading is the length of time allowed for settling. See Table 2-18: Signal Conditioning Settling Time.

If the status bits returned by Stallion indicate a low frequency (PEROVER bit set), a value of 0 Hz is returned. If they indicate a high frequency (PEROVER bit clear and FREQOVER bit set), a value of PLUS_OVLD_VAL (defined in Perform Scan) is returned.

If the FRDY interrupt is not received within 500 ms of starting a frequency measurement, the input signal is assumed to be too low in amplitude or frequency to measure, and a value of 0 Hz is returned.

VAC Discharge Mode   2-111.

After a frequency or VAC reading, the hardware is configured to discharge certain signal conditioning capacitors, charged during the measurement. This is done to avoid disturbing the measurement of a subsequent VAC or frequency measurement. The function relays are set to the VAC discharge position, as given in Table 2-15: Function Relays, and the DISCHARGE signal is set high. After 6 ms, the DISCHARGE signal is once again set low.

Autoranging   *2-112.*

The configuration of each channel includes the state of autoranging for that channel, either enabled or disabled. When performing a measurement on a channel that has autoranging enabled, the instrument first attempts a measurement on the range that was used on that channel for the previous scan. If this results in an overrange or underrange, the instrument up-ranges or down-ranges accordingly. Channels that are configured with autorange enabled, but have not yet been measured start on the highest legal range for the channel's function type.

Autoranging may decrease the measurement rate, since readings on multiple ranges may be required for a single channel. On the slow and medium rates, only the first A/D reading of a measurement is used to determine whether a range change is required.

The actual points where a channel up-ranges or down-ranges varies, depending on the outguard calibration constants. This happens because the overrange/underrange determination is made by the inguard, which is comparing uncalibrated, raw A/D counts. These points are selected so that some overlap exists between ranges, to ensure a certain amount of hysteresis when changing ranges. Also, when autoranging, on a given scan for a given channel, the instrument only up-ranges or down-ranges, not both. This avoids "infinite autoranging," where a channel measurement could hypothetically take forever as the instrument up-ranges and down-ranges continuously on a noisy input.

Overload 2-113.

A channel can be in either positive or negative overload, depending on the polarity of the input signal. Overload limits are similar to autorange limits in that their actual values can vary, depending on the outguard calibration constants.

Housekeeping Readings 2-114.

The following paragraphs describe the housekeeping functions, which are called Drift Correction in the NetDAQ *Logger for Windows* software.

Reading Types 2-115.

There are two types of housekeeping readings: reference balance and zero offset readings. There are two different reference balance readings and four different zero offset readings.

Reference Balance Readings 2-116.

Reference balance readings are similar to VDC readings, except that no channel selection is required, and no function relay switching is required. The A/D itself, however, must be configured to operate in a different mode. See Control Signals. After the Stallion chip is configured (to provide an input of zero volts to the A/D), the A/D can be triggered and then read as normal. Note that a reference balance reading has different timing than a normal reading on the 2645A; see "Timing" earlier in this chapter. The number of readings to take and average for the different reading rates are given in Table 2-22.

Table 2-22. A/D Readings to Average to Obtain a Reference Balance Measurement

Instrument	Reading Rate Fast	Reading Rate Medium	Reading Rate Slow
2640A	1	5 (60 Hz) 6 (50 Hz)	45 (60 Hz) 48 (50 Hz)
2645A	1	1	5 (60 Hz) 6 (50 Hz)

There are two reference balance readings: one with both references on, and one with both references off. These readings are intended to compensate for unequal voltage references in the A/D. They are used to obtain a scale factor, which is then applied to the P counter for normal measurements.

The scale factor is derived as follows:

$$S = 1 - \{[(16P2 - N2) - (16P0 - N0)]K2\}$$

where

S = scale factor

$P2$ = P counts (both references on)

$N2$ = N counts (both references on)

$P0$ = P counts (both references off)

$N0$ = N counts (both references off)

$K2$ = (0.1) / (16) / (1843) / (1.6)

Zero Offset Readings 2-117.

There are four zero readings: one for each gain setting of the DC buffer amplifier. Zero offset readings are similar to VDC readings, except that no channel selection is required and no function relay switching is required. The Stallion chip must be configured. The A/D is placed in normal measurement mode. The number of readings to average is the same as for a normal reading (see Table 2-20: A/D Readings to Average to Obtain a Measurement). Zero offset measurements are converted to volts in the same way as normal channel measurements, except, of course, that no zero offset is subtracted. The reference balance scale factor is used.

Housekeeping Schedule *2-118.*

Housekeeping readings are always taken in response to a "Do Housekeeping" command from the outguard, as described in "Do Housekeeping" earlier in this chapter.

Setting the HK bit in a configuration command causes the inguard to schedule housekeeping readings on a rotating basis, taking one at the end of each channel scan. It also enables a timer, which is started at the end of a scan or after a configuration command. Whenever the timer expires, the next housekeeping reading in the schedule is measured, and the timer is restarted. The timer is set to expire after 17.476 seconds.

On the medium and slow rate, all six housekeeping readings are scheduled as described in the preceding paragraph. On the fast rate, however, only zero offset readings are scheduled. This is because a single reference balance reading is longer than a normal reading on the fast rate, which would cause scans containing them to take longer.

Self-Tests *2-119.*

There are two series of self-tests performed by the inguard: those done automatically at power-up, and those done in response to a self-test command from the outguard.

Power-Up Self-Tests *2-120.*

On power-up the inguard performs a ROM checksum test and a destructive RAM test. If either of these tests fail, the inguard treats it as a fatal error and enters the boot monitor. No explicit indication of either of these tests failing is given to the outguard.

Self-Test Command   _2-121._

The self-test command from the outguard causes the following tests to be performed, in the order given. If the A/D test fails, the tests that require the A/D (zero offset test, reference balance test, ohms overload test) are not done.

A/D Test   2-122.

This test simply triggers the A/D and waits for either the A/D interrupt or a timeout. If the timeout occurs before receiving an A/D interrupt, the test fails and the A/D is assumed to be non-functional. The timeout is set to 10 ms, greater than either the 2640A or 2645A A/D reading time.

Zero Offset Test   2-123.

The zero offset test measures the four zero offsets, and ascertains that they are within reasonable limits. The test fails if any of the offsets measures greater than 2000 counts (2645A) or 12000 counts (2640A). This is approximately 0.175 volts. A typical zero offset measurement is approximately 0.1 volts.

Reference Balance Test   2-124.

The reference balance test measures the two reference balance values. The individual counter values (N counts and P counts) are tested against limits, as are the differences between the counter values. For both references on, each counter must be less than 0x8000, and their difference must be less than 0x6000. For both references off, each counter must be less than 0x2000, and their difference must be less than 0x200.

Ohms Overload Test   2-125.

For this test, a two-wire ohms measurement is attempted without any channel selected (however the tree and function relays must be set). This should result in an overload. Any other value causes the test to fail.

OTC Test   2-126.

The OTC test attempts to do an open-thermocouple check with no channel selected. Unless this results in an "open" indication, the test fails.

Chapter 3
General Maintenance

Introduction 3-1.

This chapter provides handling, cleaning, fuse replacement, disassembly, and assembly instructions. For replacement part information, refer to Chapter 6.

Warranty Repairs and Shipping 3-2.

If your instrument is under warranty, see the warranty information at the front of the Users Manual for instructions on returning the unit. The list of authorized service facilities is included in Appendix I of the Users Manual.

General Maintenance 3-3.

General maintenance includes information on the general aspects of instrument servicing, including required test equipment, power requirements, static-safe handling, and servicing surface-mount assemblies.

Required Equipment 3-4.

Equipment required for calibration, troubleshooting, and repair of the instrument is listed in Chapter 4, Table 4-1. Refer to the Fluke "Surface-Mount Device Soldering Kit" for a list of special tools required to perform circuit assembly repair. (In the USA, call 1-800-526-4731 to order this kit.)

Power Requirements 3-5.

⚠ **WARNING**

To avoid shock hazard, connect the instrument power cord to a power receptacle with earth ground.

The instrument operates on any line voltage between 107V ac and 264V ac and at any frequency between 45 and 65 Hz. However, the instrument is warranted to meet published specifications only at 50/60 Hz. The instrument also operates from dc power (9 to 16V dc). DC input power is connected to the rear input connector ALARM/TRIGGER I/O (J6), pin 8 (DCH), and pin 7 (DCL). If both ac and dc power sources are connected to the instrument, the ac power source is used if the ac line voltage exceeds approximately 8.3 times the dc voltage. Automatic switchover between ac and dc occurs without interrupting instrument operation. The instrument draws a maximum of 15 VA on ac line power or 6W on dc power.

Static-Safe Handling 3-6.

All integrated circuits, including surface mounted ICs, are susceptible to damage from electrostatic discharge (ESD). Modern integrated circuit assemblies are more susceptible to damage from ESD than ever before. Integrated circuits today can be built with circuit lines less than one micron thick, allowing more than a million transistors on a 1/4-inch square chip. These submicron structures are sensitive to static voltages under 100 volts. This much voltage can be generated on a dry day by simply moving your arm. A person can develop a charge of 2,000 volts by walking across a vinyl tile floor, and polyester clothing can easily generate 5,000 to 15,000 volts during movement against the wearer. These low voltage static problems are often undetected because a static charge must be in the 30,000 to 40,000 volt range before a person feels a shock.

Most electronic components manufactured today can be degraded or destroyed by ESD. While protection networks are used in CMOS devices, they merely reduce, not eliminate component susceptibility to ESD.

ESD may not cause an immediate failure in a component; a delayed failure or wounding effect is caused when the semiconductor's insulation layers or junctions are punctured. The static problem is thus complicated in that failure may occur anywhere from two hours to six months after the initial damage.

Two failure modes are associated with ESD. First, a person who has acquired a static charge can touch a component or assembly and cause a transient discharge to pass through the device. The resulting current ruptures the junctions of a semiconductor. The second failure mode does not require contact with another object. Simply exposing a device to the electric field surrounding a charged object can destroy or degrade a component. MOS devices can fail when exposed to static fields as low as 30 volts.

Observe the rules for handling static-sensitive devices as follows:

1. **Handle all static-sensitive components at a static-safe work area** Use grounded static control table mats on all repair benches, and always wear a grounded wrist strap. Handle boards by their nonconductive edges only. Store plastic, vinyl, and Styrofoam objects outside the work area.

2. **Store and transport all static-sensitive components and assemblies in static shielding bags or containers** Static shielding bags and containers protect components and assemblies from direct static discharge and external static fields. Store components in their original packages until they are ready for use.

Servicing Surface-Mount Assemblies   3-7.

NetDAQ incorporates Surface-Mount Technology (SMT) for printed circuit assemblies (pca's). Surface-mount components are much smaller than their predecessors, with leads soldered directly to the surface of a circuit board; no plated through-holes are used. Unique servicing, troubleshooting, and repair techniques are required to support this technology.

Refer to Chapter 5 for additional information. Also, refer to the Fluke "Surface-Mount Device Soldering Kit" for a complete discussion of these techniques (in the USA, call 1-800-526-4731 to order this kit).

Cleaning   3-8.

⚠ **WARNING**

To avoid electrical shock or damage to the instrument, never allow water inside the case. To avoid damaging the instrument's housing, never apply solvents to the instrument.

If the instrument requires cleaning, wipe it down with a cloth that is lightly dampened with water or a mild detergent. Do not use aromatic hydrocarbons, chlorinated solvents, or methanol-based fluids when wiping the instrument. Dry the instrument thoroughly after cleaning.

Replacing the Line Fuse 3-9.

The line fuse (15/100 ampere, 250V, time delay, PN 944629) is in series with the power supply and located inside the instrument. To replace the fuse, refer to Figure 3-1 and the following procedure:

⚠ **WARNING**

Do not operate the instrument without the cover properly installed.

1. Disconnect *all* rear panel cables to the instrument power, Universal Input Module, and I/O connectors.

2. Invert the instrument on a protective surface and remove the four 1/4-inch 6-32 Phillips-head screws on the bottom of the case.

3. Turn the instrument upright and remove the two 1/2-inch 6-32 Phillips-head screws from the rear panel bezel.

4. Remove the rear panel bezel and case assembly. Do not touch any internal parts of the instrument!

5. Locate the fuse holder at the back of the chassis near the power input connector. Using a non-metallic tool, carefully pry the fuse from the holder.

6. Insert the new fuse into the holder. (You *must* use a 15/100 ampere, 250V, time delay line fuse replacement, PN 944629.)

7. Reinstall the case to its original position (the rubber feet are towards the front of the instrument).

8. Reinstall the rear panel bezel (rubber feet towards the bottom) and attach it with the two 1/2-inch 6-32 Phillips-head screws.

9. Invert the instrument on the protective surface and reinstall the four 1/4-inch 6-32 screws on the bottom securing the case.

10. Reinstall the cables removed in Step 1.

1   Remove all Cables

2   Remove Bottom Screws (4 places)

Bottom

3   Remove Rear Bezel Screws (2 places)

4   Remove Rear Bezel and Case for Fuse Access

Top

Fuse (15/100, 250V Time Delay)

Figure 3-1. Replacing the Fuse

Disassembly Procedures 3-10.

The following paragraphs describe disassembly of the instrument in sequence from the fully assembled instrument to the chassis level. Start and end your disassembly at the appropriate heading levels. For disassembly procedures, refer to Figure 3-2.

⚡ WARNING

Opening the case may expose hazardous voltages. Always disconnect the power cord and other inputs before opening the case. Repairs or servicing should be performed only by qualified personnel.

NOTE

In the disassembly procedures, parts referenced by a letter in brackets, e.g. [A], are shown in Figure 3-2.

Removing the Instrument Case 3-11.

Complete the following procedure to remove the instrument case [A]. (Refer to Figure 3-2.)

⚡ WARNING

Do not operate the instrument without the cover properly installed.

1. Disconnect *all* rear panel cables to the instrument power, Universal Input Module, and I/O connectors.

2. Invert the instrument on a protective surface and remove the four 1/4-inch 6-32 Phillips-head screws [B] on the bottom of the case.

3. Turn the instrument upright and remove the two 1/2-inch 6-32 Phillips-head screws [C] from the rear panel bezel [Z].

4. Remove the rear panel bezel and case assembly. Do not touch any internal parts of the instrument!

Removing the Front Panel Assembly 3-12.

Complete the following procedure to remove the Front Panel Assembly [D].

1. Complete the procedure "Removing the Instrument Case" to gain access to the instrument assemblies. Verify the instrument is not powered from any ac or dc source.

2. Using a needle-nose pliers or nonmetallic prying device, gently disconnect the display ribbon cable [E] from the J1 connector on A2 Display PCA.

3. Grasp the Front Panel Assembly and gently push one end free of the mounting post hardware; then remove the assembly.
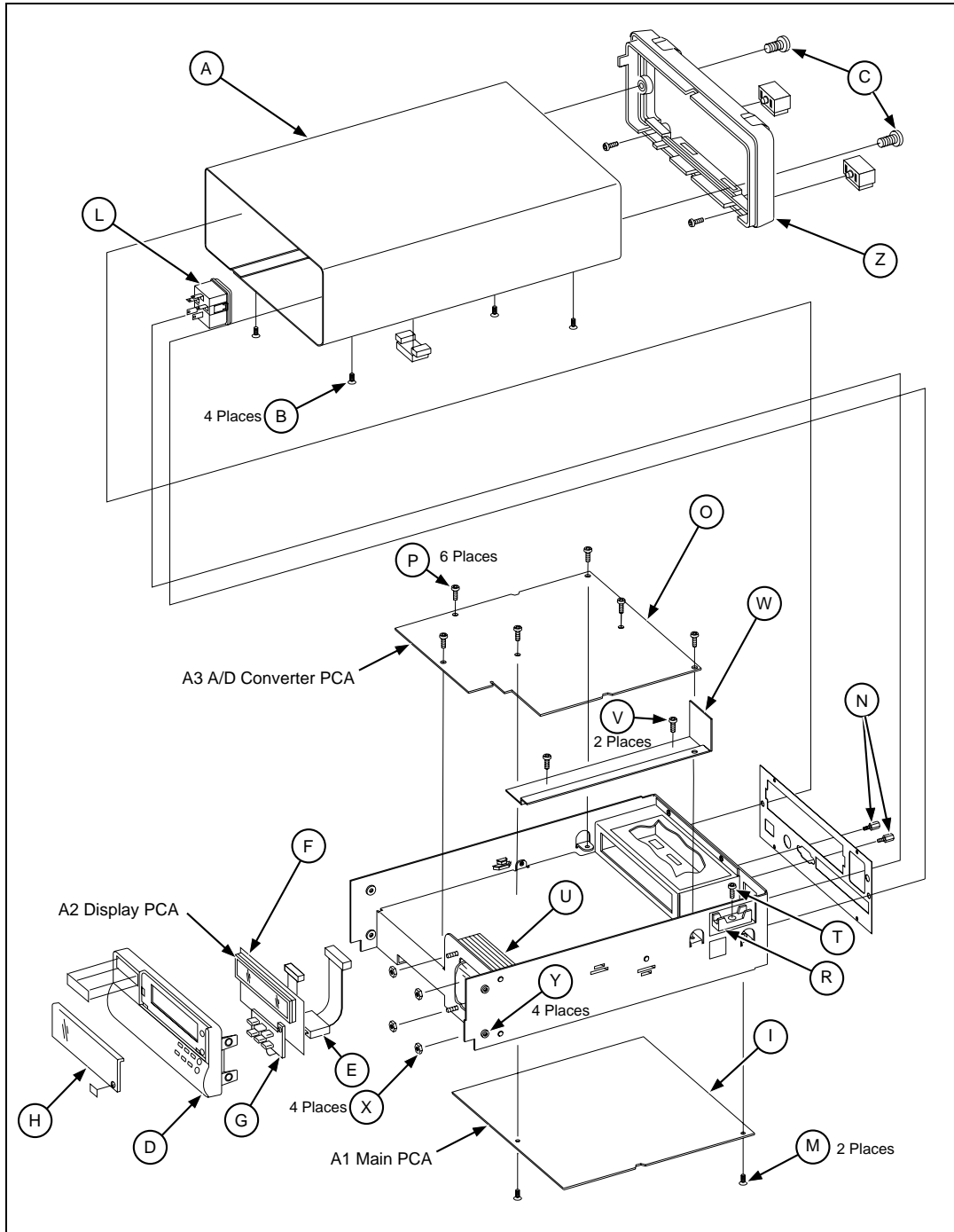
Figure 3-2. 2640A and 2645A Overall Assembly Details (Sheet 1 of 3)
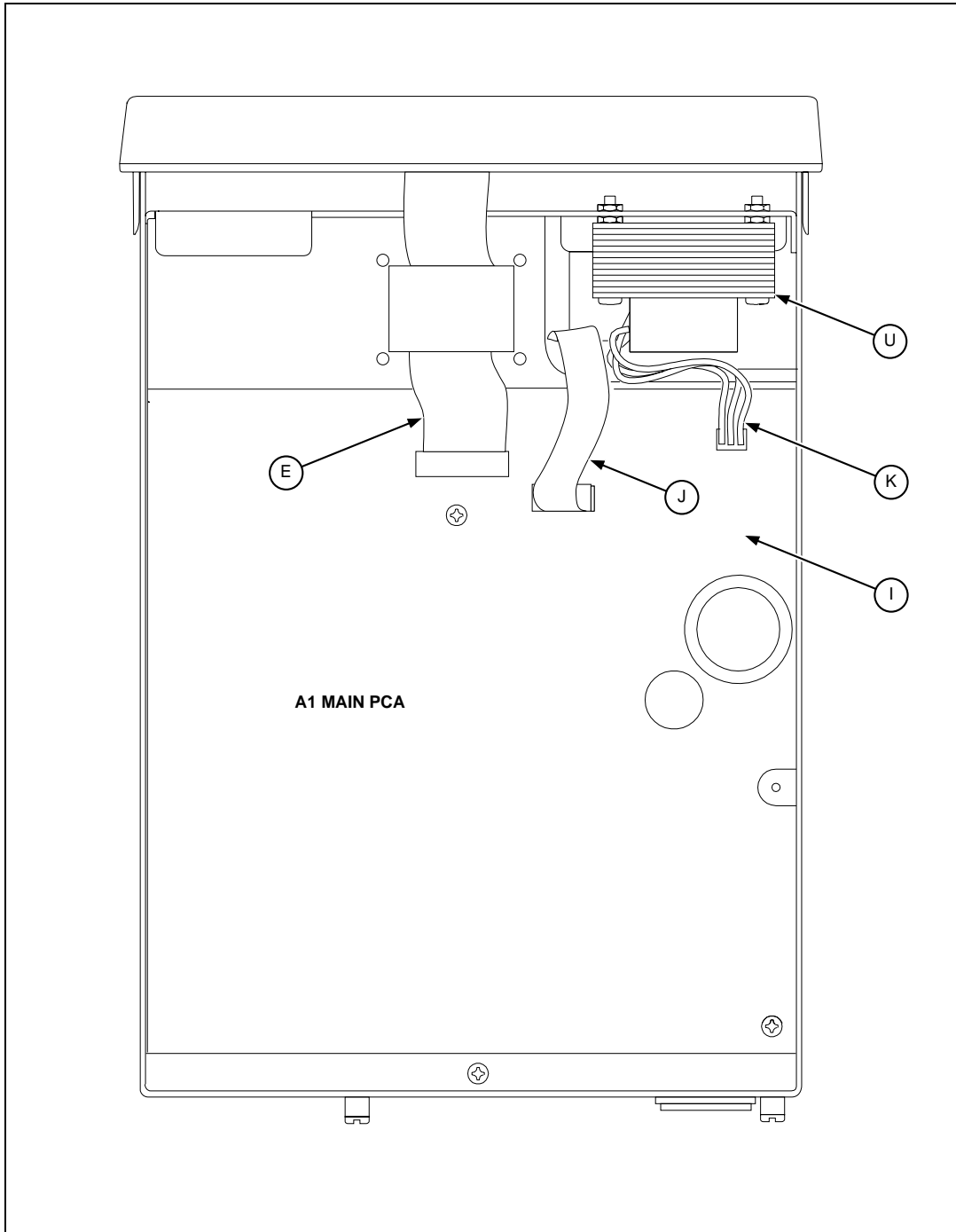
Figure 3-2. 2640A and 2645A Overall Assembly Details (Sheet 2 of 3)
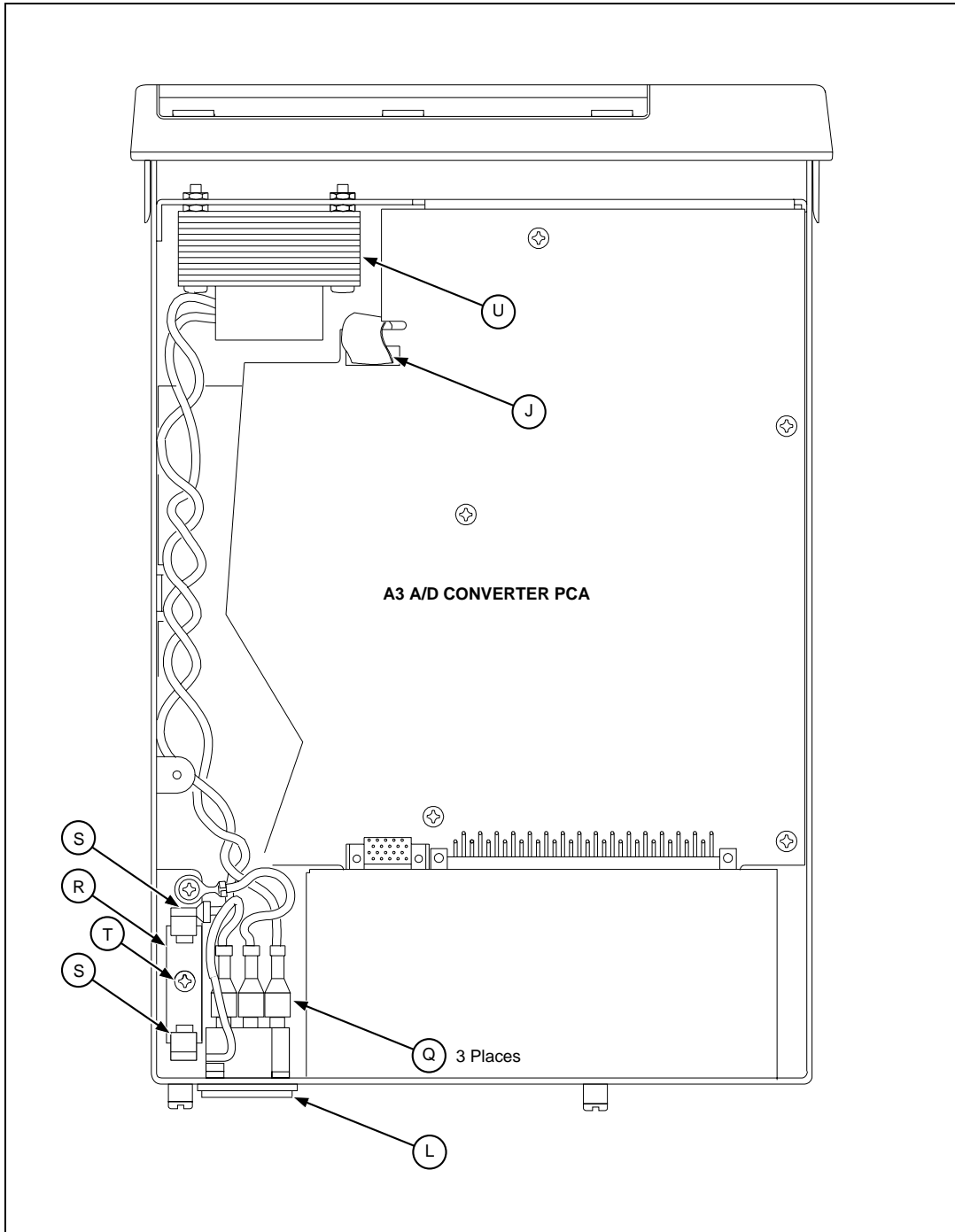
Figure 3-2. 2640A and 2645A Overall Assembly Details (Sheet 3 of 3)

Disassembling the Front Panel Assembly 3-13.

Complete the following procedure to disassemble the Front Panel Assembly [D].

1. Place the Front Panel Assembly on a protective surface to prevent any scratching or damage to the assembly.

2. Release the tabs at the sides and top that hold the A2 Display PCA [F] on the back of the Front Panel Assembly; then lift the pca out of its securing slots.

NOTE

The Display PCA provides space for securing screws, which are used only if one or more tabs are broken. If the pca has one or more securing screws, remove these as well.

3. To remove the elastomeric keypad [G], grasp the keypad and with a gentle motion pull the keypad free of the assembly.

4. To remove the display window [H], release the two snaps along the bottom edge and push the window free of the assembly.

⚠ **CAUTION**

Avoid using ammonia or methyl-alcohol cleaning agents on either the Front Panel or the display window. These types of cleaners can damage surface features and markings. Use an isopropyl-based cleaning agent or water to clean the Front Panel and the display window.

Removing the A1 Main PCA 3-14.

Complete the following procedure to remove the A1 Main PCA [I] from the chassis.

1. Complete the procedure "Removing the Instrument Case" to gain access to the instrument assemblies. Verify the instrument is not powered from any ac or dc source.

2. Using a needle-nose pliers or nonmetallic prying device, gently disconnect the display ribbon cable [E] from the connector A1J2.

3. Disconnect the pendant A/D ribbon cable [J] at the A3 A/D Converter PCA connector A3J10 and gently pull the cable and connector through the chassis opening.

4. Disconnect the transformer cable at A1J3 [K].

5. Using a needle-nose pliers or nonmetallic prying device, remove the two terminals with red wires from the instrument power switch [L] and gently pull the wires and terminals through the pca opening. (At the power switch, you may find it necessary to remove the power input terminals to gain access to the red wires. Note the color and routing of the power input terminals for the reconnection procedure.)

6. Remove the two screws [M] that secure the pca to the chassis.

7. Remove the RS-232 connector hardware [N] using a 3/16-inch nut driver.

8. Slide the pca towards the front of the instrument so that the pca edge indentations match the guide tabs on each side of the chassis, tilt slightly upwards and remove.

Removing the A2 Display PCA   3-15.

To remove the A2 Display PCA [F], see the procedure "Disassembling the Front Panel Assembly."

Removing the A3 A/D Converter PCA   3-16.

Complete the following procedure to remove the A3 A/D Converter PCA [O] from the chassis.

1. Complete the procedure "Removing the Instrument Case" to gain access to the instrument assemblies. Verify the instrument is not powered from any ac or dc source.

2. Disconnect the ribbon cable [J] at connector A3J10 that leads to the A1 Main PCA.

3. Remove the six screws [P] that secure the pca to the chassis.

4. Slide the pca towards the front of the instrument so that the pca edge indentations match the guide tabs on each side of the chassis, tilt slightly upwards and remove. (Be sure the Universal Input Module is not connected at the rear panel.)

Removing the A4 Analog Input PCA   3-17.

Complete the following procedure to remove the A4 Analog Input PCA from the Universal Input Module.

1. Remove the Universal Input Module from the instrument. Open the module and disconnect all inputs to the terminal strips.

2. Using a nonmetallic prying device, widen the side of the module next to one of the securing tabs (located near the ends of the terminal strips), and pry one edge of the pca free of the module. Lift the free edge of the pca upwards and remove from the module.

Removing Miscellaneous Chassis Components   3-18.

Complete the following procedure to remove miscellaneous chassis components, including the power switch/input connector, fuseholder, and power transformer.

Removing the Power Switch/Input Connector   3-19.

Complete the following procedure to remove the power switch/input connector [L].

1. Complete the procedure "Removing the Instrument Case" to gain access to the instrument assemblies. Verify the instrument is not powered from any ac or dc source.

2. Disconnect all five terminals [Q] from the power switch/input connector.

3. Compress the tab at one side of the power switch/input connector and partially remove the switch from the chassis. Repeat for the other tab and remove the switch from the chassis.

Removing the Fuseholder 3-20.

Complete the following procedure to remove the fuseholder [R].

1. Complete the procedure "Removing the Instrument Case" to gain access to the instrument assemblies. Verify the instrument is not ac or dc powered.

2. Remove the fuse from the fuseholder.

3. Disconnect the two terminals [S] from the fuseholder.

4. Remove the single screw [T] securing the fuseholder.

Removing the Power Transformer 3-21.

Complete the following procedure to remove the power transformer [U].

1. Remove the A3 A/D Converter PCA. (See the procedure "Removing the A3 A/D Converter PCA.")

2. Disconnect the white wire (blue wire on early production units) that leads to the transformer at the input connector.

3. Disconnect the black wire (brown wire on early production units) that leads to the transformer at the fuseholder.

4. Disconnect the transformer connection at A1J3 [K] on the A1 Main PCA.

5. Remove the two screws [V] that secure the transformer wire cover plate [W] and side the plate free from the chassis and remove.

6. Remove the four nuts [X] that secure the transformer to the chassis mounting plate.
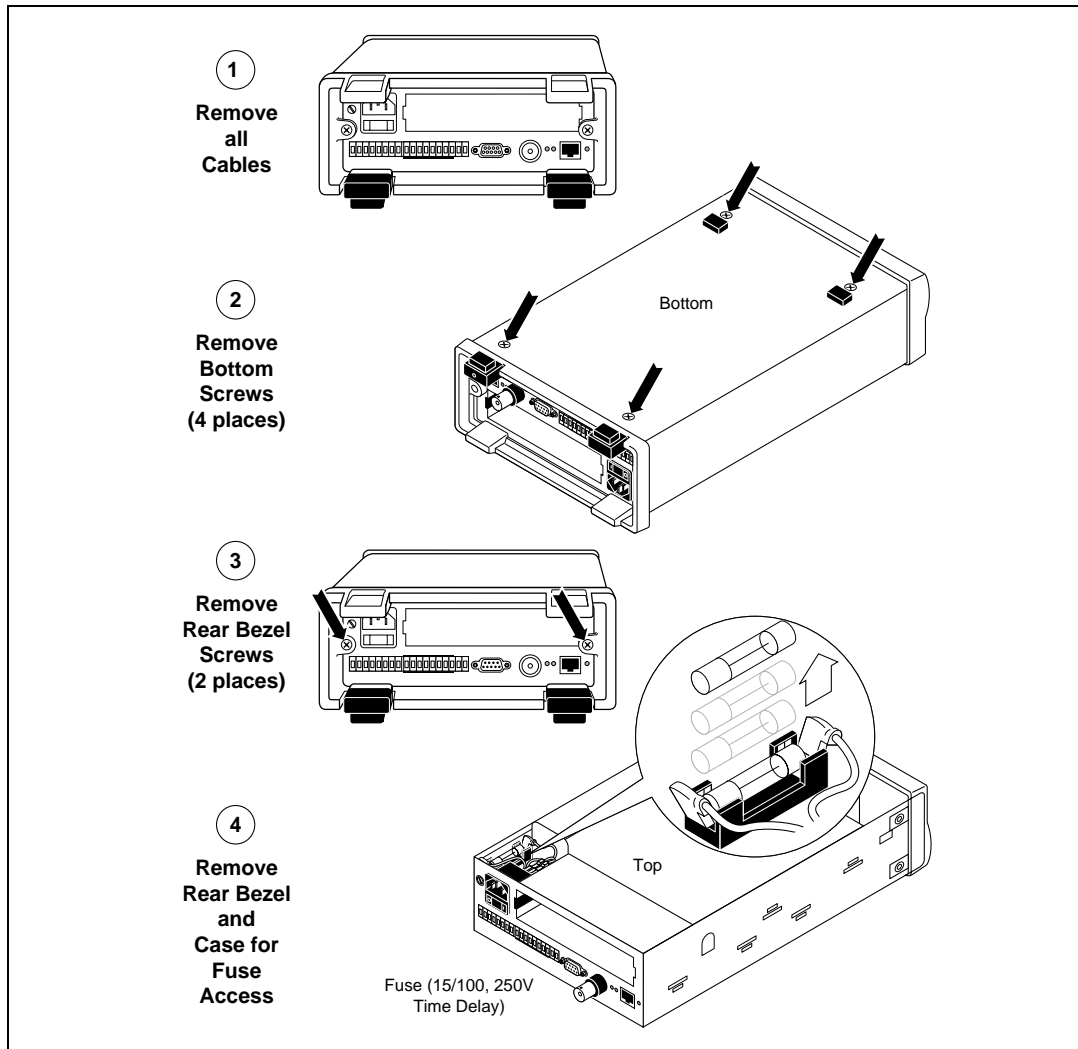
Assembly Procedures 3-22.

The following paragraphs describe assembly of the instrument in sequence from the fully unassembled instrument. Start and end your disassembly at the appropriate heading levels. For assembly procedures, refer to Figure 3-2 as required.

NOTE

In the assembly procedures, parts referenced by a letter in brackets, e.g. [A], are shown in Figure 3-2.

Installing Miscellaneous Chassis Components 3-23.

Complete the following procedure to install miscellaneous chassis components, including the power switch/input connector, fuseholder, and power transformer. Refer to Figure 3-2 and 3-3 as required.

Installing the Power Transformer 3-24.

Complete the following procedure to install the power transformer [U].

1. Install the four nuts [X] that secure the transformer to the chassis mounting plate.

2. Route the twisted white and brown wires to the fuseholder area; then install the two screws [V] that secure the transformer wire cover plate [W].

3. Reconnect the transformer connection at J3 [K] on the A1 Main PCA [I].

Red (to A1 Main PCA)

Top of Switch

Red (to A1 Main PCA)

White (to transformer)

Black (to fuseholder)

Green (to chassis)
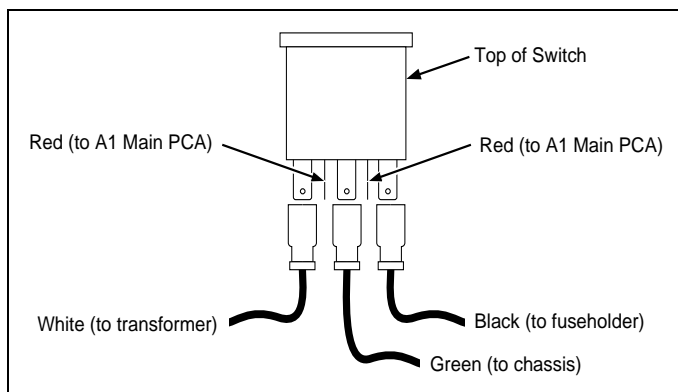
Figure 3-3. Power Input Connections at the Power Switch

4. Reconnect the brown wire that leads to the transformer at the fuseholder [R]. Refer to Figure 3-2 as required.

5. Reconnect the white wire that leads to the transformer at the input connector [L]. Refer to Figure 3-3 as required.

Installing the Fuseholder   3-25.

Complete the following procedure to install the fuseholder [R].

1. Install the single screw [T] securing the fuseholder.

2. Install a 15/100 amp, 250V, time delay fuse in the fuseholder (PN 944629).

3. Reconnect the two terminals (brown wires) [S] to the fuseholder.

Installing the Power Switch/Input Connector   3-26.

Complete the following procedure to install the power switch/input connector [L].

⚡ WARNING

Make sure you correctly connect the switch and power terminals at the power switch! There is a risk of electric shock if the connection is incorrect. Refer to Figure 3-3 for the input power terminal connections.

1. Position the power switch/input connector so the input connector portion is towards the top and the switch portion is towards the bottom of the instrument; then snap it into place.

2. Reconnect the five terminals to the power switch/input connector [Q]. Refer to Figure 3-3 as required. Note that either red wire can be connected to either switch terminal. The power input connections must be exactly as shown in Figure 3-3.

Installing the A1 Main PCA   *3-27.*

Complete the following procedure to install the A1 Main PCA [I].

1. Tilt the rear portion of the pca slightly downwards and position the pca in the chassis. Slide the pca towards the rear and into position.

2. Install the RS-232 connector hardware [N] at the rear panel using a 3/16-inch nut driver.

3. Install the two screws [M] that secure the pca to the chassis.

⚡ WARNING

Make sure you correctly connect the switch and power terminals at the power switch! There is a risk of electric shock if the connection is incorrect. Refer to Figure 3-3 for the input power terminal connections.

4. Thread the two red wires through the pca and connect to the power switch. Either red wire can be connected to either switch terminal. Do not accidentally connect the red wires to any input power terminal! (If you removed the power input terminals, reconnect them as shown in Figure 3-3.)

5. Reconnect the transformer cable at A1J3.

6. Route the pendant A/D ribbon cable [J] (from A1P10) through the chassis opening and reconnect it to the A3 A/D Converter PCA connector A3J10.

7. Gently reconnect the display ribbon cable [E] to the connector A1J2.

8. Complete the procedure "Installing the Instrument Case," as required.

Installing the A2 Display PCA   *3-28.*

To install the A2 Display PCA, see "Assembling the Front Panel Assembly."

Installing the A3 A/D Converter PCA   *3-29.*

Complete the following procedure to install the A3 A/D Converter PCA [O].

1. Tilt the rear portion of the pca slightly downwards and position the pca in the chassis. Slide the pca towards the rear and into position.

2. Install the six screws [P] that secure the pca to the chassis.

3. Reconnect the ribbon cable [J] at connector A3J10 that leads to A1P10 on the A1 Main PCA.

4. Complete the procedure "Installing the Instrument Case," as required.

Installing the A4 Analog Input PCA   *3-30.*

Complete the following procedure to install the A4 Analog Input PCA.

1. Place the pca in position in the module.

2. Widen a side of the module next to one of the securing tabs (located near the ends of the terminal strips), and press the pca firmly into place. Repeat for the other tab.

3. Reconnect the input measurement wires, as required.

Assembling the Front Panel Assembly   3-31.

Complete the following procedure to assemble the Front Panel Assembly [D].

1. Place the Front Panel Assembly on a protective surface to prevent any scratching or damage to the assembly.

2. Position the display window [H] in place; then push it firmly to snap it into position in the assembly.

3. Position the elastomeric keypad [G] in place; then gently press it into position in the assembly.

4. Position the A2 Display PCA [F] in place; then push it firmly to snap it into position in the assembly. It may be necessary to slightly distend the top of the bezel to allow the pca to snap into position.

NOTE

The Display PCA provides space for securing screws, which are used only if one or more tabs are broken. If the pca uses one or more securing screws, install these as well.

⚠ CAUTION

Avoid using ammonia or methyl-alcohol cleaning agents on either the Front Panel or the display window. These types of cleaners can damage surface features and markings. Use an isopropyl-based cleaning agent or water to clean the Front Panel and the display window.

Installing the Front Panel Assembly   3-32.

Complete the following procedure to install the Front Panel Assembly [D]:

1. Gently connect the display ribbon cable [E] to the connector on A2 Display PCA.

2. Position the Front Panel Assembly on the chassis mounting post hardware [Y].

3. Complete the procedure "Installing the Instrument Case," as required.

Installing the Instrument Case   3-33.

Complete the following procedure to install the instrument case [A]. (Refer to Figure 3-2.)

⚡ WARNING

Do not operate the instrument without the cover properly installed.

1. Reinstall the case to its original position (the rubber feet are towards the front of the instrument).

2. Reinstall the rear panel bezel (rubber feet towards the bottom) [Z] and attach it with the two 1/2-inch 6-32 Phillips-head screws [C].

3. Invert the instrument on the protective surface and reinstall the four 1/4-inch 6-32 screws [B] on the bottom securing the case.

4. Reinstall the measurement connection cables and power cord, as required.

Chapter 4
Performance Testing and Calibration

Introduction 4-1.

This section of the Service Manual provides performance tests that are used at any time to verify that the operation of the instrument networked data acquisition units (2640A or 2645A) is within published specifications. A complete calibration procedure is also included. The performance test and, if necessary, the calibration procedures are performed periodically as well as after service or repair.

Performance Test 4-2.

When received, the 2640A/2645A is calibrated and in operating condition. The following Performance Test procedures are provided for acceptance testing upon initial receipt or to verify correct instrument operation. The performance tests *must* be performed in sequence.

If the instrument fails a performance test, the instrument requires service or repair. To perform these tests, you will need a Fluke 5700A Multifunction Calibrator and several other pieces of equipment that meet the minimum specifications given in Table 4-1.

Each of the measurements listed in the following steps assume the instrument is being tested after a 1/2 hour warm-up, in an environment with an ambient temperature of 18 to 28°C, and a relative humidity of less than 70%.

⚠ WARNING

The 2640A/2645A instruments contain high voltages that are dangerous or fatal. Only qualified personnel should attempt to service the instruments.

Configuring the Performance Test Setup 4-3.

Configure the performance test setup as described below. The performance test requires a complete network connection between the host computer and instrument under test, including a host computer Ethernet interface and installation of NetDAQ *Logger for Windows* software. If you have not yet configured and tested a network connection for the host computer and instrument, complete the appropriate installation procedure for your network configuration in the separate NetDAQ *Getting Started* manual before conducting any performance testing.

1. **Connect the Instrument and the Host Computer** Connect the supplied 50-ohm coaxial cable, with a BNC "T" or "Y" and 50-ohm terminator, between the host computer BNC Ethernet port and the instrument BNC Ethernet port. The 50-ohm terminator with the ground lead is used at the instrument with the terminator ground lug connected to the ground terminal adjacent to the BNC port (Figure 4-1).

2. **Connect the 5700A to Channel 1** Connect a cable from the Output VA HI and LO connectors of the 5700A to the Universal Input Module terminals for channel 1 connecting the 5700A HI to terminal H and LO to terminal L. Insert the Universal Input Module into the instrument under test (Figure 4-2).

Table 4-1. Recommended Test Equipment

Instrument Type	Minimum Specifications			Recommended Model
Multifunction Calibrator	**DC Voltage:**			Fluke 5700A
	Range: 90 mV to 300V dc			
	Accuracy: 0.002%			
	AC Voltage:			
	Frequency	Voltage	Accuracy	
	1 kHz	29 mV to 300V	0.05%	
	100 kHz	15 mV to 300V	0.5%	
	Frequency:			
	10 kHz	1V rms	0.01%	
	Ohms:			
	Ohms	Accuracy		
	190Ω	0.005%		
	1.9 kΩ	0.005%		
	19 kΩ	0.005%		
	190 kΩ	0.005%		
	1.9 MΩ	0.005%		
Mercury Thermometer	0.02°C Resolution			Princo ASTM-56C
Thermocouple Probe	Type T			Fluke P20T
Oil/Water Bath	Thermos bottle and cap			
Digital Multimeter	General Purpose Measurement			Fluke 77
Signal Generator	Sine wave. 0.5 to 1V rms, 10 Hz to 5 kHz			Fluke 6011A
Alternative Equipment List				
Instrument Type		**Recommended Model**		
DC Voltage Calibrator		Fluke 5440B		
DMM Calibrator		Fluke 5100B (AC Volts Only)		
Function/Signal Generator		Philips PM5193 or Fluke 6011A		
Decade Resistance Source		General Resistance RDS 66A		
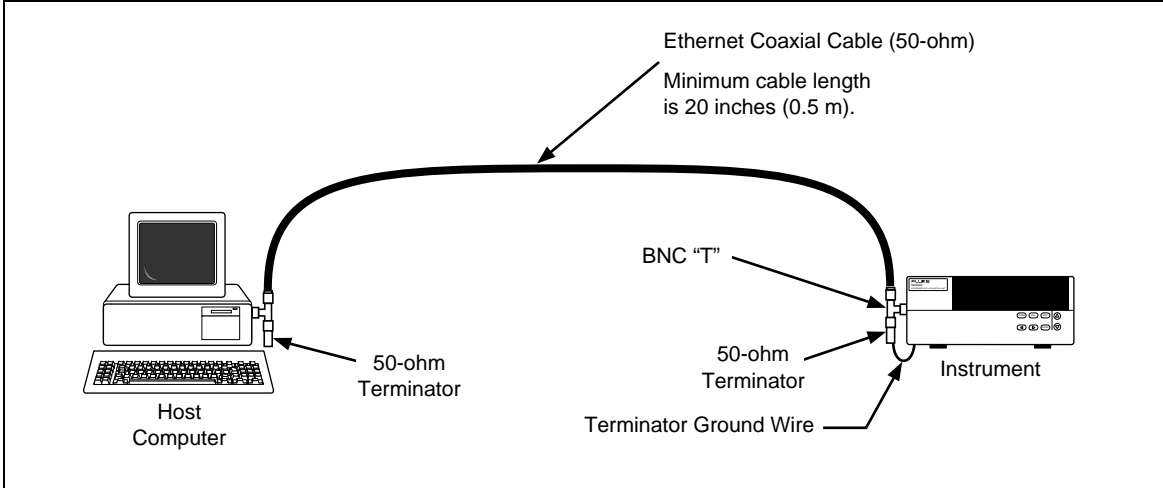
FIGURE 4-1. Performance Test Setup
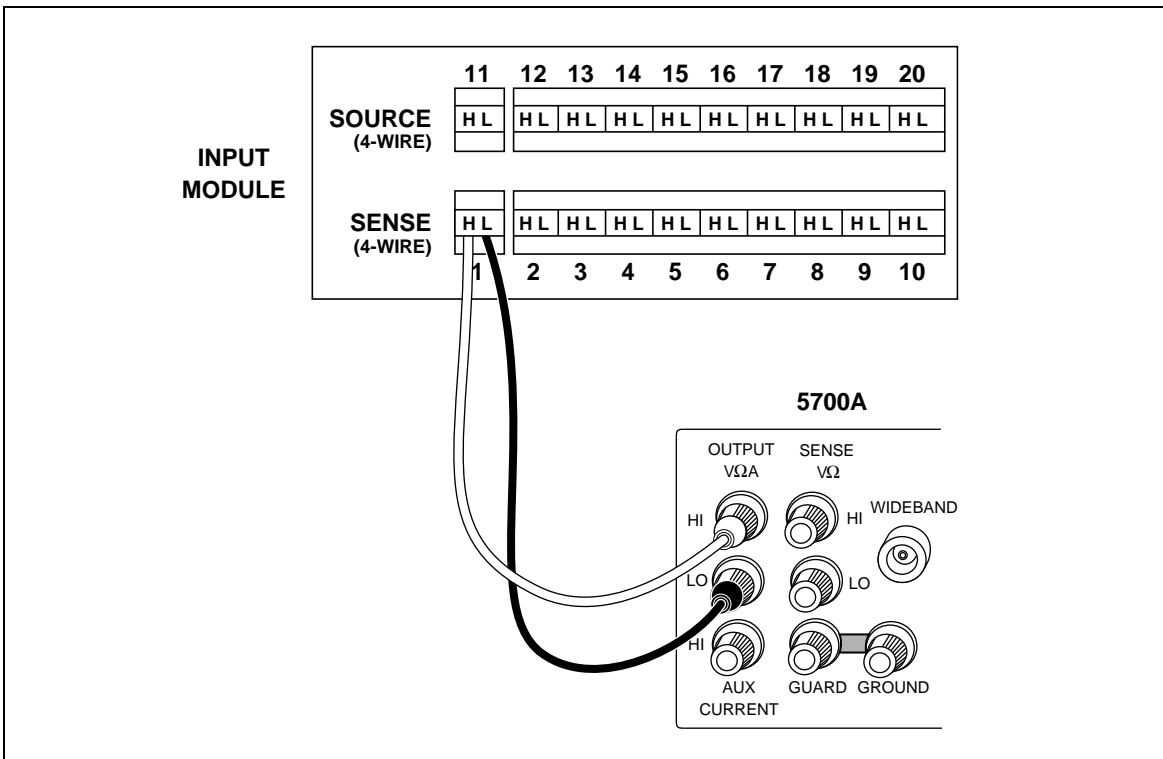
Figure 4-2. Two-Terminal Connections to 5700A

Initializing the Performance Test Setup 4-4.

Complete the following procedure to initialize the performance test setup. It is assumed you have configured the host computer and instrument as described in "Configuring the Performance Test Setup" (above). Testing begins with the instrument and host computer unpowered. This assures that at power-up, self-tests are completed successfully, the correct host computer Ethernet port is activated, the host computer configuration is accurately reflected, and other background operations are completed. This procedure clears the instrument of any existing BCN, Line Frequency, and Network settings.

1. **Apply Instrument Power with Configuration Reset** Hold down the COMM key on the instrument front panel and apply power to the instrument. After the instrument beeps and momentarily displays "rESEt" (Reset), release the COMM key. If any self-test errors are reported on the front panel display, refer to "Self-Test Diagnostics and Error Codes" in this chapter. Configuration Reset sets the instrument to the default parameters: BCN=1, Line Frequency=60, and Isolated Network.

2. **Set the Line Frequency** If the ac power applied to your instrument is 60 Hz (default), continue to Step 3. If the ac power applied to your instrument is 50 Hz, complete this step.

    Press the COMM key for 3 seconds, until your hear a beep and the SET annunciator in the display lights. Press the up/down arrow keys until LinE (Line Frequency) is displayed in the primary display. Press the ENTER key. Press the up/down arrow keys until 50 (50 Hz) is displayed in the primary display. Press the ENTER key.

3. **Apply Host Computer Power** Apply power to the host computer.

4. **Open NetDAQ *Logger for Windows*** Open NetDAQ Logger from the Fluke NetDAQ Logger group in Program Manager.

5. **Add Instrument** Select the Communications Config command from the Setup menu to open the Communications Configuration File dialog box. If the command is dimmed, Configuration Lockout is checked in the Options menu. Observe the Instruments on Network list. If the list includes instrument 01 with the correct model number (model 2640A or model 2645A), continue to Step 6.

    If instrument 01 is listed but with the wrong model number, select (highlight) the instrument on the Instruments on Network list and click the Modify button. Select the correct model and click OK. If instrument 01 is not listed, click the Add button and add instrument 01 with the correct model number. Click OK.

6. **Verify Communications**. With the Communications Configuration File dialog box still open, select instrument 01 on the Instruments on Network list and click the Verify button. The message Connection Successful! is returned for a successful communications between the instrument and host computer. If you receive an error message, refer to "Error and Status Messages" in Chapter 4. Click OK in the message box and then the Close button in the Communications Configuration File dialog box to return to the Main Window.

7. **Configure Icon** Note the Icon Bar in the Main Window. If the Icon Bar shows instrument 01, complete <u>Reset Instrument Icon</u> below. If the Icon Bar does not show instrument 01, complete <u>Create Instrument Icon</u> below.

   <u>Reset Instrument Icon</u> Select the Delete Instrument Icon form the Setup menu. If the command is dimmed, Configuration Lockout is checked in the Options menu. Click Yes in warning message. Complete <u>Create Instrument Icon</u> below. (This sequence clears all configuration data from the instrument.)

   <u>Create Instrument Icon</u> Select the Create Instrument Icon from the Setup menu. If the command is dimmed, Configuration Lockout is checked in the Options menu. Select instrument 01 on the Available Instruments List. Click OK.

8. **Select Reading Rate and Trigger Out** Click the Instrument Config button on the Button Bar, opening the Instrument Configuration dialog box. Select Reading Rate = Slow, and check the Trigger Out box. Click OK to return to the Main Window.

9. **Connect DIGITAL I/O Test Leads** Remove the 10-position DIGITAL I/O connector from the instrument rear panel or from the connector kit supplied with the instrument. Connect a test lead to each DIO line 0 to 7, plus a test lead to the Σ (Totalizer) input and the common GND line. Reinstall the DIGITAL I/O connector.

10. **Connect ALARM/TRIGGER I/O Test Leads** Remove the 8-position ALARM/TRIGGER I/O connector from the instrument rear panel or from the connector kit supplied with the instrument. Connect a test lead to each line, MA (Master Alarm), TO (Trigger Output), TI (Trigger Input), plus a test lead to the common GND line.

Accuracy Performance Tests 4-5.

This accuracy performance test assumes you have completed "Initializing the Performance Test Setup" above. Do not begin this test until the instrument has temperature stabilized for a minimum of 30 minutes. Do not use the instrument front panel monitor function for performance testing; use the higher resolution Spy window at the host computer as specified in the procedures. The Accuracy Performance Tests include the following:

- **Volts DC Accuracy Test**
- **Volts AC Accuracy Test**
- **Frequency Accuracy Tes**t
- **Analog Channel Integrity Test**
- **Computed Channel Integrity Test**
- **Thermocouple Temperature Accuracy Test**
- **Open Thermocouple Response Test**
- **Two-Terminal Resistance Accuracy Test**
- **Four-Terminal Resistance Accuracy Test**
- **RTD Temperature Accu**r**acy Test (Resistance Source)**
- **RTD Temperature Accu**r**acy Test (DIN/IEC 751 RTD Source)**

Tests for current dc are not included since these functions are derived from volts dc.

Volts DC Accuracy Test (2640A) *4-6.*

Complete the following procedure to test the accuracy of the volts dc function for the 2640A. Measurement accuracy applies to all channels, not just the channel used for the test.

1. **Configure Channel 1 for Volts DC** In NetDAQ *Logger for Windows*, configure channel 1 for volts dc, 90 mV range.

2. **Open Spy Window** Select the Spy command from the Utilities menu. Select channel 0101 (instrument 01, channel 01) from the Channel list. Click OK to open the Spy window.

3. **Verify Accuracy** Configure the 5700A for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 1).

Volts DC Range	5700A Output	Minimum Reading	Maximum Reading
90 mV	Short Circuit (Zero)	-0.000008V	+0.000008V
90 mV	+90 mV	+0.089980V	+0.090020V
90 mV	-90 mV	-0.090020V	-0.089980V
300 mV	Short Circuit (Zero)	-0.000017V	+0.000017V
300 mV	+300 mV	+0.299944V	+0.300056V
300 mV	-300 mV	-0.300056V	-0.299944V
3V	Short Circuit (Zero)	-0.00015V	+0.00015V
3V	+3V	+2.99946V	+3.00054V
3V	-3V	-3.00054V	-2.99946V
30V	Short Circuit (Zero)	-0.0017V	+0.0017V
30V	+30V	+29.9944V	+30.0056V
30V	-30V	-30.0056V	-29.9944V
300V	Short Circuit (Zero)	-0.017V	+0.017V
300V	+300V	+299.944V	+300.056V
300V	-300V	-300.056V	-299.944V

4. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Volts DC Accuracy Test (2645A) 4-7.

Complete the following procedure to test the accuracy of the volts dc function for the 2645A. Measurement accuracy applies to all channels, not just the channel used for the test.

1. **Configure Channel 1 for Volts DC** In NetDAQ *Logger for Windows*, configure channel 1 for volts dc, 90 mV range.

2. **Open Spy Window** Select the Spy command from the Utilities menu. Select channel 0101 (instrument 01, channel 01) from the Channel list. Click OK to open the Spy window.

3. **Verify Accuracy** Configure the 5700A for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 1).

Volts DC Range	5700A Output	Minimum Reading	Maximum Reading
90 mV	Short Circuit (Zero)	-0.000023V	+0.000023V
90 mV	+90 mV	+0.089965V	+0.090035V
90 mV	-90 mV	-0.090035V	-0.089965V
300 mV	Short Circuit (Zero)	-0.00005V	+0.00005V
300 mV	+300 mV	+0.29991V	+0.30009V
300 mV	-300 mV	-0.30009V	-0.29991V
3V	Short Circuit (Zero)	-0.0004V	+0.0004V
3V	+3V	+2.9992V	+3.0008V
3V	-3V	-3.0008V	-2.9992V
30V	Short Circuit (Zero)	-0.005V	+0.005V
30V	+30V	+29.991V	+30.009V
30V	-30V	-30.009V	-29.991V
50V	Short Circuit (Zero)	-0.04V	+0.04V
50V	+50V	+49.95V	+50.05V
50V	-50V	-50.05V	-49.95V

4. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Volts AC Accuracy Test 4-8.

Complete the following procedure to test the accuracy of the volts ac function for both the 2640A and 2645A. Measurement accuracy applies to all channels, not just the channel used for the test.

1. **Configure Channel 1 for Volts AC** In NetDAQ *Logger for Windows*, configure channel 1 for volts ac, 300 mV range.

2. **Open Spy Window** Select the Spy command from the Utilities menu. Select channel 0101 (instrument 01, channel 01) from the Channel list. Click OK to open the Spy window.

3. **Verify Accuracy** Configure the 5700A for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 1).

Volts AC Range	5700A Output	Minimum Reading	Maximum Reading
300 mV	20 mV@1 kHz	0.0197V	0.0203V
300 mV	20 mV@100kHZ	0.0185V	0.0215V
300 mV	300 mV@1 kHz	0.29885V	0.30115V
300 mV	300 mV@100 kHz	0.2845V	0.3155V
3V	3V@1 kHz	2.9885V	3.0115V
30V	30V@1 kHz	29.885V	30.115V
300V [2640A only]	300V@1 kHz	298.85V	301.15V

4. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Frequency Accuracy Test 4-9.

Complete the following procedure to test the accuracy of the frequency function for the 2640A and 2645A. Measurement accuracy applies to all channels, not just the channel used for the test.

1. **Configure Channel 1 for Frequency** In NetDAQ *Logger for Windows*, configure channel 1 for frequency. There is no range selection for frequency because all frequency measurements use Autoranging.

2. **Open Spy Window** Select the Spy command from the Utilities menu. Select channel 0101 (instrument 01, channel 01) from the Channel list. Click OK to open the Spy window.

3. **Verify Accuracy** Configure the 5700A for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 1).

Frequency Range	5700A Output	Minimum Reading	Maximum Reading
Autorange Only	1V@10 kHz	9.994 kHz	10.006 kHz

4. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Analog Channel Integrity Test   4-10.

Complete the following procedure to test the integrity of each analog channel (2 to 20) to verify each analog channel is capable of making measurements.

1. **Configure Channel for Ohms** In NetDAQ *Logger for Windows*, configure channels 2 (then 3, then 4, etc. because this step is repeated) to 20 for ohms-2T, 300 range [2640A] or 30K range [2645A].

2. **Connect Test Leads** Remove the Universal Input Module from the instrument, disconnect the test leads, and connect them to the channel under test (starting with channel 2). Reinstall the Universal Input Module in the instrument.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select the analog channel under test. Click OK to open the Spy window.

4. **Verify Reading** Alternately open and short the test leads. Observe the measurement for the analog channel under test in the Spy window shows Overload for opened leads and very low resistance for shorted leads (less than 10 ohms for the 2640A, or less than 1kΩ for the 2645A).

5. **Repeat Test for each Channel** Repeat steps 2 to 4 for each channels (3, 4, 5, and so forth to channel 20).

Computed Channel Integrity Test   4-11.

Complete the following procedure to test the integrity of each computed channel (21 to 30) to verify each computed channel is capable of making measurements.

1. **Configure Channels 1 and 2 for Ohms** In NetDAQ *Logger for Windows*, configure channels 1 and 2 for Ohms-2T, 30k range.

2. **Configure Channel for Average** In NetDAQ *Logger for Windows*, configure channels 21 to 30 for ChanA - ChanB (Difference) with the difference channels being analog channel 1 and analog channel 2.

3. **Connect Test Leads** Remove the Universal Input Module from the instrument and connect test leads to channels 1 and 2. Reinstall the Universal Input Module in the instrument.

4. **Open Spy Window** Select the Spy command from the Utilities menu. Select the computed channels 21 to 28. Click OK to open the Spy window.

5. **Verify Reading** Alternately open and short both sets of test leads. Observe the measurement for the computed channel under test in the Spy window shows +Overload for opened leads and very low resistance for shorted leads.

6. **Repeat Test** Repeat steps 4 to 5 for channels 29 and 30.

Thermocouple Temperature Accuracy Test   4-12.

Ensure that the Accuracy Tests (above) have been completed before performing this test.

1. **Connect a Thermocouple** Remove the Universal Input Module from the instrument and connect the supplied type T thermocouple to the channel 1 terminals with the blue lead to the H terminal and red lead to the L terminal. Reinstall the Universal Input Module.

2. **Configure Channel 1 for Thermocouples** In NetDAQ *Logger for Windows*, configure channel 1 for Thermocouples with Range (thermocouple type) T.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 01. Click OK to open the Spy window.

4. **Verify Accuracy** Insert the thermocouple and a mercury thermometer in a room-temperature bath. Allow 20 minutes for thermal stabilization. The value displayed on the mercury thermometer should equal the value in the Spy Window $\pm$ 0.5°C (2640A) or $\pm$ 1.0°C (2645A) plus any sensor inaccuracies.

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Open Thermocouple Response Test   4-13.

This test checks the Open Thermocouple response.

1. **Connect an 820 Ohm Test Resistor** Remove the Universal Input Module from the instrument and connect an 820 ohm resistor to the channel 1 terminals. Reinstall the Universal Input Module.

2. **Configure Channel 1 for Thermocouples** In NetDAQ *Logger for Windows*, configure channel 1 for Thermocouples with Range (thermocouple type) K.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 1. Click OK to open the Spy window. The value displayed should approximate the ambient temperature.

4. **Connect a 10kΩ Test Resistor** Remove the Universal Input Module from the instrument and connect a 10kΩ resistor to the channel 1 terminals to simulate an open thermocouple condition. Reinstall the Universal Input Module.

5. **Verify Open Thermocouple** The Spy window indicates an open thermocouple detect condition by displaying Open TC in place of a temperature reading.

6. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Two-Terminal Resistance Accuracy Test (2640A) 4-14.

Complete the following procedure to test the accuracy of the resistance function for the 2640A using two terminals. Measurement accuracy applies to all channels, not just the channel used for the test. (The four-terminal resistance accuracy test is more rigorous and you may wish to skip this step and continue to "Four-Terminal Resistance Accuracy Test.")

1. **Connect the Resistance Source to Channel** 1 Remove the Universal Input Module from the instrument and connect a cable from the Decade Resistance Source to the Universal Input Module terminals for channel 1. Reinstall the Universal Input Module. You may also use the 5700A resistance calibration output instead of the Decade Resistance Source. Tables are provided for both connections.

2. **Configure Channel 1 for Ohms** In NetDAQ *Logger for Windows*, configure channel 1 for Ohms-2T, 300 range [2640A] or 30K range [2645A].

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select channel 0101 (instrument 01, channel 01) from the Channel list. Click OK to open the Spy window.

4. **Verify Accuracy** Configure the Decade Resistance Source for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 2).

Resistance Range*	Decade Resistor	Minimum Reading	Maximum Reading
300Ω	Short Circuit (Zero)	0Ω	10Ω
300Ω	290Ω	289.86Ω	300.14Ω
3 kΩ	Short Circuit (Zero)	0Ω	10.5Ω
3 kΩ	2.9 kΩ	2.8986 kΩ	2.9114 kΩ
30 kΩ	29 kΩ	28.983 kΩ	29.027 kΩ
300 kΩ	290 kΩ	289.61 kΩ	290.39 kΩ
3 MΩ	2.9 MΩ	2.8914 MΩ	2.9086 MΩ
* The resistance accuracy in this table makes allowance for up to 0.1Ω of lead wire resistance plus 0.01% decade resistance tolerance. You must add any additional lead wire resistance present in your setup to the resistance values given in this table.			

Resistance Range*	5700A	Minimum Reading	Maximum Reading
300Ω	Short Circuit (Zero)	0Ω	10Ω
300Ω	190Ω	189.91Ω	200.09Ω
3 kΩ	Short Circuit (Zero)	0Ω	10.5Ω
3 kΩ	1.9 kΩ	1.8991 kΩ	1.9109 kΩ
30 kΩ	19 kΩ	18.989 kΩ	19.021 kΩ
300 kΩ	190 kΩ	189.75 kΩ	190.26 kΩ
3 MΩ	1.9 MΩ	1.8942 MΩ	1.9058 MΩ
* The resistance accuracy in this table makes allowance for up to 0.1Ω of lead wire resistance. You must add any additional lead wire resistance present in your setup to the resistance values given in this table..			

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Two-Terminal Resistance Accuracy Test (2645A)   4-15.

Complete the following procedure to test the accuracy of the resistance function for the 2645A using two terminals. Measurement accuracy applies to all channels, not just the channel used for the test. (The four-terminal resistance accuracy test is more rigorous and you may wish to skip this step and continue to "Four-Terminal Resistance Accuracy Test.")

1. **Connect the Resistance Source to Channel** 1 Remove the Universal Input Module from the instrument and connect a cable from the Decade Resistance Source to the Universal Input Module terminals for channel 1. Reinstall the Universal Input Module. You may also use the 5700A resistance calibration output instead of the Decade Resistance Source. Tables are provided for both connections.

2. **Configure Channel 1 for Ohms** In NetDAQ *Logger for Windows*, configure channel 1 for Ohms-2T, 30k range.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select channel 0101 (instrument 01, channel 01) from the Channel list. Click OK to open the Spy window.

4. **Verify Accuracy** Configure the Decade Resistance Source for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 2).

Resistance Range*	Decade Resistor	Minimum Reading	Maximum Reading
30 kΩ	Short Circuit (Zero)	700Ω	1 kΩ
30 kΩ	29 kΩ	29.681 kΩ	30.019 kΩ
300 kΩ	290 kΩ	289.07 kΩ	292.63 kΩ
3 MΩ	2.9 MΩ	2.8607 MΩ	2.9410 MΩ
* The resistance accuracy in this table makes allowance for up to 0.05 ohm of lead wire resistance plus 0.01% decade resistance tolerance. You must add any additional lead wire resistance present in your setup to the resistance values given in this table.			

Resistance Range*	5700A	Minimum Reading	Maximum Reading
30 kΩ	Short Circuit (Zero)	700Ω	1 kΩ
30 kΩ	19 kΩ	19.686 kΩ	20.014 kΩ
300 kΩ	190 kΩ	189.60 kΩ	192.10 kΩ
3 MΩ	1.9 MΩ	1.8740 MΩ	1.9277 MΩ
* The resistance accuracy in this table makes allowance for up to 0.05 ohm of lead wire resistance. You must add any additional lead wire resistance present in your setup to the resistance values given in this table.			

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Four-Terminal Resistance Accuracy Test (2640A) 4-16.

Ensure that the Accuracy Tests (above) have been completed before performing this test on the 2640A.

1. **Connect the Resistance Source to Channels 1 and 11** Remove the Universal Input Module from the instrument and connect a cable from the Decade Resistance Source to the Universal Input Module terminals for channel 1 (Sense) and channel 11 (Source) as shown in Figure 4-3. Reinstall the Universal Input Module. You may also use the 5700A resistance calibration output instead of the Decade Resistance Source. Tables are provided for both connections. Refer to Figure 4-4 for the 5700A four-wire connections.

2. **Configure Channel 1 for Resistance** In NetDAQ *Logger for Windows*, configure channel 1 for Ohms-4T, 300 range.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 01. Click OK to open the Spy window.

Figure 4-3. Four-Terminal Connections to the Universal Input Module (Resistor)
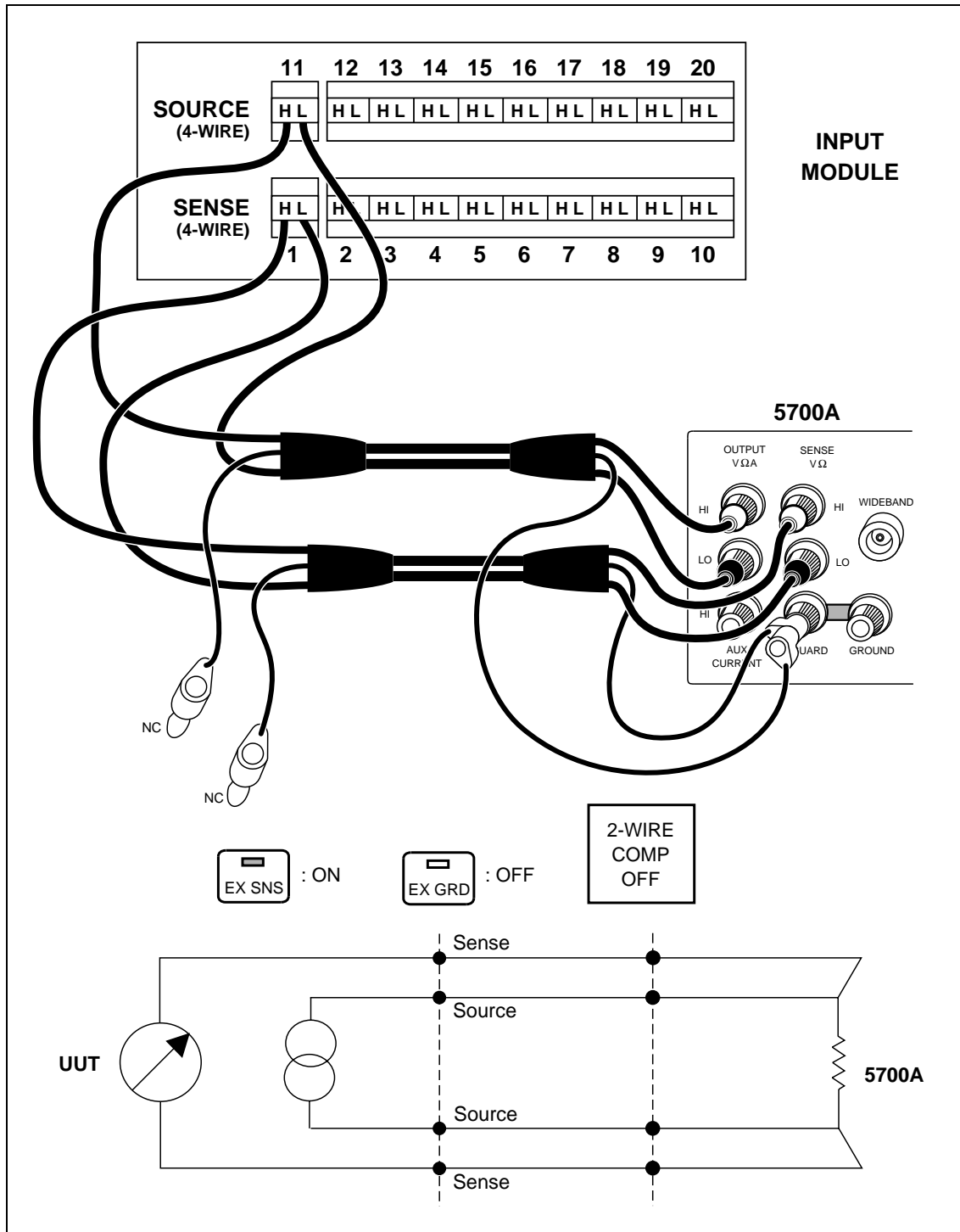
Figure 4-4. Four-Terminal Connections to the Universal Input Module (5700A)

4. **Verify Accuracy** Configure the Decade Resistance Source for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 2).

Resistance Range	Decade Resistor	Minimum Reading*	Maximum Reading*
300Ω	Short Circuit (Zero)	0Ω	0.050Ω
300Ω	290Ω	289.861Ω	290.139Ω
3 kΩ	Short Circuit (Zero)	0Ω	0.50Ω
3 kΩ	2.9 kΩ	2.89849 kΩ	2.90137 kΩ
30 kΩ	29 kΩ	28.9834 kΩ	29.0166 kΩ
300 kΩ	290 kΩ	289.621 kΩ	290.379 kΩ
3 MΩ	2.9 MΩ	2.89146 MΩ	2.90854 MΩ
* The resistance accuracy in this table makes allowance for up to 0.01% decade resistance tolerance.			

Resistance Range	5700A	Minimum Reading	Maximum Reading
300Ω	Short Circuit (Zero)	0Ω	0.050Ω
300Ω	190Ω	189.912Ω	190.088Ω
3 kΩ	Short Circuit (Zero)	0Ω	0.50Ω
3 kΩ	1.9 kΩ	1.89912 kΩ	1.90088 kΩ
30 kΩ	19 kΩ	18.9893 kΩ	19.0107 kΩ
300 kΩ	190 kΩ	189.750 kΩ	190.250 kΩ
3 MΩ	1.9 MΩ	1.89425 MΩ	1.90575 MΩ

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Four-Terminal Resistance Accuracy Test (2645A) 4-17.

Ensure that the Accuracy Tests (above) have been completed before performing this test on the 2645A.

1. **Connect the Resistance Source to Channels 1 and 11** Remove the Universal Input Module from the instrument and connect a cable from the Decade Resistance Source to the Universal Input Module terminals for channel 1 (Sense) and channel 11 (Source) as shown in Figure 4-3. Reinstall the Universal Input Module. You may also use the 5700A resistance calibration output instead of the Decade Resistance Source. Tables are provided for both connections. Refer to Figure 4-4 for the 5700A four-wire connections.

2. **Configure Channel 1 for Resistance** In NetDAQ *Logger for Windows*, configure channel 1 for Ohms-4T, 300 range.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 01. Click OK to open the Spy window.

4. **Verify Accuracy** Configure the Decade Resistance Source for the output values below and verify the Spy window measurement is between the minimum and maximum values. Change the channel 1 range as required (see Step 2).

Resistance Range	Decade Resistor	Minimum Reading*	Maximum Reading*
300Ω	Short Circuit (Zero)	0Ω	0.1Ω
300Ω	290Ω	289.81Ω	290.19Ω
3 kΩ	Short Circuit (Zero)	0Ω	1.0Ω
3 kΩ	2.9 kΩ	2.8981 kΩ	2.9019 kΩ
30 kΩ	29 kΩ	28.981 kΩ	29.019 kΩ
300 kΩ	290 kΩ	288.37 kΩ	291.63 kΩ
3 MΩ	2.9 MΩ	2.8600 MΩ	2.9400 MΩ
* The resistance accuracy in this table makes allowance for up to 0.01% decade resistance.			

Resistance Range	5700A	Minimum Reading	Maximum Reading
300Ω	Short Circuit (Zero)	0Ω	0.1Ω
300Ω	190Ω	189.86Ω	190.14Ω
3 kΩ	Short Circuit (Zero)	0Ω	1.0Ω
3 kΩ	1.9 kΩ	1.8986 kΩ	1.9014 kΩ
30 kΩ	19 kΩ	18.986 kΩ	19.014 kΩ
300 kΩ	190 kΩ	188.90 kΩ	191.10Ω
3 MΩ	1.9 MΩ	1.8733 MΩ	1.9267 MΩ

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

RTD Temperature Accuracy Test (Resistance) (2640A)   *4-18.*

The following RTD accuracy test applies to the 2640A and uses the four-wire connection (see Figure 4-3).

1. **Connect the Decade Resistance Source to Channels 1 and 11** Remove the Universal Input Module from the instrument and connect a cable from the Decade Resistance Source to the Universal Input Module terminals for channel 1 (Sense) and channel 11 (Source) as shown in Figure 4-3.

2. **Configure Channel 1 for RTD-4W** In NetDAQ *Logger for Windows*, configure channel 1 for RTD-4W and RTD R0 for 100 ohms.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 01. Click OK to open the Spy window.

4. **Verify Accuracy** Configure the Decade Resistance Source for the output values below and verify the Spy window simulated temperature measurement is between the minimum and maximum values.

Decade Resistance Source Value	Simulated Temperature (°C)	Minimum Reading	Maximum Reading
100	0°C	-0.13°C	+0.13°C
200	266.34°C	266.13°C	266.55°C
300	557.70°C	557.40°C	558.00°C

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

RTD Temperature Accuracy Test (Resistance) (2645A)   4-19.

The following RTD accuracy test applies to the 2645A and uses the four-wire connection (see Figure 4-3).

1. **Connect the Decade Resistance Source to Channels 1 and 11** Remove the Universal Input Module from the instrument and connect a cable from the Decade Resistance Source to the Universal Input Module terminals for channel 1 (Sense) and channel 11 (Source) as shown in Figure 4-3.

2. **Configure Channel 1 for RTD-4W** In NetDAQ *Logger for Windows*, configure channel 1 for RTD-4W and RTD R0 for 100 ohms.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 01. Click OK to open the Spy window.

4. **Verify Accuracy** Configure the Decade Resistance Source for the output values below and verify the Spy window simulated temperature measurement is between the minimum and maximum values.

Decade Resistance Source Value	Simulated Temperature (°C)	Minimum Reading	Maximum Reading
100	0°C	-0.31°C	+0.31°C
200	266.34°C	265.94°C	266.74°C
300	557.70°C	557.07°C	558.33°C

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

RTD Temperature Accuracy Test (DIN/IEC 751 RTD)   4-20.

The following RTD accuracy test applies to both the 2640A and 2645A and uses the four-wire connection (see Figure 4-3).

1. **Connect the RTD Source to Channels 1 and 11** Remove the Universal Input Module from the instrument and connect the RTD to the Universal Input Module terminals for channel 1 (Sense) and channel 11 (Source) as shown in Figure 4-3.

2. **Configure Channel 1 for RTD-4W** In NetDAQ *Logger for Windows*, configure channel 1 for RTD-4W and RTD R0 for 100 ohms (assuming the reference R0=100; enter the correct value for R0).

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select analog channel 01. Click OK to open the Spy window.
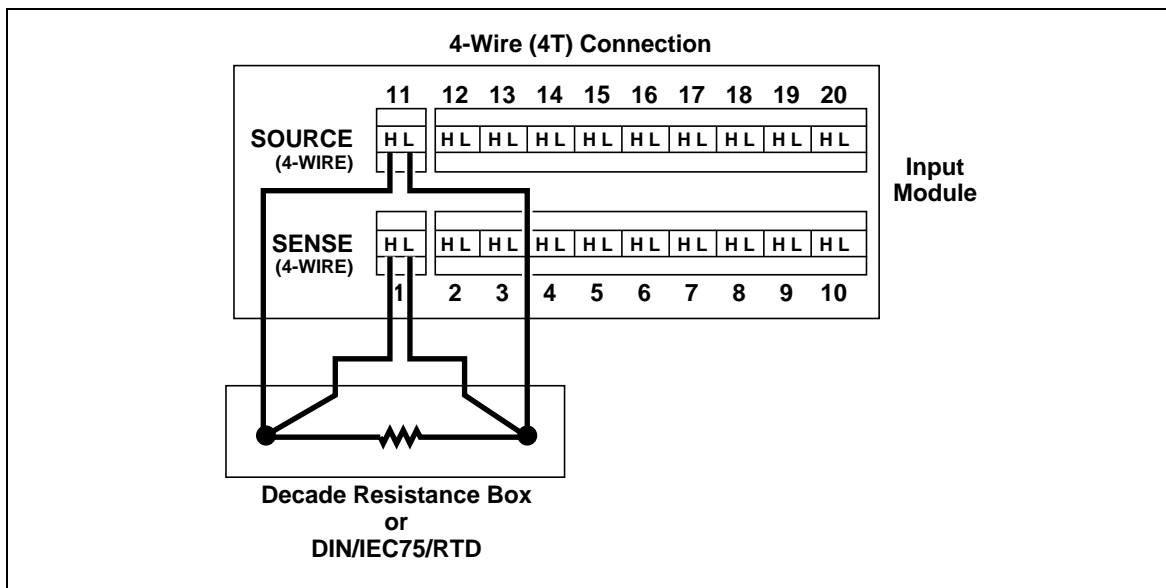
4. **Verify Accuracy** Insert the RTD and a mercury thermometer in a room-temperature bath. Allow 20 minutes for thermal stabilization. The value displayed on the mercury thermometer should equal the value in the Spy Window $\pm$0.15°C (2640A) or $\pm$0.32°C (2645A) plus sensor inaccuracies.

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Digital Input/Output Tests   4-21.

The Digital Input/Output Tests check the eight Digital I/O lines on the DIGITAL I/O connector for output and input functions.

Digital I/O Output Test   4-22.

This test checks the Digital I/O lines when used as outputs.

1. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01DIO. Click OK to open the Spy window.

2. **Verify Digital I/O Output for all Unset Lines** The Spy window summarizes the 8 DIO binary lines as a decimal equivalent, i.e., 255 for the present condition of all lines unset (11111111).

3. **Measure DIO Lines** Using a digital multimeter, measure the output of each DIO line, referenced to the GND line, for a voltage greater than +3.8V dc.

4. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

5. **Configure Channels 1 to 8 for Volts DC** In NetDAQ *Logger for Windows*, configure channels 1 to 8 for Volts dc, 3V range.

6. **Configure Channels 1 to 8 for Alarms** In NetDAQ *Logger for Windows*, configure each channel 1 to 8 for an Alarm 1 with Alarm Sense=LO, Alarm Value=1 and Digital Outputs assigned as below.

> Channel 1 - Digital Output DO0
> Channel 2 - Digital Output DO1
> Channel 3 - Digital Output DO2
> Channel 4 - Digital Output DO3
> Channel 5 - Digital Output DO4
> Channel 6 - Digital Output DO5
> Channel 7 - Digital Output DO6
> Channel 8 - Digital Output DO7

7. **Verify Channels and Alarm Configuration** After Steps 5 and 6 are completed, the portion of the Main Window for channels and alarms configuration will appear as shown below.

Chan	Function	Range	Alarm 1	Alarm 2	Trg	Mx+B	Units	Label
0101	VDC	3V	LO->DO0	OFF	NA	OFF	VDC	Label
0102	VDC	3V	LO->DO1	OFF	NA	OFF	VDC	Label
0103	VDC	3V	LO->DO2	OFF	NA	OFF	VDC	Label
0104	VDC	3V	LO->DO3	OFF	NA	OFF	VDC	Label
0105	VDC	3V	LO->DO4	OFF	NA	OFF	VDC	Label
0106	VDC	3V	LO->DO5	OFF	NA	OFF	VDC	Label
0107	VDC	3V	LO->DO6	OFF	NA	OFF	VDC	Label
0108	VDC	3V	LO->DO7	OFF	NA	OFF	VDC	Label

8. **Start Instrument Scanning** Click the Start Instrument button on the Button Bar to start the instruments scanning. The instruments must be scanning to set the DIO lines.

9. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01DIO. Click OK to open the Spy window.

10. **Verify Digital I/O Output for all Set Lines** The Spy window summarizes the 8 DIO binary lines as a decimal equivalent, i.e., 0 for the present condition of all lines set (00000000).

11. **Measure DIO Lines** Using a digital multimeter, measure the output of each DIO line, referenced to the GND line, for a voltage less than +0.8V dc.

12. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

13. **Stop Instrument Scanning** Click the Stop Instrument button on the Button Bar to stop the instruments scanning.

Digital Input Test   4-23.

This test checks the Digital I/O lines when used as inputs.

1. **Connect Test Leads to DIGITAL I/O Connector** Remove the 10-position DIGITAL I/O connector from the instrument rear panel. Connect a test lead to each DIO line 0 to 7, plus a test lead to the GND line. Also connect a test lead to the Σ (Totalizer) output. Reinstall the connector.

2. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01DIO. Click OK to open the Spy window.

3. **Verify Digital I/O Input for all Set Lines** In sequence, individually ground each DIO line to the GND line using the DIO wires connected in Step 1. Note the change in the DIO status reported in the Spy window as follows:

> None grounded Reported DIO Status = 255
> DIO0 grounded Reported DIO Status = 254
> DIO1 grounded Reported DIO Status = 253
> DIO2 grounded Reported DIO Status = 251
> DIO3 grounded Reported DIO Status = 247
> DIO4 grounded Reported DIO Status = 239
> DIO5 grounded Reported DIO Status = 223
> DIO6 grounded Reported DIO Status = 191
> DIO7 grounded Reported DIO Status = 127

4. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

Totalizer Tests   4-24.

The Totalizer Tests check the Totalizer feature for counting and sensitivity.

Totalizer Count Test   4-25.

This test checks the ability of the Totalizer feature to count.

1. **Configure Channel 1 for Volts DC** In NetDAQ *Logger for Windows*, configure channel 1 for Volts dc, 3V range.

2. **Configure Channel 1 for Alarms** In NetDAQ *Logger for Windows*, configure channel 1 for an Alarm 1 with Alarm Sense=LO, Alarm Value=1 and Digital Output=DO0.

3. **Connect Test Leads** At the DIGITAL I/O connector, connect the DIO0 test lead to the Σ (Totalizer) test lead.

4. **Start Instrument Scanning** Click the Start Instrument button on the Button Bar to start instrument scanning. Scanning is initiated to enable the return of TOTAL status to the Spy window.

5. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01TOTAL. Click OK to open the Spy window.

6. **Verify Totalizer Count** The current totalizer count is 1 since it counted the number of times channel 1 went into alarm.

7. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

8. **Increase Totalizer Count** Alternately click the Stop Instrument and Start Instrument buttons several times, which advances the Totalizer count as channel 1 goes into alarm at the start of each scan.

9. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01TOTAL. Click OK to open the Spy window.

10. **Verify Totalizer Count** The Spy window summarizes the new Totalizer count and is equal to the number of times the instrument has started and stopped scanning since the beginning of this test.

11. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

12. **Stop Scanning** Click the Stop Instrument button on the Button Bar to stop instrument scanning.

Totalizer Sensitivity Test   4-26.

This test checks the ability of the Totalizer feature to count voltage transition at a particular sensitivity level.

1. **Connect Test Leads** At the DIGITAL I/O connector, connect the Σ (Totalizer) test lead and GND test lead to a signal generator's output terminals. Adjust the signal generator for an output of 1.5V rms sine wave at 10 Hz.

2. **Start Instrument Scanning** Click the Start Instrument button on the Button Bar to start instrument scanning. Scanning is initiated to enable the return of TOTAL status to the Spy window.

3. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01TOTAL. Click OK to open the Spy window.

4. **Verify Totalizer Count** The Spy window summarizes the Totalizer count. Verify the totalizer count is advancing at approximately 10 Hz per Spy window update (nominal 1 second intervals).

5. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

6. **Stop Scanning** Click the Stop Instrument button on the Button Bar to stop instrument scanning.

Master Alarm Output Test   *4-27.*

This test checks the Master Alarm output for a logic low when a channel is in alarm.

1. **Connect Test Leads to ALARM/TRIGGER I/O Connector** Remove the 8-position ALARM/TRIGGER I/O connector from the instrument rear panel. Connect a test lead to each line, MA (Master Alarm), TO (Trigger Output), TI (Trigger Input), plus a test lead to the GND line. Reinstall the connector.

2. **Measure Unset MA Line** Using a digital multimeter, measure the output of the unset MA test lead, referenced to the GND test lead, for a voltage greater than +3.8V dc.

3. **Verify Configuration Channel 1 for Volts DC** In NetDAQ *Logger for Windows*, verify channel 1 is configured for Volts dc, 3V range.

4. **Verify Configuration Channel 1 for Alarms** In NetDAQ *Logger for Windows*, verify channel 1 is configured for an Alarm 1 with Alarm Sense=LO, Alarm Value=1 and Digital Output=DO0.

5. **Start Instrument Scanning** Click the Start Instrument button on the Button Bar to start instrument scanning. Scanning is initiated to enable the Master Alarm output.

6. **Measure Set MA Line** Using a digital multimeter, measure the output of the set MA test lead, referenced to the GND test lead, for a voltage less than +0.8V dc.

7. **Stop Scanning** Click the Stop Instrument button on the Button Bar to stop instrument scanning.

Trigger Input Test   *4-28.*

This test checks the ability of the Trigger Input line to trigger measurement scanning.

1. **Configure Trigger Input** In NetDAQ *Logger for Windows*, configure the scan parameters for External Trigger with an Interval 2 of 1 second. Be sure Interval Trigger is not enabled.

2. **Verify Configuration Channel 1 for Volts DC** In NetDAQ *Logger for Windows*, verify channel 1 is configured for Volts dc, 3V range.

3. **Start Instrument Scanning** Click the Start Instrument button on the Button Bar to enable instrument scanning, although no measurement scanning takes place because the external Trigger Input is not set.

4. **Open Logging Status Window** Select the Show Logging Status command from the Options menu to display the Logging Status window.

5. **Verify Logging Status** Note in the Logging Status window that the Retrieved Scans count is zero and not incrementing.

6. **Set Trigger Input** While monitoring the Logging Status window, connect the TI (Trigger Input) test lead to the GND test lead. Note in the Logging Status window, the Retrieved Scans count increments at 1-second intervals. Disconnect the TI and GND test lead connection.

7. **Stop Scanning** Click the Stop Instrument button on the Button Bar to stop instrument scanning.

Trigger Output Test   *4-29.*

This test checks the Trigger Output (125μs logic low) that occurs each time the instrument scans.

1. **Configure Interval Trigger** In NetDAQ *Logger for Windows*, configure the scan parameters for Interval Trigger with an Interval 1 of 1 second.

2. **Verify Configuration Channel 1 for Volts DC** In NetDAQ *Logger for Windows*, verify channel 1 is configured for Volts dc, 3V range.

3. **Measure Unset Trigger Output Line** Using a digital multimeter, measure the output of the unset TO test lead, referenced to the GND test lead, for a voltage greater than +3.8V dc.

4. **Verify Trigger Output is Enabled** In NetDAQ *Logger for Windows*, click the Instrument Config button on the Button Bar. In the Instrument Configuration dialog box, verify the Trigger Out box is checked. Click OK to return to the Main Window.

5. **Connect Trigger Output** Connect the TO test lead on the ALARM/TRIGGER IO connector to the Σ (Totalizer) test lead on the DIGITAL I/O connector. This allows each Trigger Output pulse to be counted by the Totalizer.

6. **Start Instrument Scanning** Click the Start Instrument button on the Button Bar to enable instrument scanning.

7. **Open Spy Window** Select the Spy command from the Utilities menu. Select 01TOTAL. Click OK to open the Spy window.

8. **Verify Totalizer Count** The Spy window summarizes the Totalizer count. Note the Totalizer is incrementing at 1-second intervals as it counts the Trigger Output pulse at the start of each scan.

9. **Close Spy Window** To close the Spy window, double-click the upper left-hand corner control-menu box.

10. **Stop Scanning** Click the Stop Instrument button on the Button Bar to stop instrument scanning.

Calibration   4-30.

The instrument features calibration that is completed over the NetDAQ networked data acquisition unit RS-232 interface, and it is not necessary to open the instrument case. Using known reference sources, closed-case calibration has many advantages. There are no parts to disassemble, no mechanical adjustments to make, and the instrument can be calibrated by an automated instrumentation system. The instrument should normally be calibrated on a regular cycle, typically every 90 days to 1 year. The chosen calibration cycle depends on the accuracy specification you wish to maintain. The instrument should also be calibrated if it fails the performance test or has undergone repair.

The calibration procedure uses the CAL ENABLE switch under the Calibration Seal on the instrument front panel. Do not press CAL ENABLE unless you intend to calibrate the instrument. If you have entered calibration and wish to exit, press CAL ENABLE until CAL is removed from the primary display, or just turn the instrument power off.

Once the instrument is in calibration mode, closed-case calibration is made for the four calibration groups as follows:

- Volts DC
- Volts AC
- Resistance
- Frequency

Once begun, each group must be completed successfully for the results of the calibration to be made permanent. It is not necessary to perform all calibration groups.

Methods of Calibration   4-31.

There three methods of instrument calibration as follows:

- **Automatic using Fluke MET/CAL software** MET/CAL is a software package developed by Fluke that automates the calibration of Fluke instruments and popular instruments from other selected manufacturers.

- **Semiautomatic using NetDAQ *Logger for Windows*** Calibration takes place in conjunction with NetDAQ *Logger for Windows*, that is, a feature of the software is used to calibrate the instrument. Since calibration is accomplished over an RS-232 connection between the instrument RS-232 port and a host computer serial COM port, it is not necessary to have a network connection to accomplish calibration.

- **Manual using a terminal and individual commands** Calibration takes place using a host computer in a terminal mode. With this method all commands and responses are considered individually.

All methods use the instrument RS-232 serial interface. Procedures cannot be performed over the network interface or from the instrument front panel.

Preparing for Calibration   4-32.

Regardless of the method you are using for calibration (automatic, semiautomatic, or manual), the preparation for calibration is identical. Complete the following procedure to prepare for calibration.

1. Connect the instrument RS-232 serial port to a host computer COM serial port as shown in Figure 4-5. You can connect two instruments as shown, although only one is calibrated at a time. The "RS" cables used are standard null-modem cables (reversed transmit and receive lines) that may be ordered from Fluke.

2. Wire the Universal Input Module so the high and low inputs to channels 1 and 11 are externally available. In addition, a four-wire short must be applied to channels 2 and 12. (See Figure 4-6.) Plug the module into the instrument.

3. Power the instrument and allow at least a 30-minute warmup period. The instrument must be stabilized in an environment with an ambient temperature of 22 to 24°C and relative humidity of less than 70%.

4. Using the buttons at the instrument front panel, set the desired baud rate for the instrument RS-232 port (see below). This is the only selectable RS-232 parameter. The other instrument RS-232 parameters are fixed: data bits=8; stops bits=1; parity=none; echo=none; flow control=xon/xoff.

COMM	Press the COMM key to <u>review</u> the baud rate, or press and hold the COMM key for 3 seconds to <u>set</u> the baud rate (the SET annunciator lights).
▲ ▼	Press the up/down arrow keys until rS232 is shown in the primary display (comm is displayed in the secondary display).
ENTER	Press the ENTER key. bAud is displayed in the secondary display and the current baud rate in the primary display.
▲ ▼	Press the up/down arrow keys to select the desired number baud rate: 4800, 9600, 19200, or 38400. The factory default value is 9600 baud.
ENTER	Press the ENTER key to exit. (Pressing any other function key will cancel <u>set</u> operations.)

5. Activate the calibration mode at the instrument by pressing and holding the instrument front panel CAL Enable button for approximately 4 seconds. Release the button after instrument beeps and CAL is shown on the primary display.

NOTE

The CAL Enable button is located on the right side of the display beneath a calibration seal. Press this button with a blunt-tipped object. Do not press CAL ENABLE unless you intend to calibrate the instrument. If you have activated Calibration and wish to exit, press CAL ENABLE momentarily a second time, or turn the instrument off.
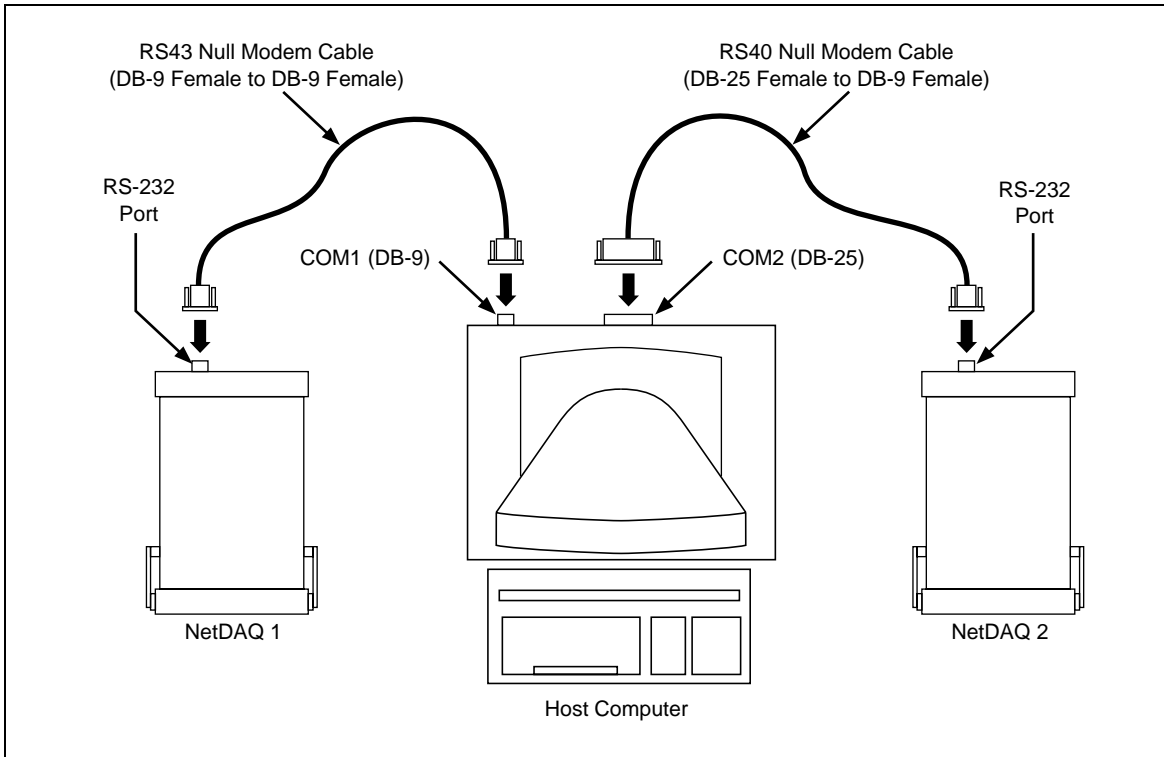
Figure 4-5. Instrument and Host Computer Calibration Setup
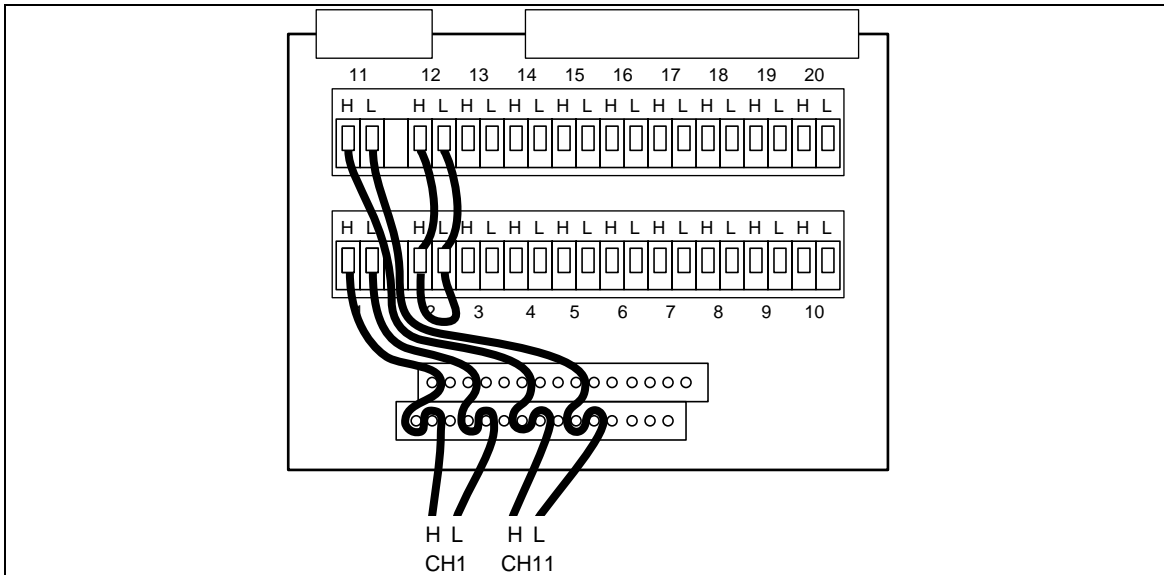
Figure 4-6. Universal Input Module Calibration Connections

There are two connection methods used between the leads from the instrument Universal Input Module and the 5700A Calibrator. The volts dc, volts ac, and resistance functions use the two-wire connection shown in Figure 4-7. The resistance function uses the four-wire connection shown in Figure 4-8.

Ending Calibration 4-33.

When you are using the manual method of calibration and have completed the calibration of the desired functions (dc volts, ac volts, ohms, and frequency), press the front panel CAL Enable button again to clear CAL from the primary display. When using the calibration features of NetDAQ *Logger for Windows*, calibration is ended automatically when you exit the calibration mode.

RS-232 Instrument Configuration Parameters 4-34.

When CAL is shown in the primary display indicating you are in the calibration mode, the instrument configuration parameters are set as listed in Table 4-2.

Table 4-2. RS-232 Instrument Configuration for Calibration Procedures

Parameter	Setting
Channel Configuration	Unique to calibration step
Reading Rate	Slow
Trigger Type	All disabled
Intervals	All disabled
Drift Correction	Enabled
External Trigger Output	Disabled
Temperature Units	Celsius
Queue Overflow Mode	Discard old
Totalizer Debounce	Disabled
Autodisable Scanning	On

Calibration Procedure (Automatic) 4-35.

Automatic calibration uses Fluke MET/CAL software. All procedures are provided in the MET/CAL Users Manual. These procedures assume you have completed the "Preparing for Calibration" procedure above.

Calibration Procedure (Semiautomatic) 4-36.

Semiautomatic calibration uses the calibration feature built into the NetDAQ *Logger for Windows* software. This procedure assumes you have completed the "Preparing for Calibration" procedure above.

Complete the following procedure to calibrate an instrument using NetDAQ *Logger for Windows* software. This procedure integrates the four calibration cycles: VDC, VAC, ohms, and frequency. Complete only the cycle or cycles of interest.

1. If you have not already done so, complete the "Preparing for Calibration" procedure earlier in this chapter. Note the instrument baud rate and host computer COM port used for interconnection.
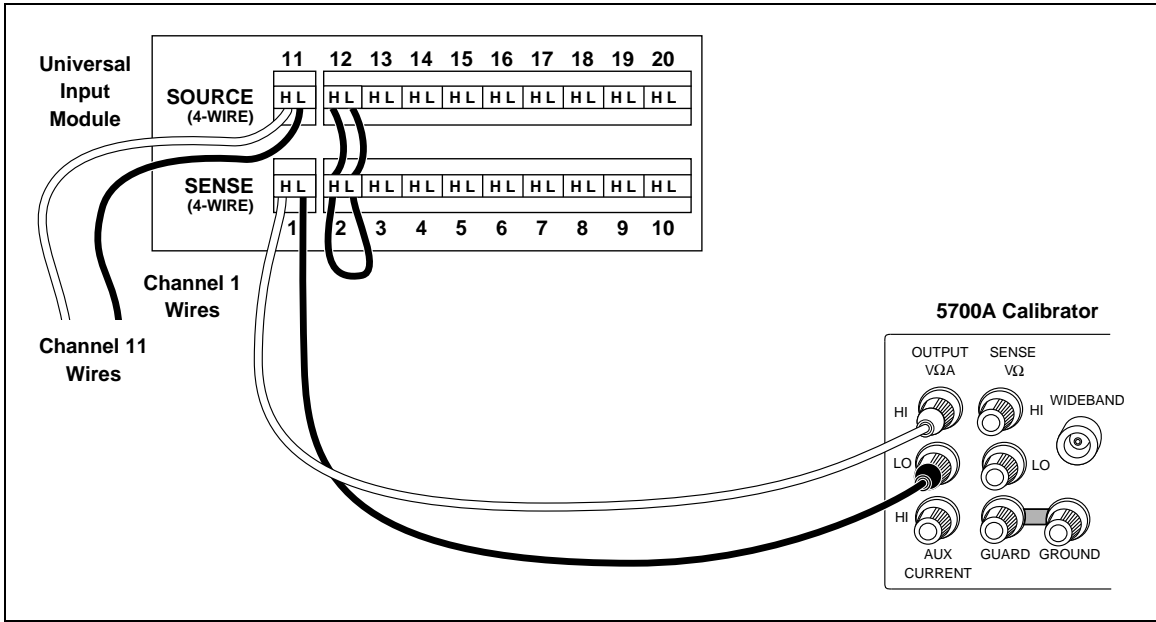
Figure 4-7. Two-Wire Calibration Connection
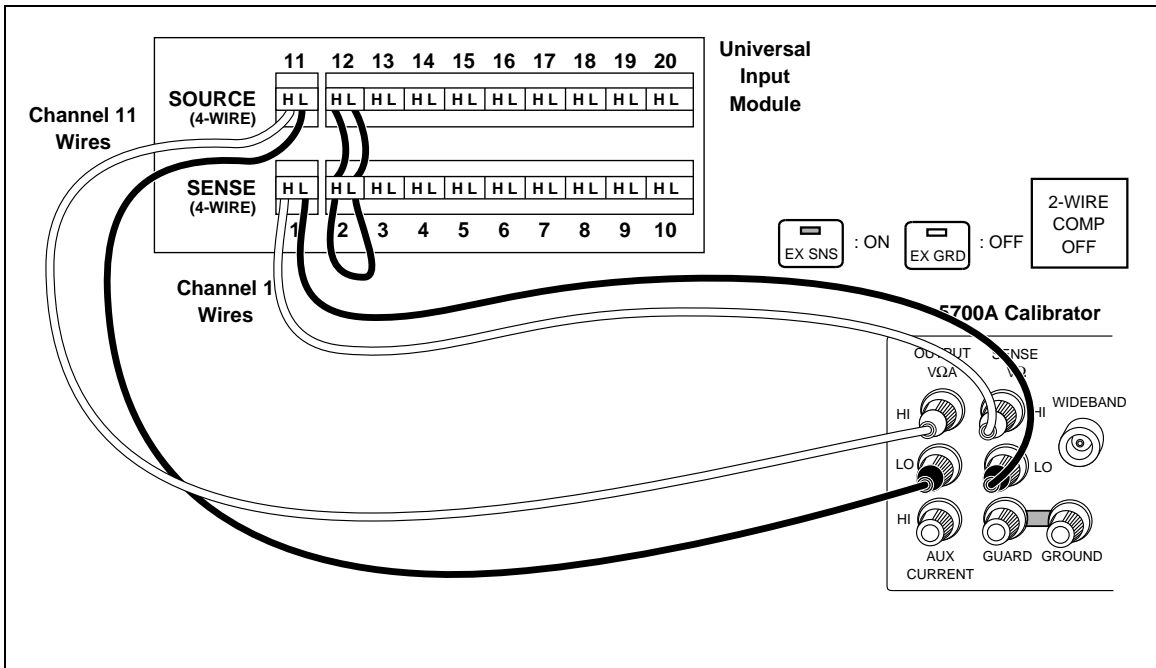
Figure 4-8. Four-Wire Calibration Connection

2. At the host computer, open NetDAQ Logger from the Fluke NetDAQ Logger group in Program Manager. Under the Utilities menu, look for a listing of the command Instrument Calibration (see below). If the Instrument Calibration command is shown, continue to Step 4; otherwise, continue to Step 3.
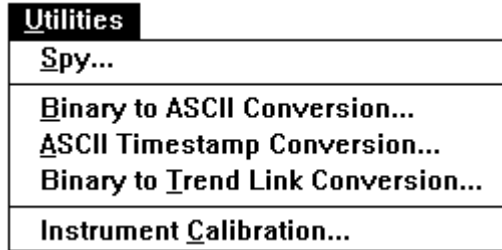
3. Close the *Logger for Windows* application. Complete the following procedure to append the /C switch on the NetDAQ Logger command line, which enables and displays the Instrument Calibration command under the Utilities menu.

    a. Select (but do not open) the NetDAQ Logger icon in the Fluke NetDAQ Logger group in Program Manager (below).
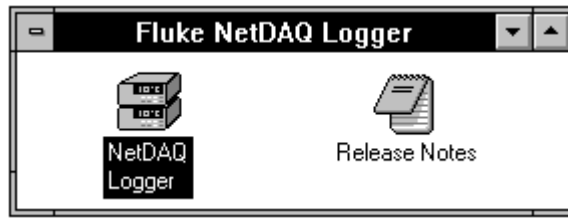
    b. Select the Properties command in Program Manager File menu to open the Program Item Properties dialog box.

    c. Append the /C switch at the end of the command line text. Example: `C:\NETDAQ\NETDAQ.EXE /C`, as shown below. If you have also included a setup file on the command line, place the /C switch after the setup file name. Click OK.
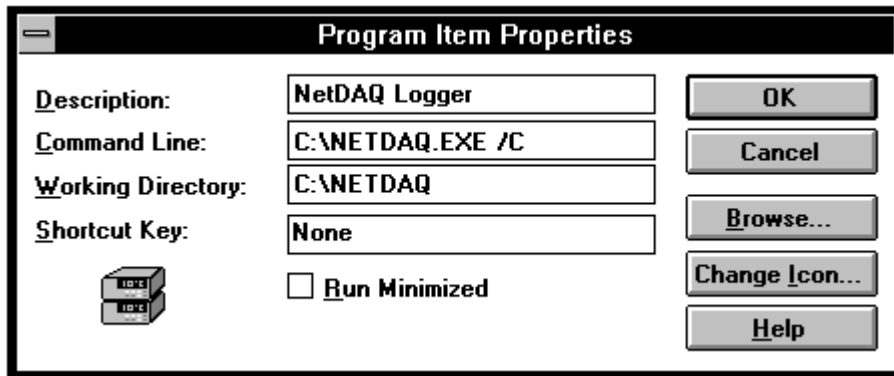
    d. Open NetDAQ Logger from the Fluke NetDAQ Logger group in Program Manager.

4. Select the Instrument Calibration command from the Utilities menu, opening the Instrument Calibration dialog box (below).
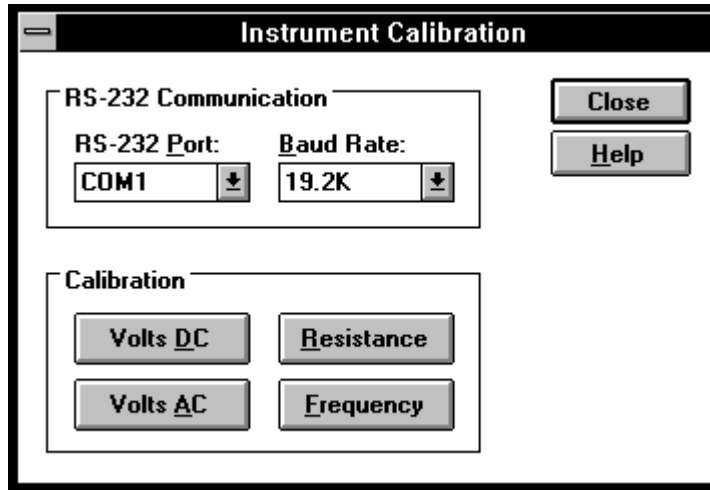
5. Select the COM port and baud rate noted in Step 1. The instrument default baud rate is 9600 baud.

VDC Calibration Procedure   4-37.

This procedure uses the calibration feature of NetDAQ *Logger for Windows*. Complete the "Calibration Procedure (Semiautomatic)" before using this procedure.

1. Click the Volts DC button in the Instrument Calibration dialog box, opening the first Calibration Steps - Volts DC dialog box (below).
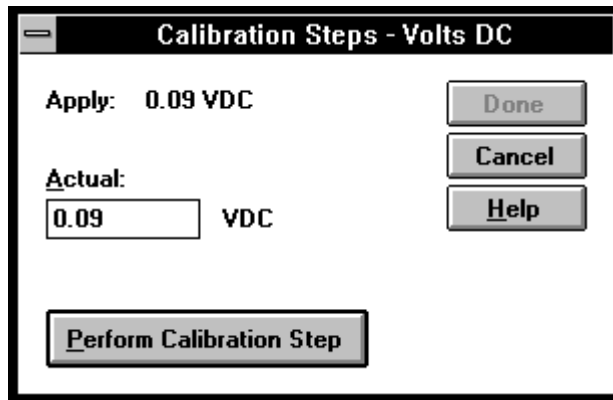
If you get an error message, check the RS-232 parameter settings, and cabling, and make sure no other application such as terminal or internal modem is using the selected COM port. The error "Calibration Mode not enabled" means you have not pressed the CAL enable button at the instrument front panel.

2. Connect the 5700A Calibrator as shown in Figure 4-7 and source an output of 0.09V dc. Click the Perform Calibration Step button to calibrate the selected value. After the calibration step completes, the next calibration appears in the Actual box.

3. In a similar manner, source the 5700A Calibrator for the values 0.3V, .75V, 3V and so forth until the Done button is no longer dimmed.

4. Click the Done button to exit the volts dc calibration cycle.

5. If this completes your calibration requirements, click the Close button in the Instrument Calibration dialog box to return to the NetDAQ *Logger for Windows* Main Window. Otherwise, continue to the next calibration function.

VAC Calibration Procedure *4-38.*

This procedure uses the calibration feature of NetDAQ *Logger for Windows*. Complete the "Calibration Procedure (Semiautomatic)" before using this procedure.

1. Click the Volts AC button in the Instrument Calibration dialog box, opening the first Calibration Steps - Volts AC dialog box (below).
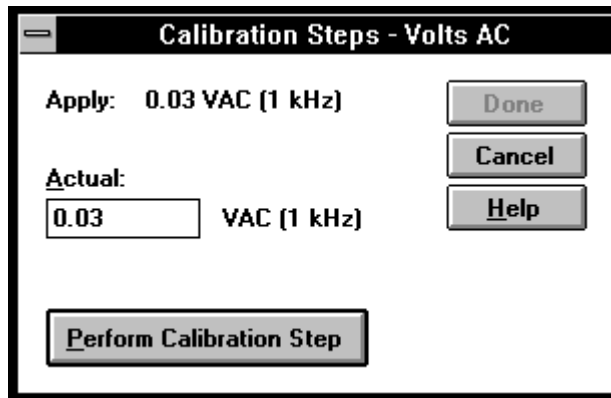
```
┌─────────────────────────────────────────┐
│ ▭      Calibration Steps - Volts AC       │
├─────────────────────────────────────────┤
│                                           │
│  Apply:   0.03 VAC (1 kHz)      ┌───────┐ │
│                                 │ Done  │ │
│                                 └───────┘ │
│                                 ┌───────┐ │
│  Actual:                        │Cancel │ │
│  ┌──────────┐                   └───────┘ │
│  │ 0.03     │   VAC (1 kHz)     ┌───────┐ │
│  └──────────┘                   │ Help  │ │
│                                 └───────┘ │
│                                           │
│  ┌──────────────────────────┐            │
│  │ Perform Calibration Step  │            │
│  └──────────────────────────┘            │
└─────────────────────────────────────────┘
```

If you get an error message, check the RS-232 parameter settings, and cabling, and make sure no other application such as terminal or internal modem is using the selected COM port. The error "Calibration Mode not enabled" means you have not pressed the CAL enable button at the instrument front panel.

2. Connect the 5700A Calibrator as shown in Figure 4-7 and source an output of 0.03V ac at a frequency of 1 kHz. Click the Perform Calibration Step button to calibrate the selected value. After the calibration step completes, the next calibration appears in the Actual box.

3. In a similar manner, source the 5700A Calibrator for the values 0.3V, 0.3V, 3V, 3V (values repeat) and so forth until the Done button is no longer dimmed.

4. Click the Done button to exit the volts ac calibration cycle.

5. If this completes your calibration requirements, click the Close button in the Instrument Calibration dialog box to return to the NetDAQ *Logger for Windows* Main Window. Otherwise, continue to the next calibration function.

Resistance Calibration Procedure 4-39.

This procedure uses the calibration feature of NetDAQ *Logger for Windows*. Complete the "Calibration Procedure (Semiautomatic)" before using this procedure.

1. Click the Resistance button in the Instrument Calibration dialog box, opening the first Calibration Steps - Resistance dialog box (below).
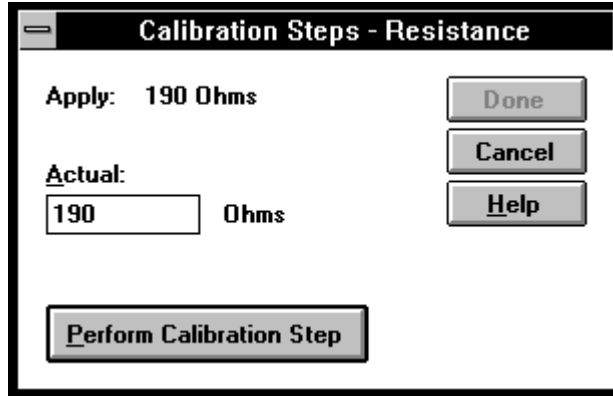
```
┌─────────────────────────────────────────┐
│ ─     Calibration Steps - Resistance    │
│                                          │
│  Apply:   190 Ohms          ┌─────────┐  │
│                             │  Done   │  │
│                             └─────────┘  │
│  Actual:                    ┌─────────┐  │
│  ┌──────────┐               │ Cancel  │  │
│  │190       │  Ohms         └─────────┘  │
│  └──────────┘               ┌─────────┐  │
│                             │  Help   │  │
│                             └─────────┘  │
│  ┌────────────────────────────────┐      │
│  │  Perform Calibration Step      │      │
│  └────────────────────────────────┘      │
└─────────────────────────────────────────┘
```

If you get an error message, check the RS-232 parameter settings, and cabling, and make sure no other application such as terminal or internal modem is using the selected COM port. The error "Calibration Mode not enabled" means you have not pressed the CAL enable button at the instrument front panel.

2. Connect the 5700A Calibrator as shown in Figure 4-8 and source an output of 190 ohms. Note that this must be a four-wire connection. Also verify the calibrator output is set up for a four-wire source. Click the Perform Calibration Step button to calibrate the selected value. After the calibration step completes, the next calibration appears in the Actual box.

3. In a similar manner, source the 5700A Calibrator for the values 1.9k, 19k, 190k ohms and so forth until the Done button is no longer dimmed.

4. Click the Done button to exit the resistance calibration cycle.

5. If this completes your calibration requirements, click the Close button in the Instrument Calibration dialog box to return to the NetDAQ *Logger for Windows* Main Window. Otherwise, continue to the next calibration function.

Frequency Calibration Procedure 4-40.

This procedure uses the calibration feature of NetDAQ *Logger for Windows*. Complete the "Calibration Procedure (Semiautomatic)" before using this procedure.

1. Click the Frequency button in the Instrument Calibration dialog box, opening the Calibration Steps - Frequency dialog box (below).
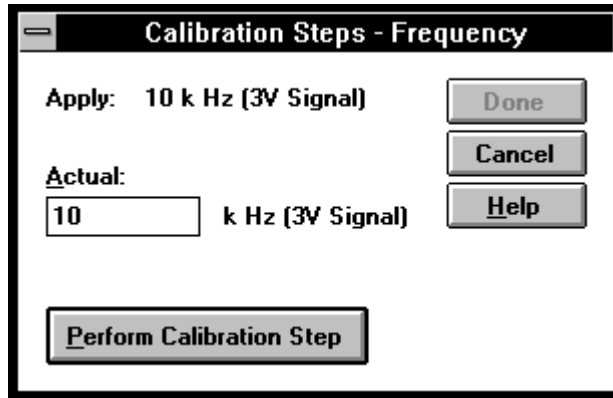
If you get an error message, check the RS-232 parameter settings, and cabling, and make sure no other application such as terminal or internal modem is using the selected COM port. The error "Calibration Mode not enabled" means you have not pressed the CAL enable button at the instrument front panel.

2. Connect the 5700A Calibrator as shown in Figure 4-7 and source an output of 3V ac at 10 kHz. Click the Perform Calibration Step button. There is only a single value.

3. Click the Done button to exit the frequency cycle.

Calibration Procedure (Manual) 4-41.

Manual calibration uses a calibration command set operated over an ASCII terminal or a computer running a terminal emulation program. The following procedure assumes you will be using the Windows Terminal feature of your host computer. If you are using a different terminal, adapt this procedure to suit.

Complete the following procedure to prepare the Windows Terminal feature.

1. Complete the "Preparing for Calibration" procedure earlier in this chapter. Note the instrument baud rate and host computer COM port that you selected for use.

2. Open Windows to the Program Manager screen on your host computer.

3. Open Terminal (below) from the Accessory group of Program Manager.
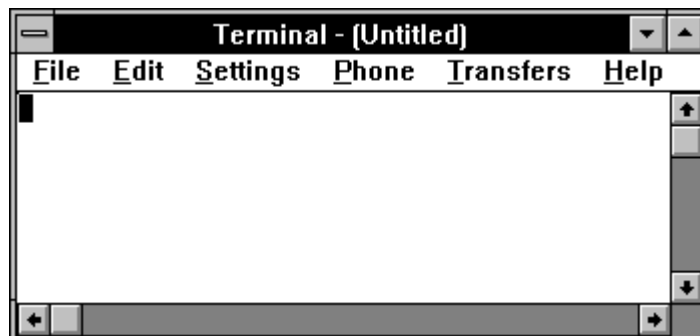
4. Select the Communications command from the Setting menu. Enter the same
RS-232 baud rate and host computer COM noted in Step 1. The other parameters are
selected as shown below. Click OK.
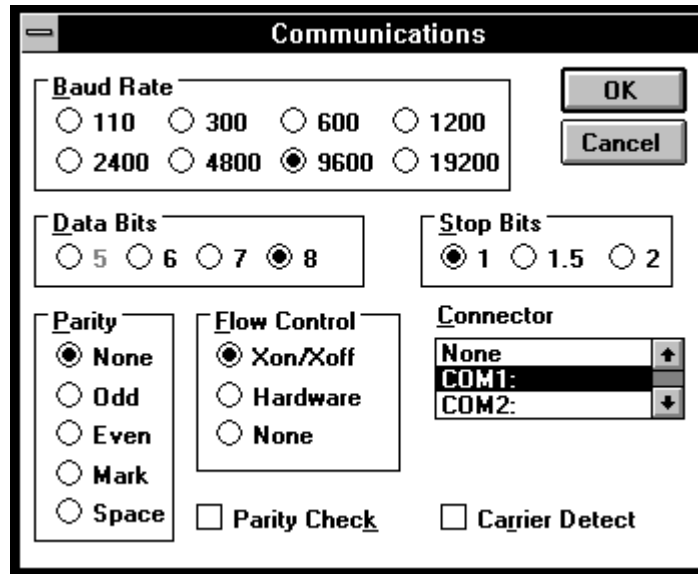
5. Select the Terminal Preferences command from the Settings menu. Check the boxes
Local Echo and Outbound (see below). Click OK.
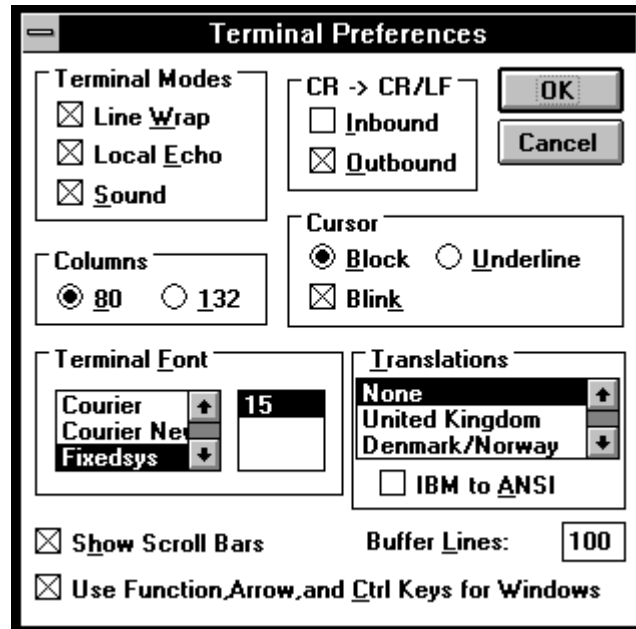
6. Press the <Enter> key a few times and notice the => returns, indicating a successful connection (see below). If you do not receive these returns, the RS-232 link is not operating. Check the communication parameter settings and cabling.

```
┌─────────────────────────────────────────────────┐
│ ─        Terminal - [Untitled]          ▼  ▲    │
│  File  Edit  Settings  Phone  Transfers  Help    │
│ =>                                            ↑  │
│                                                  │
│ =>                                               │
│ █                                                │
│                                                  │
│                                               ↓  │
│ ←  ▐▌                                      → │
└─────────────────────────────────────────────────┘
```
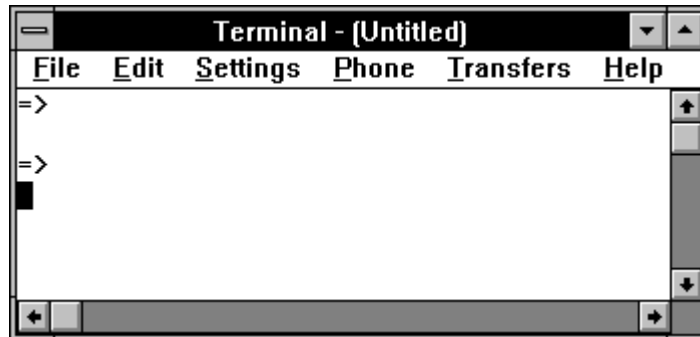
Manual Calibration Commands   4-42.

The calibration procedures are performed in the terminal mode using the commands CAL, CAL?, CAL_REF, CAL_REF?, CAL_STEP, and CAL_CLR. Refer to Table 4-3 for information regarding these commands. After each command is entered, the terminal returns one of three responses, as shown in Table 4-4.

Table 4-3. Calibration Commands

Command	Description	Cal Mode Only?
CAL x	Start calibration of a new function, where x = an integer from 1 to 4. For example, CAL 1 for VDC calibration. 1 = VDC 2 = VAC 3 = Resistance 4 = Frequency	Yes
CAL?	Return identifier of currently active calibration procedure. For example, CAL? returns 2 for active calibration of the VAC mode. 0 = No cal procedure currently active 1 = VDC 2 = VAC 3 = Resistance 4 = Frequency	Yes
CAL_REF <value>	Calibrate to <value>, rather than the default calibration reference value.	Yes
CAL_REF?	Return the present calibration reference.	Yes
CAL_STEP?	Calibrate and return the calibrated value of the input.	Yes
CAL_CLR	Reset all calibration constants to nominal values, clearing present calibration. Use with caution. This clears all contents for all functions, VDC, VAC, resistance, and frequency.	Yes

Table 4-4. Manual Calibration Command Responses

Response	Description
=>	indicates the command was executed correctly.
!>	indicates that a device-dependent error was generated and the calibration step could not be executed. Verify that the input to NetDAQ channel 1 is the correct value and polarity, is connected correctly, and the 5700A is in the Operate mode.
?>	indicates the command was entered with incorrect syntax, for example, misspelling the command. Reenter the command using the correct syntax.

Manual VDC Calibration Procedure   4-43.

The VDC calibration procedure calculates gain and offset calibration constants for all of the VDC ranges. The 750 mV range is not user accessible, but is used to measure the reference junction voltage and must be calibrated.

Complete the following procedure to manually calibrate the VDC function.

1. If you have not already done so, complete the procedure "Preparing for Calibration" earlier in this chapter.

2. Connect the instrument and 5700A Calibrator as shown in Figure 4-7.

3. Complete the sequence of manual steps shown in Table 4-5. Measuring channel 1 provides the full scale reading, and measuring the short on channel 2 determines the zero offset error. Both readings are accomplished automatically with the CAL_STEP? command.

Table 4-5. Manual VDC Calibration

Command	Response	Action
CAL 1	=>	Puts NetDAQ in VDC calibration.
CAL_REF?	+90.0000E-3	5700A - Source 90 mV dc.
CAL_STEP?	+90.0000E-3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+300.000E-3	5700A - Source 300 mV dc.
CAL_STEP?	+300.000E-3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+750.000E-3	5700A - Source 750 mV dc.
CAL_STEP?	+750.000E-3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+3.00000E+0	5700A - Source 3V dc.
CAL_STEP?	+3.00000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+30.0000E+0	5700A - Source 30V dc.
CAL_STEP?	+30.0000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+300.000E+0 (2640A) +50.0000E+0 (2645A)	5700A - Source +300V dc (2640A). 5700A - Source +50V dc (2645A).
CAL_STEP?	+300.000E+0 (2640A) +50.0000E+0 (2645A)	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.

4. Resolve any calibration problems based on the following:

    - An execution error !> is returned by the CAL_STEP? command if the full scale measurement is off by more than 5% from the target or if the zero measurement is off by more than 1% of full scale from the target. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

    - When CAL_STEP? reports an execution error !> due to an out-of-range measurement, it returns the raw measured reading to give you an indication of what was measured. When CAL_STEP? completes successfully, it returns the reference value.

    - If CAL_STEP? returns an execution error !> while measuring the short circuit on channel 2, the procedure freezes at the internal step that measures the short. This way, you can send a CAL_REF? command and it will return 0 V, indicating that the problem was probably caused by a misapplied short on channel 2.

    - A device-dependent error is returned by the CAL_STEP? command if an internal error such as a measurement timeout is detected. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

    - An execution error !> is returned by the CAL_REF command if the specified reference is less than 33% of full scale or greater than 100% of full scale.

Manual VAC Calibration Procedure 4-44.

The VAC calibration procedure calculates gain and offset calibration constants for all of the VAC ranges.

Complete the following procedure to manually calibrate the VAC function.

1. If you have not already done so, complete the procedure "Preparing for Calibration" earlier in this chapter.

2. Connect the instrument and 5700A Calibrator as shown in Figure 4-7.

3. Complete the sequence of manual steps shown in Table 4-6. Measurements are made on channel 1 for each VAC range: one at 10% of full scale and one at 100% of full scale. All AC voltages must be applied at 1 kHz. The VAC gain and offset calibration constants for each range are determined from the two measurements.

4. Resolve any calibration problems based on the following:

    - An execution error !> is returned by the CAL_STEP? command if the full-scale measurement is off by more than 10% from the target or if the low-scale measurement is off by more than 1% of full scale (10% from the target). When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

    - A device-dependent error is returned by the CAL_STEP? command if an internal error such as a measurement timeout is detected. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

    - An execution error !> is returned by the CAL_REF command for the full scale measurement if the specified reference is less than 33% of full scale or greater than 100% of full scale for any range. An execution error !> is returned by the CAL_REF command for the low scale measurement if the specified reference is less than 10% of full scale or greater than 30% of full scale for any range.

Table 4-6. Manual VAC Calibration

Command	Response	Action
CAL 2	=>	Puts NetDAQ in VAC calibration.
CAL_REF?	30.0000E-3	5700A - Source 30 mV ac @ 1 kHz
CAL_STEP?	30.0000E-3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	300.000E-3	5700A - Source 300 mV ac @ 1 kHz
CAL_STEP?	300.000E-3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	300.000E-3	5700A - Source 300 mV ac @ 1 kHz
CAL_STEP?	300.000E-3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	3.00000E+0	5700A - Source 3V ac @ 1 kHz
CAL_STEP?	3.00000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	3.0000E+0	5700A - Source 3V ac @ 1 kHz
CAL_STEP?	3.0000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	30.0000E+0	5700A - Source 30V ac @ 1 kHz
CAL_STEP?	30.0000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
[2640A only for remainder of steps]		
CAL_REF?	30.0000E+0	5700A - Source 30V ac @ 1 kHz
CAL_STEP?	30.0000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	300.0000E+0	5700A - Source 300V ac @ 1 kHz
CAL_STEP?	300.0000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.

Manual Resistance Calibration Procedure   4-45.

The resistance calibration procedure calculates gain and offset calibration constants for all of the four-wire ohms ranges. The same calibration constants are used for the corresponding two-wire ohms ranges.

Complete the following procedure to manually calibrate the ohms function.

1. If you have not already done so, complete the procedure "Preparing for Calibration" earlier in this chapter.

2. Connect the instrument and 5700A Calibrator as shown in Figure 4-8.

3. Complete the sequence of manual steps shown in Table 4-7. The default values were chosen assuming that a Fluke 5700A will be used to supply the reference resistors. For each range, channels 1 and 2 are configured to four-wire ohms and a measurement is made for each channel. Making a four-wire ohms measurement on channel 1 provides the full scale reading and measuring the four-wire short on channels 2 and 12 determines the zero offset error. The four-wire ohms gain and offset calibration constants are determined from these two measurements.

The 5700A provides a limited set of reference resistors where the best resistor for each range is at 63.3% of full scale. This will give very good results, but making the measurement closer to the full scale value using fixed resistors may give better results. When you are using fixed resistors, you must use the CAL_REF command to tell instrument the value of the new reference resistor. When you are using fixed resistors, you connect the leads as they are for any four-wire ohms measurement.

4. Resolve any calibration problems based on the following:

- An execution error !> is returned by the CAL_STEP? command if the full scale measurement is off by more than 5% from the target or if the zero measurement is off by more than 1% of full scale. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

- When CAL_STEP? reports an execution error !> due to an out-of-range measurement, it returns the raw measured reading to give you an indication of what was measured. When CAL_STEP? completes successfully, it returns the reference value.

- If CAL_STEP? returns an execution error !> while measuring the four-wire short on channels 2 and 12, the procedure freezes at the internal step that measures the short. This way, you can send a CAL_REF? command and it will return 0 W, indicating that the problem was probably caused by a misapplied short on channels 2 and 12.

- A device-dependent error is returned by the CAL_STEP? command if an internal error such as a measurement timeout is detected. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

- An execution error !> is returned by the CAL_REF command if the specified reference is less than 33% of full scale or greater than 100% of full scale for any range.

Table 4-7. Manual Resistance Calibration

Command	Response	Action
CAL 3	=>	Puts NetDAQ in resistance calibration.
CAL_REF?	+190.000E+0	5700A - Source 190 ohms
CAL_STEP?	+190.000E+0	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+1.90000E+3	5700A - Source 1.9k ohms
CAL_STEP?	+1.90000E+3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+19.0000E+3	5700A - Source 19k ohms
CAL_STEP?	+19.0000E+3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+190.000E+3	5700A - Source 190k ohms
CAL_STEP?	+190.000E+3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.
CAL_REF?	+1.90000E+6	5700A - Source 1.9M ohms
CAL_STEP?	+1.90000E+6	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.

Manual Frequency Calibration Procedure 4-46.

The Frequency calibration procedure calculates a calibration constant that corrects for errors in the frequency counter crystal frequency. It is sufficiently accurate to measure a single frequency point and calculate the scale factor assuming that the other endpoint is 0 Hz.

Complete the following procedure to manually calibrate the frequency function.

1. If you have not already done so, complete the procedure "Preparing for Calibration" earlier in this chapter.

2. Connect the instrument and 5700A Calibrator as shown in Figure 4-7.

3. Complete the sequence of manual steps shown in Table 4-8. Channels 1 is configured to frequency, and a single measurement is made.

Table 4-8. Manual Frequency Calibration

Command	Response	Action
CAL 4	=>	Puts NetDAQ in frequency calibration.
CAL_REF?	+10.0000E+3	5700A - Source 3V ac @ 10 kHz
CAL_STEP?	+10.0000E+3	NetDAQ computes the calibration constant and returns the calibrated reading. Allow several seconds.

4. Resolve any calibration problems based on the following:

- An execution error !> is returned by the CAL_STEP? command if the frequency measurement is off by more than 5% from the target. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

- When CAL_STEP? reports an execution error !> due to an out-of-range measurement, it returns the raw measured reading to give you an indication of what was measured. When CAL_STEP? completes successfully, it returns the reference value.

- A device-dependent error is returned by the CAL_STEP? command if an internal error such as a measurement timeout is detected. When an error is detected, the cal constant is not updated, and the procedure remains at the same step.

- An execution error !> is returned by the CAL_REF command if the specified reference is less than 10 kHz or greater than 100 kHz.

Diagnostic Testing and Troubleshooting

Introduction 5-1.

The instrument provides error code information and semi-modular design to aid in troubleshooting. This section explains the error codes and describes procedures needed to isolate a problem to a specific functional area. Finally, troubleshooting hints for each functional area are presented.

But first, if the instrument fails, check the line voltage fuse and replace as needed. If the problem persists, verify that you are operating the instrument correctly by reviewing the operating instructions found in the instrument Users Manual.

⚡ WARNING

Opening the case may expose hazardous voltages. Always disconnect the power cord and measuring inputs before opening the case. And remember that repairs or servicing should be performed only by qualified personnel.

Required calibration equipment is listed in Chapter 4 of this manual. Signal names followed by a '*' are active (asserted) low. Signal names not so marked are active high.

Servicing Surface-Mount Assemblies 5-2.

The instrument incorporates Surface-Mount Technology (SMT) for printed circuit assemblies (pca's). Surface-mount components are much smaller than their predecessors, with leads soldered directly to the surface of a circuit board; no plated through-holes are used. Unique servicing, troubleshooting, and repair techniques are required to support this technology. The information offered in the following paragraphs serves only as an introduction to SMT. It is not recommended that repair be attempted based only on the information presented here. Refer to the Fluke "Surface-Mount Device Soldering Kit" for a complete demonstration and discussion of these techniques. (In the USA, call 1-800-526-4731 to order.)

Since sockets are seldom used with SMT, "shotgun" troubleshooting cannot be used; a fault should be isolated to the component level before a part is replaced. Surface-mount assemblies are probed from the component side. The probes should make contact only with the pads in front of the component leads. With the close spacing involved, ordinary test probes can easily short two adjacent pins on an SMT IC.

This Service Manual is a vital source for component locations and values. With limited space on the circuit board, chip component locations are seldom labeled. Figures provided in Chapter 6 of this manual provide this information. Also, remember that chip components are not individually labeled; keep any new or removed component in a labeled package.

Surface-mount components are removed and replaced by reflowing all the solder connections at the same time. Special considerations are required.

- The solder tool uses regulated hot air to melt the solder; there is no direct contact between the tool and the component.
- Surface-mount assemblies require rework with wire solder rather than with solder paste. A 0.025-inch diameter wire solder composed of 63% tin and 37% lead is recommended. A 60/40 solder is also acceptable.

- A good connection with SMT requires only enough solder to make a positive metallic contact. Too much solder causes bridging, while too little solder can cause weak or open solder joints. With SMT, the anchoring effect of the through-holes is missing; solder provides the only means of mechanical fastening. Therefore, the pca must be especially clean to ensure a strong connection. An oxidized pca pad causes the solder to wick up the component lead, leaving little solder on the pad itself.

Refer to the Fluke "Surface-Mount Device Soldering Kit" for a complete discussion of these techniques.

Error Detection   5-3.

At power-up, the instrument software performs self-tests. If any errors in instrument operation are detected, they are reported on the instrument front panel with Error in the primary display and a decimal error code number in the secondary display. If there is more than one error, they are displayed sequentially. Selftest errors can be retrieved from RS-232 commands and the network.

A selftest includes a test of the following items:

- **FLASH** ROM parameters, communication parameters and calibration constants.
- **RAM** Instrument and channel configuration plus RAM images of FLASH ROM parameters.
- **Ethernet** Ethernet chip and static Ethernet RAM.
- **Display** Display processor and display board
- **Inguard** Specific tests for ROM checksum, RAM, A/D converter, zero offset test, reference balance test, ohms overload test, and otc.

A summary of the possible error codes are shown in Table 5-1, including the front panel error code (in decimal) and the corresponding network and RS-232 error code (in hexadecimal). The faults that might cause each error are described in "Troubleshooting the Instrument" later in this chapter.

Table 5-1. Selftest Error Codes

Front Panel Error Codes	RS-232 Query Error Codes	Error Codes in hexadecimal	Error Code Description
(None)	0	0x00000000	No selftest error.
1	1	0x00000001	Bad boot software image in FLASH ROM.
2	2	0x00000002	Bad main software image in FLASH ROM.
3	4	0x00000004	RAM test failure.
4	8	0x00000008	Display test failure.
5	16	0x00000010	Display not responding.
6	32	0x00000020	Calibration constants corrupt.
7	64	0x00000040	Inguard not responding.
8	128	0x00000080	Inguard A/D failure.
9	256	0x00000100	Inguard zero offsets test failed.

Table 5-1. Selftest Error Codes (cont)

Front Panel Error Codes	RS-232 Query Error Codes	Error Codes in hexadecimal	Error Code Description
10	512	0x00000200	Inguard reference balance test failed.
11	1024	0x00000400	Inguard overload detection failed.
12	2048	0x00000800	Inguard open thermocouple detect failed.
13	4096	0x00001000	Communication parameters corrupt.
14	8192	0x00002000	Ethernet address parameter corrupt.
15	16384	0x00004000	RAM constants corrupt.
16	32768	0x00008000	Ethernet chip or RAM failure.

FLASH ROM Parameter Defaults   5-4.

The FLASH ROM (U21 Main Board) parameters are reset to defaults following the first power-on and following power-cycles after any FLASH ROM parameters are discovered to be corrupt. These defaults are listed in Table 5-2.

Table 5-2. FLASH ROM Parameter Defaults

Parameter	Default
Ethernet Address	ff:ff:ff:ff:ff:ff
Calibration Constants	All gains are set to 1.0; all offsets are set to 0.0
IP Address	255.255.255.255
Port Number	4369
RS-232 Baud Rate	19200
BCN	1
Line Frequency	60 Hz
Network Type	0 (isolated network)

Background Testing   5-5.

Background testing is performed to ensure that communication, configuration, and calibration constants do not become corrupt over time. Every 10 seconds, one of the parameter sets is verified (verifying all parameter sets at once is too CPU intensive). The following parameter sets are checked:

- FLASH ROM communication parameters
- FLASH ROM calibration constants
- FLASH ROM Ethernet address
- RAM instrument and channel configuration
- RAM pre-computed range scaling and calibration constants used in evaluation
- RAM copy of calibration constants
- RAM copy of Ethernet address

When a parameter set is discovered to be corrupt, the background testing task records the error in the error/status register, and performs any corrective action required. The errors and actions performed on the errors are listed in the below Table 5-3.

Table 5-3. Corrective Action for Background Error Checking

Error	Action
FLASH ROM communication parameters corrupt.	Reset to defaults on next power-up.
FLASH ROM calibration constants corrupt.	Reset to defaults on next power-up.
FLASH ROM Ethernet address corrupt.	Reset to defaults on next power-up. Network interfaces will not activate.
Any RAM constants corrupt.	None.

Internal Software Errors   5-6.

Internal software errors are any software conditions which should never occur. Internal errors are recorded in an internal store, and can be retrieved with the User Network Interface request NETCMD_IERROR. In addition, the front panel will display the error number, and the error/status bit EST_INTERNAL_ERROR will be set.

Retrieving Error Codes using RS-232   5-7.

You can retrieve error codes from the instrument using the instrument rear-panel RS-232 port and an ASCII terminal, or PC running ASCII terminal emulation.

Complete the following procedure to retrieve error codes from the instrument using an RS-232 connection.

1. Connect the instrument to a PC COM port and setup the RS-232 parameters and connection as described in the procedure "Calibration Procedure (Manual)" in Chapter 4.

2. Enter the command *TST? to invoke the instrument selftest routine and return the result, or just SELFTEST? for the results of the most recent self test. If you use *TST?, allow several seconds for the tests to complete. The *TST? test does not include the RAM test because this test cannot be performed when the instrument is operating.

3. Observe the returned number after the selftest routine. Refer to Table 5-1 for an analysis of the return. For example, a return of 64 is the same as error code 7 on the front panel display.

Retrieving Error Codes using the Network   5-8.

A selftest can be performed from the User Network Interface with the NETCMD_RUN_SELFTEST network command.

Selecting the Diagnostic Tools   5-9.

This section describes the instrument diagnostic tool menu and other diagnostic features. The diagnostic tool menu is hidden from the user. There are three separate diagnostic tools that can be selected from the menu, each of which is described below.

Complete the following procedure to select the diagnostic tools.

1. Power the instrument and allow it to complete the normal power-on sequence.

2. Press and hold the ⬤DIO key for 3 seconds until "tool" appears in the secondary display.

3. Use the up/down arrow keys to sequence you through the three diagnostic selections:

   - dio (used to set any of the instrument rear-panel dio7 to dio0 digital i/o lines)
   - idS (used to display the various firmware versions active within the instrument)
   - conF (used to configure the reading rate, and channel functions and ranges)

4. Select the desired diagnostic tool using the up/down arrow keys; then press the ⬤ENTER key.

Other diagnostic tools include the display test and COMM parameter reset.

Diagnostic Tool dio   5-10.

The dio diagnostic tool allows you to change the status of any eight dio lines dio7 to dio0 located on the instrument rear-panel DIGITAL I/O connector.

Complete the following procedure to change the status of any dio line.

1. Select the dio diagnostic tool using the procedure "Selecting the Diagnostic Tool Menu."

2. Use the left/right arrows to select the desired dio line dio7 to dio0. The format is nnnn-nnnn, representing dio lines dio7 to dio0, respectively. The secondary display shows the selected line, for example, dio:7.

3. Use the up/down arrow keys to select the desired dio line status, 0 or 1.

4. In a similar manner, select the desired dio status for each line dio7 to dio0; then press the ⬤ENTER key to return to the diagnostic tool menu.

5. Select another diagnostic tool using the up/down arrow key, or exit by pressing the ⬤DIO key. The dio lines remain set after exiting this procedure.

Diagnostic Tool idS   5-11.

The idS diagnostic tool allows you to view the firmware versions installed in your instrument.

Complete the following procedure to view the firmware versions in your instrument.

1. Select the idS diagnostic tool using the procedure "Selecting the Diagnostic Tool Menu."

2. With inStr shown in the secondary display, and the instrument model number shown in the primary display, press the up/down arrow keys to sequence through the firmware selections shown in Table 5-4.

Table 5-4. Instrument Firmware Descriptions

Primary Display*	Secondary Display
2640A -or- 2645A	inStr (Instrument Model Number)
02.02	FP9A (A1 Main pca, FPGA** Version)
01.00	diSP (Display CPU Version)
00.09	Atodb (A/D Boot Version)
01.02	AtodM (A/D Software Version)
02.07	boot (Main Boot Version)
01.05	MAin (Main Software Version)
* The firmware versions shown in this table are typical. Actual firmware versions may vary. ** Field Programmable Gate Array	

3. After viewing the desired information, press the ENTER key to return to the diagnostic tool menu.

4. Select another diagnostic tool using the up/down arrow key, or exit by pressing the DIO key.

Diagnostic Tool conF 5-12.

The conF diagnostic tool allows you to configure the reading rate, and channel functions and channel ranges for channels 1 to 20.

Complete the following procedure to configure the reading rate and channel functions.

1. Select the conF diagnostic tool using the procedure "Selecting the Diagnostic Tool Menu."

2. **Reading Rate** Use the up/down arrow keys to show rAtE in the primary display; then press the ENTER key. Using the up/down arrow keys, sequence through the reading rates SLO (Slow), FASt (Fast), and HALF (Medium), stopping at the desired rate; then press ENTER.

3. Select the conF diagnostic tool using "Selecting the Diagnostic Tool Menu."

4. **Channel Functions** Use the up/down arrow keys to show chAn in the primary display; then press the ENTER key.

   a. Using the left/right and up/down arrow keys, select the desired channel for configuration (01 to 20); then press the ENTER key.

   b. Using the up/down arrow keys, chose the measurement function for the selected channel; then press the ENTER key.

   c. Using the up/down arrow keys, chose the range for the measurement function (except frequency, which has no range selection); then press the ENTER key.

5. Repeat Step 4 for each channel you wish to configure.

6. Select another diagnostic tool using the up/down arrow key, or exit by pressing the DIO key.

Diagnostic Display Test 5-13.

For a constant front panel display with all segments lit, turn off the instrument, then turn the power on again while holding down the front panel ◀ key. After the instrument beeps, release the key. The front panel display remains on until any front panel key is pressed. This allows you to inspect the display segments.

COMM Parameter Reset 5-14.

To reset all the communication parameters to the factory defaults (Table 5-5), turn off the instrument, then turn the power on again while holding down the front panel COMM key. After the instrument beeps, and the message "rESEt" is displayed for one second, release the key.

Table 5-5. Instrument Default COMM Parameters

Parameter	Default Setting
Base Channel Number	1
Line Frequency	60 Hz
Network Selection	Isolated Network
Socket Port	4369
Internet Protocol Address	---.---.---.--- (dashes)
Baud Rate	38400

Using the RS-232 Interface 5-15.

The instrument supports calibration adjustment and verification using ASCII commands on the RS-232 interface since Met/Cal does not have network capability, and field calibration stations probably won't either. The instrument also supports several commands for factory testing and several for software testing. The RS-232 interface is also used to download the main software to flash.

The RS-232 interface does not perform acquisition scans and does not save measured data in the scan queue or last scan record. The user can configure the function, range, and number of terminals for channel one only. RS-232 can be used to get a measurement on channel one. Other configuration elements cannot be set by the user through the RS-232 interface. The computed channels are not accessible. Alarms are not configurable through the RS-232 interface. The instrument does not set master alarm output, trigger out, or DIO output in response to an RS-232 measurement query. The user has no access to the totalizer value or the state of the DIO lines through the RS-232 interface. When calibration is enabled, the secondary display shows "CAL." The instrument does not output measurements to an RS-232 printer as Hydra did. The REM annunciator will not be lit because the instrument does not provide commands like Databucket's REMS, LOCS, RWLS.

Command Processing 5-16.

The instrument RS-232 interface processes input and output in a manner similar to Hydra. The instrument receives a command or query from the host. The instrument returns a response to a valid query. The instrument always returns a prompt after processing an input line (the prompt follows the response in the case of a query).

An input line to the instrument consists of one or more semicolon-separated commands followed by an input terminator. The instrument will accept CR/LF or LF as the input terminator. The instrument reads input into a 350-byte input queue until it finds the input terminator. The instrument does not echo input. While processing the queued input, the instrument parses and processes each command in sequence. Therefore, earlier commands can execute even if a later command contains a syntax error.

The prompts have the following meanings:

=> No error. Command was parsed and executed with no errors.

?> Command error. The command contained a syntax error. For example, the command name or an argument contained a type; the command was not a legal command; an argument was of the wrong type; too many or too few arguments were supplied. Since parity is always set to none, parity errors cause garbage in the input buffer, and this will generate a syntax error (at best).

!> Execution or device-dependent error. An execution error occurs when the command was recognized to be an instrument command but was not legal given the current state of the instrument, or had an inappropriate parameter value. A device-dependent error occurs when an instrument-specific limitation is exceeded (such as input queue size), or when the instrument tries to execute the command but it fails (for example, due to a bad CRC).

If a command cannot be recognized (i.e., syntax error), the instrument returns the ?> error prompt and does not do any more processing on that command or the remaining contents of the input queue. If a query had already been processed on that line, its response would be sent before the prompt.

If the input queue size is exceeded, the instrument throws away all further input until it receives a terminator, and generates a device-dependent error. None of the commands in the queue are executed. The instrument returns the !> prompt when it encounters the input terminator.

If the instrument receives an input line before its last prompt has been read out of its output queue, the instrument will generate an execution error, return the !> error prompt instead of whatever prompt it had planned to return, and ignore the second input line.

If an input line contains more than one query command, the responses will be returned in one response line separated by semicolons.

When sending a response or prompt, the instrument appends an output terminator which is the CR/LF character. The instrument output can be held off with XON/XOFF.

The string formats and general syntax rules are the same as Hydra's.

The following settings are fixed: eight data bits, no parity, no echo, XON/XOFF flow control, no CTS flow control. The user can set the baud rate to 4800, 9600, 19200, or 38400.

Instrument Configuration   5-17.

The FUNC command is used to select a measurement function, range, and number of terminals on channel one only. When executing the *RST or *TST? command, or when exiting calibration mode, the instrument sets the configuration to the values shown below in Table 5-6:

Table 5-6. Instrument Configuration

Configuration Element	Power-on	Reset/Selftest
Channel 1 to 20 configuration: function, range, terminals, TC type, RTD R0	Channel 1 only is VDC, Autorange	Off
Channel 1 to 20 OTC	Off	Off
Channel 21 to 30 Equation	Off	Off
Channel 1 to 30 Mx+B	1x+0	1x+0
Channel 1 to 30 Alarm Limits	Off/0	Off/0
Channel 1 to 30 Alarm Association	None	None
Channel 1 to 30 Alarm Trigger	Disabled	Disabled
Reading Rate	Slow	Slow
Primary Interval	0	0
Conditional Interval	0	0
Alarm-Check Interval	0	0
Primary Interval Triggering	Disabled	Disabled
External Triggering	Disabled	Disabled
Alarm Triggering	Disabled	Disabled
Scan Queue Mode	Overwrite Old Scans	Overwrite Old Scans
Trigger Output	Disabled	Disabled
Temperature Scale (F or C)	C	C
Totalizer Debounce	Disabled	Disabled
Housekeeping (Drift Correction)	Enabled	Disabled
Inactive Client Scan-Disable	Enabled	Enabled

The prompts provide error information. And the *TST? query provides failure information. Power-on selftest results can be retrieved with the SELFTEST? query.

Command Set 5-18.

The instrument RS-232 command set is shown in Table 5-7: RS-232 Command Set. The calibration commands are described in more detail in Chapter 4. These are: CAL, CAL_CLR, CAL_CONST, CAL_CONST?, CAL_REF, CAL_REF?, and CAL_STEP?. The other commands are described in this chapter. The instrument does not accept the calibration commands unless calibration mode is enabled. In calibration mode, the instrument does not accept some non-calibration commands. It is expected that users will make all calibration adjustments and exit calibration mode before performing calibration verification. Calibration verification readings will be made in the slow reading rate, which is the power-on and reset default, therefore no command is provided for setting the rate.

Table 5-7. RS-232 Command Set

Command	Description	Cal	Not Cal
*IDN?	Identification query	*	*
*OPC?	Operation complete query	*	*
*RST	Reset	*	*
*TST?	Self test query		*
SELFTEST?	Return current selftest results	*	*
CAL	Start calibration procedure for indicated function	*	
CAL?	Return the identifier of any CAL procedure in progress	*	
CAL_CLR	Reset calibration constants to nominal value	*	
CAL_CONST?	Query the value of a particular calibration constant	*	*
CAL_REF	Specify value to calibrate to (in place of default reference value)	*	
CAL_REF?	Query the present calibration reference value	*	
CAL_STEP?	Calibrate and query the calibrated value of the input	*	
FUNC	Configure function, range, terminals for channel 1		*
FUNC?	Query function, range, terminals for channel 1		*
MEAS?	Trigger and query a measurement on channel 1		*

The RS-232 commands are described in this chapter using the following format:

- **Command:** The command name and syntax.
- **Description:** A description of the command.
- **Parameters:** A description of the required and optional parameters.
- **Response:** A description of data returned.
- **Restrictions:** When the command is allowed/disallowed.
- **Notes:** Any additional useful information.

Command: *IDN?

Description: Identification query.

Parameters: None

Response: FLUKE, <model>, <serial-number>, <versions>

       <model> = 2640A, 2645A

       <serial-number> = 0

       <versions> = MMx.x MBx.x F/PAx.x ABx.x D0x.0x LMxx.xx

              MM is for outguard main software

              MB is for outguard boot monitor software

              FA is for 2645A inguard (A/D) main software

              PA is for 2640A inguard (A/D) main software

              BAis for inguard boot software

              D is for display microprocessor software

              LM is for FPGA logic

Restrictions: None

Notes: The <serial-number> field is always zero. The instrument could store the serial number in flash, and let it be set once from the RS-232 interface. But if a replacement board were ever sent to a customer, it would not have the serial number.

Command: *OPC?

Description: Operation complete query. *OPC? causes the instrument to output an ASCII "1."

Parameters: None

Response: <state> = 1

Restrictions: None

Notes: *OPC? is used in conjunction with a non-query command to get a response from the instrument when the non-query command is finished executing. For example, sending "CAL 1; *OPC?" will get the "1" response when the instrument is ready to execute calibration procedure 1.

Command: *RST

Description: Reset. Resets the configuration to the values in Table 5-6: Instrument Configuration. Clears DIO and other settings as shown in Table 5-8: Power-on/Reset Instrument State.

Parameters: None

Response: None

Restrictions: None.

Notes: If *RST is used in calibration mode, the instrument exits calibration mode. If *RST is used to exit calibration mode before the completion of a calibration procedure for a function (VDC, VAC, OHMS, FREQ), any new calibration constants for that function will not be saved.

Table 5-8. Power-on/Reset Instrument State

State Element	Power-on	Reset/Selftest
32-bit totalizer	Cleared to 0	Cleared to 0
Digital Output	Deasserted	Deasserted
Master Alarm Output	Deasserted	Deasserted
Trigger Output	Deasserted	Deasserted
External Trigger Input	FPGA interrupt disabled	FPGA interrupt disabled
Front Panel	Quiescent	Goes to quiescent
Error/Status	Errors from startup	Errors not cleared/Status always current
Selftest Status	Errors from startup	Not affected/Results of test
Scanning	Disabled	Goes to disabled
Monitor	Disabled	Goes to disabled
Spy	Disabled	Goes to disabled
Scan Queue	Empty	Gets flushed
Last Scan Record	Empty	Gets flushed
Latest Channel Measurements	Empty	Gets flushed
Network Connections	None	Not affected

Command: *TST?

Description: Selftest query. Initiates asynchronous selftest and then returns the selftest results. This command resets the instrument configuration and state the same as *RST.

Parameters: None

Response: <selftest-result> = an integer which binary-encodes the selftest results as shown in Table 5-1: Selftest Error Codes. Multiple selftest errors are indicated by the selftest codes or'd together.

Restrictions: Not allowed in calibration mode.

Command: SELFTEST?

Description: Selftest results query. Returns the selftest results from the last selftest performed. This command can be used to retrieve the power-on selftest results.

Parameters: None

Response: <selftest-result> = an integer which binary-encodes the selftest results as shown in Table 5-1. Multiple selftest errors are indicated by the selftest codes or'd together.

Restrictions: Not allowed in calibration mode.

Command: CAL

Description: Initiate calibration procedure for the specified measurement function.

Parameters: <procedure>

<procedure> =

1 = VDC

2 = VAC

3 = Ohms

4 = Frequency

Response: None

Restrictions: Only allowed in Calibration Mode

Notes: If executed during a calibration procedure, it aborts the current procedure and begins another.

This command returns an execution error if not in the Calibration Mode.

This command returns a device dependent error if an internal error such as a guard crossing error is detected while attempting to determine the instrument type.

This command returns a device dependent error if it is unable to set the default cal configuration. This could happen if scanning was enabled via the network interface after the cal procedure was initiated.

Command: CAL?

Description: Return the procedure identifier of any calibration procedure in progress

Parameters: none

Response: <procedure>

where <procedure> =

0 = No calibration procedure currently active

1 = VDC

2 = VAC

3 = Ohms

4 = Frequency

Restrictions: Only allowed in Calibration Mode

Notes: This command returns an execution error if not in the Calibration Mode.

NetDAQ *Logger for Windows* uses this command to determine when a calibration procedure has completed.

Command: CAL_REF

Description: Specify value to calibrate to in place of default reference

Parameters: <new calibration reference value>

<new calibration reference value> = floating point reference value

Response: None

Restrictions: Calibration mode only

Notes: This command returns an execution error if the specified calibration reference is invalid. The allowable limits for each reference are specified for each procedure in Chapter 4, "Performance Testing and Calibration." This command returns an execution error if no cal procedure is active.

Command: CAL_REF?

Description: Query the present calibration reference value

Parameters: None

Response: <reference value>

<reference value> = floating point number

Restrictions: Calibration mode only

Notes: This command returns an execution error if no cal procedure is active.

Command: CAL_STEP?

Description: Calibrate and query the calibrated value of the input

Parameters: None

Response: <calibrated value>

　　　　　　　　　<calibrated value> = floating point number

Restrictions: Calibration mode only

Notes: This command returns an execution error if the measured reading is outside of the limits specified for each function. For vdc, resistance and frequency functions, the calibration constant value cannot exceed $\pm$5% of the function range; for vac the calibration constant cannot exceed $\pm$10% of the function range.

This command returns an execution error if no cal procedure is active.

This command returns a device dependent error if an internal error such as measurement timeout is detected.

If the CAL_STEP? command completes successfully, the "calibrated value" returned is the reference value. If the command fails because the measured reading is outside of the specified limits, the raw measurement is returned.

A device dependent error is returned if an internal error such as a Guard Crossing error, measurement timeout, or a configuration failure is detected. No value is returned in this case.

This command sets the EST_BUSY bit in the error status register while changing the instrument configuration. The scan queue is also cleared.

Command: FUNC 1, <function> [, <range> [, <terminals>]]

Description: Configure the measurement function, range, and number of terminals for channel one.

Parameters: <function> = OFF, VDC, VAC, OHMS, FREQ

　　　　　　　　　<range> = 1, 2, ... 5, AUTO (see Table 5-9: Range Settings)

　　　　　　　　　<terminals> = 2 or 4 for OHMS

Response: None.

Restrictions: Not allowed in calibration mode.

　　　　<range> and <terminals> may not be specified with <function> = OFF.

　　　　<terminals> may not be specified with <function> = VDC, VAC, or FREQ.

　　　　<terminals> must be specified with <function> = OHMS.

　　　　<range> must be specified for VDC, VAC, and OHMS.

　　　　<range> may be specified for FREQ, but it is not used.

A <range> value which is "na" in Table 5-9: Range Settings generates an execution error.

Notes: Since only channel one can be configured, range 4 is shown as 300V here for the2640A. On the 2640A, channels 1 and 11 can measure 300V while the other channels can measure only 150V.

If the instrument type cannot be determined (2640A/2645A), then a device dependent error is generated.

Table 5-9. Range Settings

<range>	2645A VDC	2640A VDC	2645A VDC	2640A VDC	2645A 2-W Ohms	2640A 2-W Ohms	4-W Ohms	FREQ
1	300mV	300mV	300mV	300mV	na	300Ω	300Ω	opt
2	3V	3V	3V	3V	na	3kΩ	3kΩ	opt
3	30V	30V	30V	30V	30kΩ	30kΩ	30kΩ	opt
4	50V	300V	50V	300V	300kΩ	300kΩ	300kΩ	opt
5	90mV	90mV	na	na	3MΩ	3MΩ	3MΩ	opt
6	750mV	750mV	na	na	na	na	na	opt

Command: FUNC? 1

Description: Query the measurement function, range, and number of terminals for channel one.

Parameters: None

Response: <function> [, <range> [, <terminals>]]

<function> = OFF, VDC, VAC, OHMS, FREQ

<range> = 1, 2, ... 5, AUTO (see Table 5-9: Range Settings)

<terminals> = 2 or 4

Restrictions: Not allowed in calibration mode.

Notes: If channel one is not configured, this query returns just OFF.

When <function> is OFF, <range> and <terminals> are not returned.

When <function> is FREQ, <range> is always returned as AUTO.

When <function> is VDC, VAC, or FREQ, <terminals> is not returned.

When <function> is OHMS, <terminals> is always returned.

When channel 1 is configured for RTD (via network interface) <function> is OHMS and <range> is AUTO.

When channel 1 is configured for thermocouple (via network interface) <function> is VDC and <range> is 6.

Command: MEAS?

Description: Takes a measurement on channel one and returns the measured value. This command is new to the instrument.

Parameters: None

Response: <measurement> = IEEE-488.2 NR3 ASCII representation of a floating point value: leading sign;

5 or 6 digits with embedded decimal point for 2645A and 2640A respectively, padded

with leading and trailing zeroes if necessary;
"E";
a signed exponent of -3, +0, +3, or +6.

For example +115.67E+0.

An overload condition is indicated by a value of +001.00E+9 or -001.00E+9 in the 2645A, +001.000E+9 or -001.000E+9 for the 2640A.

Restrictions: Not allowed in calibration mode. If channel one is not configured, this command generates an execution error and does not return a value.

Notes: While processing this query, the instrument does not return a response or a prompt until the measurement has been taken.

The instrument generates a device dependent error if the measurement does not arrive after 30 seconds.

Open thermocouples return a +999.99[9]E+9.

Troubleshooting the Instrument 5-19.

The following paragraphs describe an organized method of instrument troubleshooting. The overall approach is to start with power-up self-test error codes and then proceed to more and more detailed procedures. Begin troubleshooting with "General Troubleshooting." These procedures locate about 90% of the instrument faults. The remaining faults require sleuthing that is beyond the scope of this manual. For these cases, review Chapter 2 "Theory of Operation" and approach the difficulty in a logical manner adapting the troubleshooting procedures, as required. As a last resort, contact the factory or Fluke Service Center (see Chapter 6) for assistance.

General Troubleshooting 5-20.

General troubleshooting uses the instrument response to self-test as a clue to the fault location. If the instrument completes self-test and displays an error code on the front panel, refer to Table 5-10. If the instrument appears dead and will not even self test, refer to Table 5-11. If the instrument passes self test but is not operating correctly, then refer to "Troubleshooting the A3 A/D Converter PCA" for analog problems, and "Troubleshooting the A1 Main PCA" for digital problems. For assembly and disassembly procedures, see Chapter 3, "General Maintenance."

Table 5-10. Relating Selftest Errors to Instrument Problems

Error Code	Error Code Description	Suspect Assembly	Error Code Discussion
1	Bad boot software image in FLASH ROM.	A1 Main PCA	**Background** The A1U21 FLASH memory device is divided into sections. One of these sections is the memory for the boot software, which is used for instrument initialization. After the instrument is initialized, the main code takes over and runs the instrument. **Failure** For this error to occur, the boot software is either missing or is corrupted and must be reloaded. **Correction** Reloading the boot software is a factory procedure only. The only recourse is to order a new A1U21 device programmed at the factory if the software is corrupted. Also see "Troubleshooting the Digital Kernel."
2	Bad main software image in FLASH ROM.	A1 Main PCA	**Background** The A1U21 FLASH memory device is divided into sections. One of these sections is the main software that runs the instrument. **Failure** For this error to occur, the main software is either missing or is corrupted and must be reloaded. This failure is detected by a boot monitor condition, which means the boot software completed but the main software did not take over instrument operation. **Correction** Reloading the main software is discussed in "Updating Embedded Instrument Firmware" later in this chapter. Also see "Troubleshooting the Digital Kernel."
3	RAM test failure.	A1 Main PCA	**Background** The A1U20, A1U30, A1U34, and A1U35 static RAM devices are divided into two banks: RAM1 (A1U20 and A1U30) and RAM2 (A1U34 and A1U35). The boot software uses a portion of RAM1 as a memory device. **Failure** For this error to occur, the RAM1 devices did not function correctly during the boot process. Either the RAM devices failed, or the address decoding for the RAM devices failed. Most of the address decoding is located internal to the A1U1 microprocessor, while the RAM1* and RAM2* enable signals are generated by logic devices A1U14 and A1U15 from A1U1 address bits 18 and 20. Note that depending on the RAM devices used, resistor/jumpers A1R125 and A1R126 (near A1U14) may or may not be used. **Correction** Check the enable signals at the RAM devices, including the enable RAM1* and read/write signals. If the inputs are correct, the devices themselves are suspect. If the inputs are incorrect, work backwards towards the signal source and locate the device that is not performing. Also see "Troubleshooting the Digital Kernel." Check the A1U29 I/O and Memory Decoder to make sure the proper enables and strobes are produced.

Table 5-10. Relating Selftest Errors to Instrument Problems (cont)

Error Code	Error Code Description	Suspect Assembly	Error Code Discussion
4	Display test failure.	A2 Display PCA [Note 1]	**Background** The A1U1 microprocessor requests the A2 Display PCA to run a self-test and report the results. **Failure** For this error to occur, the A2 Display PCA is able to communicate with A1U1 microprocessor but the Display self-test is "fail." **Correction** Almost certainly the A2 Display PCA has a problem. Refer to paragraph "A2 Display PCA Troubleshooting."
5	Display not responding.	A2 Display PCA [Note 1]	**Background** The A1U1 microprocessor requests the A2 Display PCA to run a self-test and report the results. **Failure** For this error to occur, the A2 Display PCA did not respond to the A1U1 microprocessor request to run a self-test. Neither "pass" nor "fail" was reported as if the A2 Display PCA is dead or missing. **Correction** Check the ribbon-cable connection between A1J2 and A2J1, or the power supply voltages to the A2 Display PCA. Refer to paragraph "A2 Display PCA Troubleshooting." The A1U1 microprocessor could be damaged for the interface with the A2 Display PCA.
6	Calibration constants corrupt.	A1 Main PCA	**Background** The A1U21 FLASH memory device is divided into sections. One of these sections is the memory for the calibration constants. Although the calibration constants are used by the A/D converter on the outguard A3 A/D Converter PCA, they are stored on the inguard A1 Main PCA because the Flash memory on the A3 A/D Converter cannot be programmed while the instrument is operating, i.e., programmed with calibration constants. **Failure** For this error to occur, the calibration constants stored in A1U21 have become corrupted. One possibility is that you started a calibration routine and then didn't complete it. When you start a calibration routine, it sets a "start" flag; when you complete a calibration routine, it sets a "finish" flag. If the software detects a start flag and no finish flat, you will receive this error. **Correction** If the only problem is calibration values, complete the calibration procedures in Chapter 4. One other possibility is a A1U21 device failure.

Table 5-10. Relating Selftest Errors to Instrument Problems (cont)

Error Code	Error Code Description	Suspect Assembly	Error Code Discussion
7	Inguard not responding.	A3 A/D Converter PCA	**Background** The A1U1 processor requests the inguard A3 A/D Converter PCA to run a self-test and report the results. **Failure** For this error to occur, the A3 A/D Converter PCA did not respond to the A1U1 microprocessor request to run a self-test. Neither "pass" nor "fail" was reported as if the A3 A/D Converter PCA is dead or missing. **Correction** Check the ribbon-cable connection between A1P10 and A3J10, or the power supply voltages to the A3 A/D Converter PCA. Refer to paragraph "A3 A/D Converter PCA Troubleshooting." The A1U1 microprocessor could be damaged for the interface with the A3 A/D Converter PCA, or possibly the optics opto-isolator devices A1U5 and A1U7 for the serial data guard crossing. (Note that the guard crossing serial data is similar to RS-232, except it uses normal logic levels instead of RS-232 logic levels.) Another possibility is the digital kernel on the A3A/D Converter PCA has failed. See "Troubleshooting the A3 A/D Converter PCA."
8	Inguard A/D failure.	A3 A/D Converter PCA	**Background** The A1U1 microprocessor requests the A/D portion of the inguard A3 A/D Converter PCA to run a self-test and report the results. **Failure** For this error to occur, the A/D portion of the A3 A/D Converter PCA self-test report would be "fail." **Correction** The A/D portion of the A3 A/D Converter PCA depends on accurate power supply levels ($\pm$50 mV). In particular Vddr (+5.6V dc at A3U8-1), Vcc (+5.0V dc at A3U8-3), Vdd (+5.2V dc at A3C31) and Vss (-5.2V dc at A3C33). See "Troubleshooting the A3 A/D Converter PCA" and "Troubleshooting the Power Supply."
9	Inguard zero offsets test failed.	A3 A/D Converter PCA	**Background** Each measurement function, VDC, VAC, resistance, and frequency is subject to some sort of signal conditioning and if this circuitry fails, it could introduce an expectedly large offset error. **Failure** This error suggests a problem in the signal conditioning path, rather than the A/D converter itself. **Correction** Check the components for each signal conditioning method, depending the function that has failed. You can, for example, apply different functions, i.e., vac, vdc, resistance or frequency, and note which function measures incorrectly. Then look in the signal conditioning components for the failure. Be sure A3W8 jumper is in place.

Table 5-10. Relating Selftest Errors to Instrument Problems (cont)

Error Code	Error Code Description	Suspect Assembly	Error Code Discussion
10	Inguard reference balance test failed.	A3 A/D Converter PCA	**Background** The A/D converter uses two very precise voltages for operation: +3.45V dc and -3.45V dc. These voltages are applied to resistor network A3Z1-1 and A3Z1-3, with a balanced output at A3Z1-2. When the two reference voltages are exact, the A3Z1-2 output is nearly zero. **Failure** This error occurs when the output of the balance reference check at A3Z1-2 is not nearly zero. **Correction** Troubleshoot the reference voltage circuitry at A3U12 and A3U20 and related components. During proper operation, A1U12-6 is within a few microvolts of ground potential. Check the inputs and outputs of A3U12 and A3U20 and look for an incorrect output, indicating a device failure.
11	Inguard overload detection failed.	A3 A/D Converter PCA	**Background** This self-test is created by configuring for an ohms measurement, with treeing relays pulled in, but no channel relays are set. This creates an overload measurement as the A/D converter tried to measure the resistance of an open circuit. **Failure** The error occurs when the A/D converter did not detect an overload condition for measuring an open circuit. **Correction** There is a problem in the ohms conditioning circuitry or possibly a problem in the A3U30 Stallion device. The dc buffer might also be affected. Normally, this error occurs in conjunction with other errors. If there are not other errors, then the signal conditioning circuitry is more likely at fault. Also check the ohms current source at A3U31 and related components. When the precision 1 mA current sink is operating correctly, the voltage across A3R128 is exactly 3.45V dc and the voltage across A3Z7-9 and A3Z7-11 is 1.00V dc. If all the voltages are correct, the A3U30 Stallion device becomes more suspect.

Table 5-10. Relating Selftest Errors to Instrument Problems (cont)

Error Code	Error Code Description	Suspect Assembly	Error Code Discussion
12	Inguard open thermocouple detect failed.	A3 A/D Converter PCA	**Background** The open thermocouple detect circuit checks on the amount of a 19.2 kHz voltage developed across a "thermocouple." Similar to the overload detection, the self-test does not set any channel relays and the detection circuit should detect the "open" thermocouple. **Failure** For this error to occur, the open-thermocouple circuit has failed to detect the simulated open thermocouple condition. **Correction** Check the circuitry formed by the open thermocouple detect circuit formed by A3U32 peak detector and comparator and associated components operates by applying a 19.2 kHz clock from A3U5 via A3C82 into the measurement line. It checks on the amount of 19.2 kHz voltage is developed. If the developed voltage exceeds a certain level, this is detected as an open thermocouple with a logic output at A3U32-7. Similar to the overload detection, the self-test does not set any channel relays and the detection circuit should detect the "open" thermocouple. Also check the relays in the circuit path.
13	Communication parameters corrupt.	A1 Main PCA	**Background** The A1U11 real-time clock device has resident RAM that stores the RS-232 communication parameters (baud rate). A1U11 is powered by Vbb, the source of which is either the battery BT1 or the supply Vcc, depending if the instrument is powered or not (via A1U10). **Failure** For this error to occur, the RS-232 parameter is no longer stored in A1U11 RAM or the addressing is missing. **Correction** This might happen if the battery BT1 is dead, or a problem with A1U10 power supply monitor, or the A1U11 chip itself. Also check A1U29 for I/O and memory decoding.
14	Ethernet address parameter corrupt.	A1 Main PCA	**Background** The A1U21 FLASH memory device is divided into sections. One of these sections is the memory for the Ethernet address. This is a unique address assigned at the time of manufacturer. **Failure** For this error to occur, the Ethernet address is either missing or is corrupted and must be reloaded, or the addressing is missing. **Correction** Reloading the Ethernet address is a factory procedure only. The only recourse is to order a new A1U21 device programmed at the factory if the Ethernet address is corrupted. Also see "Troubleshooting the Digital Kernel." Also check A1U29 for I/O and memory decoding.

Table 5-10. Relating Selftest Errors to Instrument Problems (cont)

Error Code	Error Code Description	Suspect Assembly	Error Code Discussion
15	RAM constants corrupt.	A1 Main PCA	**Background** The A1U11 real-time clock device has resident RAM that stores constants. A1U11 is powered by Vbb, the source of which is either the battery BT1 or the supply Vcc, depending if the instrument is powered or not (via A1U10).
			Failure For this error to occur, the constants are no longer stored in A1U11 RAM.
			Correction This might happen if the battery BT1 is dead, or a problem with A1U10 power supply monitor, or the A1U11 chip itself.
16	Ethernet chip or RAM failure.	A1 Main PCA	**Background** The Ethernet controller (A1U32) has associated RAM (A1U33). The addition of the 10BASE2 transceiver (A1U16) completes the device complement of the Ethernet interface.
			Failure For this error to occur, the self-test that simulates Ethernet activity using A1U32 and A1U33 has to fail.
			Correction Check Ethernet operation using both 10BASE2 and 10BASE-T. If the Ethernet interface operates over 10BASE-T but not 10BASE2, then the Ethernet transceiver A1U16 is suspect. If Ethernet does not operate over either interface, then A1U32 and A1U33 are suspect. Also see "Troubleshooting the Digital Kernel." Also check A1U29 for I/O and memory decoding.
Note 1 Obviously if the display is not operating, the display may not show an error code. You can extract the error codes via the RS-232 interface. See "Retrieving Error Codes using RS-232."			

Table 5-11. Hints for Troubleshooting "Dead" Instruments

Possible Fault	Discussion
Blown Fuse	If the instrument is completely dead, you may have blown the line fuse. See "Replacing the Line Fuse" in Chapter 3.
Power Supply	Self-test starts with the outguard A1 Main PCA. If self-test won't even begin, then something is wrong either at the A1 Main PCA or with a power supply voltage. If the A3 A/D Converter PCA has a short circuit of some kind, it could load down a power supply voltage such that the current limiting feature is folding the supply back. For example, the +5.6V dc Vddr supply might only measure 1.2V dc. This in turn would kill the A1 Main PCA. To check this possibility, turn the instrument power off; then disconnect the A3 A/D Converter PCA by removing the ribbon cable at A3J10. Power the instrument again. If this time the instrument goes into self test, then you need to troubleshoot the A3 A/D Converter PCA and look for the load that is pulling the power supply down. See "Power Supply Troubleshooting." [Power Supply - look for overwarm devices]
Dead A2 Display PCA	It may appear that self-test didn't begin because the display is dead and therefore didn't shown anything. To verify the display is dead, extract the error code over the RS-232 port instead of from the front panel display. (See "Retrieving Error Codes using RS-232.")
Dead A1U1 Microprocessor	If the A1U1 microprocessor or related component in the kernel has failed, self-test will not initialize. See "Troubleshooting the Digital Kernel."
Power-On Reset	If the input line voltage is too low, the A1U10 Power-On Reset/Power-Fail Detector might be generating a POR* (power-on reset) or PFAIL* (power failure) condition. Or if for some other reason the output of the raw dc supply falls below approximately 8.25V dc (measured at A1WP1 and A1WP2 terminals, with the power switch on). Locate the low voltage or missing voltage condition.
A1U1 Microprocessor Task Interrupt	Check the CINT* signal at A1U11-3 for a nominal output of 64 Hz, which is used to switch from one task to the next. If the A1U1 microprocessor is not getting this signal, it won't switch tasks and the microprocessor will appear dead.

A1 Main PCA Troubleshooting 5-21.

The following paragraphs provide troubleshooting hints for the A1 Main PCA. Use this material in conjunction with Chapter 2, "Theory of Operation."

⚡ WARNING

To avoid electric shock, disconnect all channel inputs from the instrument before performing any troubleshooting operations.

Troubleshooting the A1 Main PCA Digital Kernel 5-22.

When the instrument is first powered, the resident RAM portion of the A1U1 microprocessor begins to initialize the digital kernel. This activity may be monitored at one of the A1U1 microprocessor chip select outputs, for example, FLSH* at A1U1-128, or RAM* at A1U1-127. (It might be easier to measure signals at places other than the pins of the A1U1 microprocessor; for example, measure A1U1-128 at resistor A1R144.) If there is brief chip-select activity and then the activity stops, this indicates that the A1U1 microprocessor tried to start operation, but one or more of the outboard devices did not respond and the A1U1 microprocessor was unable to continue initialization. If there is no chip-select activity when power is first applied to the instrument, then the A1U1 microprocessor may have been damaged by static electricity.

If the problem seems to be in the outboard devices, then probe them with a logic analyzer or oscilloscope looking for missing signals or dc power, or by touch to find a device that is excessively warm. (Be careful to touch only the case of the device and not the pins.) These devices include A1U21 Flash Memory, A1U20, A1U30, A1U34, A1U35 Static RAM, A1U11 Real-Time Clock, A1U10 Power Monitor, A1U12 Flash Programming Power Supply, and related logic devices such as AND gates, OR gates, and inverters.

Check the A1U1 crystal frequency at A1TP11 to make sure there is a clock input to the A1U1 microprocessor. The crystal frequency should measure 15.36 MHz.

Check the jumper A1W3 near A1U21 Flash Memory and make sure it is in place. If this jumper is missing, the instrument will appear completely dead. Check all the jumper positions, as shown in Table 5-12.

Table 5-12. A1 Main PCA Jumper Positions

Jumper	If Missing	If in Place
W1	**A1U1-109 enable PB1/disable IACK6***	A1U1-109 disable PB1/enable IACK6*
W2	**A1U21 programming power via Vpp**	A1U21 programming power via Vcc
W3	Flash disabled (dead Instrument)	**Flash enabled**
W4	Boot Baud rate 19.2k	**Boot Baud rate 38.4k**
W5	**A1U1-108 enable PB0/disable IACK7***	A1U1-108 disable PB0/enable IACK7*
Normal jumper position is shown in **bold**.		

Check that no programming power is applied to A1U21-1 Flash Memory (+12V dc). Programming power is applied only when storing (for example) calibration constants. During normal operation, A1U21-1 should not be powered. If power is being applied to A1U21-1 during normal operation, check to make sure jumper A1W2 is not in place (see Table 5-12) and probe A1U12 to find the cause for the presence of Vpp.

Check A1U29 I/O and Memory Decoder. If this device is not responding correctly, a whole host of address problems will occur, including RAM and Flash write and read strobes. A failure of this device would result in several error code reports.

Troubleshooting the RS-232 Interface   5-23.

If the instrument RS-232 port does not seem to operate, be sure you have selected the correct RS-232 baud rate for the interface with a terminal or PC running terminal emulation software. If everything seems to be correct, troubleshoot the RS-232 interface A1U13 drivers, in particular, A1TP12 for the receive (RX) input.

Troubleshooting the Ethernet Interface   5-24.

If Ethernet operates on 10BASE-T but not 10BASE2, the A1U16 transceiver is suspect. Check pin A1U16-18 for a nominal -7V dc and A1U16-19 for a nominal -8V dc. Since the A1U16 device is powered by power supply module A1U38, you should also check A1U38 for the correct output of -9V dc. Also check A1U2, which processes the A1U32 Ethernet Controller interrupt output. Finally, if there still is an Ethernet problem, the fault could be caused by the A1U32 Ethernet Controller itself or its associated RAM device, A1U33. One check is to measure the bias voltage at A1U32-21 (at resistor A1R107). For a normally operating A1U32 device, this voltage is a nominal +1.22V dc.

Troubleshooting the Digital I/O Lines and Trigger Out Lines   5-25.

When the instrument is powered, the A1U31 Field Programmable Gate Array is programmed by the A1U1 microprocessor as part of the initialization routine. Thus programmed, the FPGA interfaces with the keys portion of the A2 Display PCA and the DIO lines such as the instrument rear panel DIGITAL I/O dio7 to dio0, as well as the trigger output and input lines. If there are any problems in this area, check the A1U31 signal conditions, in particular, the D-clock output at A1U31-19. If all appears well, check the associated receivers A1U3 and A1U4, and drivers A1U17 and A1U27. Often if a receiver or driver device fails, you will lose a block of dio lines. Power supply voltage levels are important here because of threshold levels. Check the power supply voltages. Note that the fanout for the trigger output line is increased by A1Q10 so that this output can be connected to 20 trigger input lines without overloading the signal. If there are problems with loading of the trigger output line, check A1Q10.

Troubleshooting the Totalizer and Trigger In Lines   5-26.

The Totalizer and Trigger In inputs are processed by A1U8 and associated devices, and applied to the A1U31 FPGA. If you have problems with these features, check for the correction inputs to the FPGA. If the inputs are correct, then the FPGA is suspect or the programming of the FPGA is suspect.

Troubleshooting the Power Supply 5-27.

To troubleshoot the power supply circuits, check the test points for each voltage, proceeding from the raw dc supply through the 5V switcher and subsequent regulator circuits. If one of the supplies is folded back due to excessive current draw, unplug the ribbon cable at A3J10 on the A3 A/D Converter PCA to see if this unloads the power supply. If this works, then troubleshoot the A3 A/D Converter PCA. When tracking down power supply loads, use a sensitive voltmeter and look for resistive drops across filter chokes, low value decoupling resistors, and circuit traces. Also check for devices that are too warm. On the A3 A/D Converter PCA, all devices run cool except A3U5 microprocessor and A3U8 FPGA, which run warm, but not hot.

A2 Display PCA Troubleshooting 5-28.

The following provides troubleshooting hints for the A2 Display PCA. Use this material in conjunction with Chapter 2, "Theory of Operation." A Display Extender Cable is available from Fluke (PN 867952) for use during troubleshooting.

⚠ WARNING

To avoid electric shock, disconnect all channel inputs from the instrument before performing any troubleshooting operations.

The Display Controller reads the DTEST* and LTE* inputs to determine how to initialize the display memory. DTEST* and LTE* default to logic 1 and logic 0, respectively, to cause all display segments to be initialized to "on". DTEST* is connected to test points A2TP4, and LTE* is connected to A2TP5. Either test point can be jumpered to VCC (A2TP6) or GND (A2TP3) to select other display initialization patterns. Display Test Patterns #1 and #2 are a mixture of "on" and "off" segments with a recognizable pattern to aid in troubleshooting. When either of the special display patterns is selected, the beeper is also sounded for testing without interaction with the Microprocessor. Table 5-13 indicates the display initialization possibilities.

Table 5-13. A2 Display PCA Initialization Routines

A2TP4 DTEST*	A2TP5 LTE*	Power-Up Display Initialization
1	1	All segments OFF
1	0	All segments ON (default)
0	1	Display Test Pattern #1
0	0	Display Test Pattern #2

Figures 5-1 and 5-2 show Display Test Patterns #1 and #2, respectively. Refer to the Display Assembly schematic diagram in Chapter 7 for grid/anode assignments.
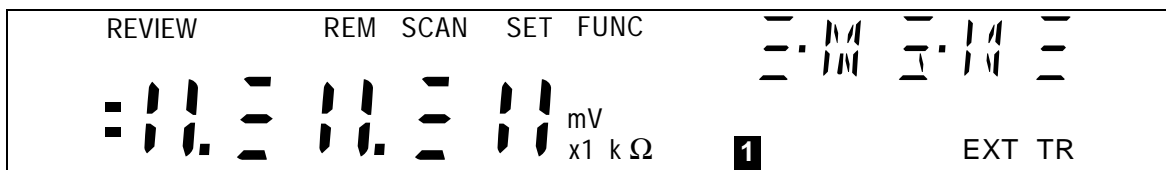

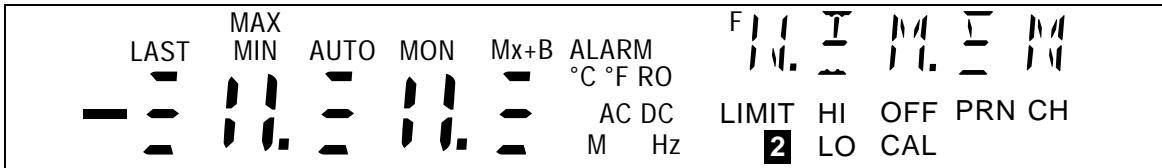**Figure 5-1. Display Test Pattern #1**

Figure 5-2. Display Test Pattern #2

When the instrument display is initially powered up, all display segments should come on automatically. If this display does not appear, proceed with the following steps:

NOTE

If the display is operational but has problems when front-panel buttons are pressed, proceed directly to step 9.

1. Check the three power supplies with respect to GND on the Display Assembly.

Vcc (A2U1-21)	+4.9V dc
Vee (A2U1-4)	-5.0V dc
Vload (A2U1-5)	-30.0V dc

2. Check the filament drive signals FIL1 and FIL2; these connect to the last two pins on each end of A2DS1. These signals should be 5.4V ac with FIL2 biased to be about 6.8V dc higher than the Vload supply (nominally a -23.2V dc level). FIL1 and FIL2 should be 180 degrees out of phase. If the dc bias of FIL2 is not at about -23.2V dc, the display segments that should be "off" will show a shadowing (or speckling) effect.

3. Check the clock signal CLK1 at A2TP2, A2U1-2, and A2U4-3. This signal should be a 512-kHz square wave (1.953 microseconds per cycle). This signal depends on an E clock signal (also known as DCLK) of 1.024 MHz from the Main Assembly. If the E clock is not correct, the problem may be in the A1 Main PCA or in the ribbon cable system connecting the two assemblies.

4. Check the state of the RESET signal (A2U1-1). This signal should be low once the reset time is completed (after power-up). Also verify that the RESET* signal (A2U6-3) is high after the reset time is completed.

5. Verify that the DISRX signal (A2U1-39) goes low after RESET (A2U1-1) goes low. If this sequence does not occur, communication to the Microprocessor is held off with the DISRX signal high. If DISRX stays high but is not shorted to VCC, A2U1 must be faulty.

6. Verify activity for both the DISTX and DSCLK signals. These signals are driven by the Microprocessor and must be transitioning for the Display Controller to receive commands from the Microprocessor.

7. If all segments of a particular digit do not turn on at power-up, the grid drive from A2U1 may not be connected properly to A2DS1. Grids are numbered from 10 to 0 (left to right as the display is viewed). For a digit to be enabled, the respective grid drive signals (GRID(10:0)) must be at approximately Vcc (+4.9V dc.) For a digit to be disabled, the drive must be at Vload (-30.0V dc.)

8. If a segment under each of several (or all) grids fails to be turned on (or off) properly, one of the anode drive signals may not be connected properly from A2U1 to A2DS1. When an anode signal is at Vcc, and a grid signal is at Vcc, the corresponding segment on the display is illuminated.

9. If the Microprocessor has difficulty recognizing front-panel button presses, the switch scanning signals SWR1 through SWR6 should be checked. When no switch contacts are being closed, the switch scanning lines should have about 20 kΩ of resistance between each other (through two 10 kΩ pull-up resistors to Vcc). Unless one of the switches is closed, none of the switch scanning lines should be shorted directly to GND at any time.

Variations in the Display 5-29.

Under normal operation, the display presents various combinations of brightly and dimly lit annunciators and digits. However, you may encounter other, random irregularities across different areas of the display under the following circumstances:

- After prolonged periods of displaying the same information.
- If the display has not been used for a prolonged period.

This phenomenon can be cleared by activating the entire display and leaving it on overnight (or at least for several hours). Use the following procedure to keep the display fully lit:

1. With power OFF, press and hold the left arrow key, then press power ON.

2. Wait a moment for the instrument to beep, then release the key. The entire display will now stay on until you are ready to deactivate it.

3. At the end of the activation period, press any button on the front panel; the instrument resumes the mode in effect prior to the power interruption (Active or Inactive.)

A3 A/D Converter PCA Troubleshooting 5-30.

The following paragraphs provide troubleshooting hints for the A3 A/D Converter PCA. Use this material in conjunction with Chapter 2, "Theory of Operation."

⚡ WARNING

To avoid electric shock, disconnect all channel inputs from the instrument before performing any troubleshooting operations.

A3 Kernel 5-31.

If the microprocessor detects a fault, it drives the HALT* signal low and in essence halts itself. Monitor the HALT* line and if it is not steady and toggles between low and high, then there is most certainly a problem with the A3 kernel. In this instance, check the pull-up resistors for the data and addressing lines, and then signal conditions at the kernel devices. Incorrect jumper settings (Table 5-14) can also cause kernel problems.

Table 5-14. A3 A/D Converter PCA Jumper Positions

Jumper	If Missing	If in Place
W5	**VBOOT enable at A3Q1** (this jumper is in place when loading new A/D firmware. If you forgot to remove the jumper, you would receive this error)	VBOOT disable at A3Q1 prevents A3U6 from initializing (error 7 is reported at the front panel, or error 64 over the RS-232 interface)
W6	Flash disabled (error 7 is reported at the front panel, or error 64 over the RS-232 interface)	**Flash enabled**
W8	A/D HI disable, between the dc buffer amplifier and a/d converter (A/D converter failure)	**A/D HI enable, between the dc buffer amplifier and a/d converter (A/D converter operate)**
Normal jumper position is shown in **bold**.		

Break/Reset Circuit 5-32.

Check the break/reset circuit formed by A3U1 and A3U3, and related components. The result line at A3U1-7, IG RESET* (Inguard Reset). At power up, IG RESET* should stay low for about 250 ms and then go high for normal operation. If IG RESET* fails to go high, then troubleshoot the reset circuit. When IG RESET* goes high, the signal HALT* at A3U1-1 should also go high. HALT* is an I/O pin on the A3U5 microprocessor.

Out of Tolerance Readings 5-33.

Out-of-tolerance readings may occur even though self-test passed. This could be an out of calibration problem due to too long a cycle between instrument calibrations, or due to a failure. Clues come from the range and function where the problem occurs. If the problem is all functions and all ranges, this points to A/D converter problems, in particular the precision voltages used for measurements. To locate problem, complete the Performance Test in Chapter 4 and note which parameters are out of tolerance. If all parameters are out of tolerance, this points towards a failure in the A/D converter circuitry, in particular, dc power supply voltages that are incorrect. If only certain functions or ranges are out of tolerance, then the problem may be in the treeing and channel select relays, or signal conditioning circuitry, or A3U30 Stallion device and related circuit elements. When you have identified the functions and ranges that are not correct, note the signal paths on the schematic and look for a common element.

For dc volt problems that affect all channels, look for faults in the dc buffer and Stallion device. For dc volt problems on individual channels or groups of channels, check the channel select (2640A only) and treeing relays.

For resistance problems, check the dc volts characteristics first. If there are no problems, then the difficulty is not in the dc buffer circuitry. This would suggest a problem in the ohms conditioning circuit or the A3U30 Stallion device.

For ac volt problems, check the dc volts characteristics first. If there are no problems, then the difficulty is probably in the ac-to-dc conversion circuitry.

Troubleshooting Relay Problems   5-34.

Both the 2640A and 2645A use mechanical reed relays for signal switching, although the 2645A uses solid-state relays for channel selection. The mechanical relays have a life of 100,000,000 operations. If you use your instrument in long-duration, high-speed measurement runs at high voltages and high common mode voltages, then the relays may start to act up after a few years. This includes failure to open, failure to close, excessive contact resistance, and so forth. If your instrument is not subject to these extremes, then relay failures become less likely. An example of a relay failure is when the reading on one channel affects the readings on another channel (beyond the normal effects of cross-talk for ac measurements). This is especially true for dc volts, resistance, or thermocouple measurements. If a group of channels is causing problems, particular for channels 1 to 10, and 11 to 20, then it may be a bus problem (bank1 and bank2). If the banks are interacting, the treeing relays A3K21 to A3K24 may be at fault. You may find it easier to measure relay conditions by removing the A3 A/D Converter PCA and measuring at the bottom of the pca. However, removing the pca could unstick a stuck relay and complicate relay troubleshooting. Also, for relay troubleshooting, applying +1V dc to the even channels and -1V dc to the odd channels can assist you in signal tracing. Crossed relays, for example, might cause a 0V reading where you expected +1V.

A4 Analog Input PCA Troubleshooting   5-35.

The A4 Analog Input PCA is essentially a passive assembly of terminal blocks, with the exception of a small active network formed around A4Q1 that provides a temperature reference for thermocouple measurements. If thermocouple measurements are out of tolerance, A4Q1 may be suspect.

To verify the operation of A4Q1, connect multimeter test leads across A4R2 (marked and clearly visible in the open module) and power the instrument. At normal room temperatures, the voltage across A4R2 is a nominal 1V dc. If the measured voltage is 0V, A4Q1 is probably open and should be replaced. For this test, you may find it easier if you remove the cover portion of the Universal Input Module by gently lifting one of the tabs the form the cover hinge and removing the cover.

⚡ WARNING

To avoid electric shock, disconnect all channel inputs from the instrument before performing any troubleshooting operations.

The A4Q1 circuit is calibrated at the factory by adjusting the potentiometer A4R3. Do not disturb this adjustment unless you have replaced A4Q1. If you have replaced A4Q1, allow the instrument to stabilize in an ambient temperature of exactly 22*C and then adjust A4R3 for a reading of 1.00V dc across A4R2.

Troubleshooting Calibration Failures 5-36.

The paragraphs in this section describe troubleshooting actions when there is a calibration failure. Calibration procedures are provided in Chapter 4.

Calibration of the instrument through the computer interface is described in Chapter 4 of this manual. Generally, a calibration failure is indicated by a Device Dependent Error and a "!>" prompt after a CAL_STEP? command. These indications occur if the analog input varies from what the instrument expects to see by more than +/-5% or +/-15%, depending on the calibration step.

Before suspecting a fault with the instrument, verify that the calibration is being conducted properly.

- Check the connections between the source and the instrument. Are all the connections in place?
- Check the output of the calibration source. Does it equal the value called for by this calibration step?
- Check the calibration source. Is it in operate mode? Has it reverted to standby?

If a calibration step has failed, the instrument remains on that step so that the output from the calibration source may be corrected or the calibration reference value (CAL_REF) being used by the instrument may be changed if it was improperly entered. The calibration step may be repeated by sending the CAL_STEP? command to the instrument again.

Calibration of the instrument utilizes a simple "calibration by function" approach. If you suspect calibration errors, but the instrument does not exhibit the symptoms mentioned above, verify that you are observing the following calibration rules:

- Independent calibration of any function results in the storage of calibration constants for that function only.
- Once calibration is begun, all steps for that function must be completed before the calibration constants are stored. If all steps are not completed and the procedure is terminated, no constants for that function are stored; only calibration constants for previously completed functions are stored.

Retrieving Calibration Constants 5-37.

If a calibration error is suspected, the stored constant can be retrieved and verified over the computer interface. Acceptable calibration constants for each function and range are listed in Table **Error! Reference source not found.**. The equations below specify how to calculate the VDC, VAC, and Resistance gain and offset calibration constants:

Gain = (highTarget - lowTarget) / (highMeas - lowMeas)

Offset = -((lowMeas * Gain) - lowTarget)

Where:

highTarget = high scale target value

lowTarget = low scale (or zero) target value

highMeas = high scale measured value

lowMeas = low scale (or zero) measured value

Table 5-15. Calibration Constants

CAL Constant Number	Function	Function Range	Comment	Minimum Allowable Value	Maximum allowable Value
0	VDC	90 mV	Gain	+0.95000E+0	+1.05000E+0
2	VDC	90 mV	Offset	-0.00090E+0	+0.00090E+0
4	VDC	300 mV	Gain	+0.95000E+0	+1.05000E+0
6	VDC	300 mV	Offset	-0.00300E+0	+0.00300E+0
8	VDC	3V	Gain	+0.95000E+0	+1.05000E+0
10	VDC	3V	Offset	-0.03000E+0	+0.03000E+0
12	VDC	30V	Gain	+0.95000E+0	+1.05000E+0
14	VDC	30V	Offset	-0.30000E+0	+0.30000E+0
16	VDC	50V (2645A) 150/300V (2640A)	Gain	+0.95000E+0	+1.05000E+0
18	VDC	50V (2645A) 150/300V (2640A)	Offset	-0.50000E+0 -3.00000E+0	+0.50000E+0 +3.00000E+0
20	VDC	750 mV	Gain	+0.95000E+0	+1.05000E+0
22	VDC	750 mV	Offset	-0.00750E+0	+0.00750E+0
24	VAC	300 mV	Gain	+0.90000E+0	+1.10000E+0
26	VAC	300 mV	Offset	-0.00300E+0	+0.00300E+0
28	VAC	3V	Gain	+0.90000E+0	+1.10000E+0
30	VAC	3V	Offset	-0.03000E+0	+0.03000E+0
32	VAC	30V	Gain	+0.90000E+0	+1.10000E+0
34	VAC	30V	Offset	-0.30000E+0	+0.30000E+0
36	VAC	N/A (2645A) 150/300 V (2640A)	Gain	+0.90000E+0	+1.10000E+0
38	VAC	N/A (2645A) 150/300 V (2640A)	Offset	-3.00000E+0	+3.00000E+0
40	Resistance	300Ω	Gain	+0.95000E+0	+1.05000E+0
42	Resistance	300Ω	Offset	-3.00000E+0	+3.00000E+0
44	Resistance	3 kΩ	Gain	+0.95000E+0	+1.05000E+0
46	Resistance	3 kΩ	Offset	-3.00000E+1	+3.00000E+1
48	Resistance	30 kΩ	Gain	+0.95000E+0	+1.05000E+0
50	Resistance	30 kΩ	Offset	-3.00000E+2	+3.00000E+2
52	Resistance	300 kΩ	Gain	+0.95000E+0	+1.05000E+0
54	Resistance	300 kΩ	Offset	-3.00000E+3	+3.00000E+3
56	Resistance	3 MΩ	Gain	+0.95000E+0	+1.05000E+0
58	Resistance	3 MΩ	Offset	-3.00000E+4	+3.00000E+4
60	Frequency	All	CFC*	+0.95000E+0	+1.05000E+0

*CFC = crystal frequency correction

The frequency counter calibration constant is simply the Gain constant calculation where the lowTarget and lowMeas are both assumed to be zero.

FrequencyConstant = targetFreq / measFreq

To retrieve the calibration constants, set up the instrument in the manual calibration configuration described in "Calibration Procedure (Manual)" in Chapter 4. Then retrieve the desired calibration constant with the CAL_CONST? xx command, where xx denotes the calibration constant number shown in Table 5-15. Each constant reflects the correction applied to the uncompensated measurement result as an offset or as a gain multiplier. For example, `CAL_CONST? 8` might return +998.939E-3 indicating the uncompensated value for the 3V dc range is multiplied by 0.998939 to achieve specification.

Loading Embedded Instrument Firmware   5-38.

Instrument firmware consists of the following components:

Main Firmware Loaded from a floppy disk on the PC to the instrument via the instrument rear panel RS-232 port. This is a closed-case procedure and it is not necessary to open the instrument to load the Main Firmware. The Main Firmware is identical for both model instruments.

A/D Firmware Loaded from a floppy disk on the PC to the instrument directly to a 3-pin connection on the A3 A/D Converter PCA. This also requires a separate power supply connection to the A3 A/D Converter PCA Flash Memory, and custom cables for making the connections. This is not a closed-case procedure and it is necessary to open the instrument to load the A/D Firmware. The A/D Firmware is different for each instrument.

Firmware is stored in the instrument in electrically erasable and programmable memory devices. A diskette containing the necessary loading software and latest release of the firmware may be obtained from either your local Fluke authorized service center, or from the Fluke factory. You may also contact the factory directly: Fluke Data Acquisition Sales Support, (206) 356-5870 or FAX, (206) 356-5790.

To review which versions of the Main and A/D firmware are presently in your instrument, see "Diagnostic Tool idS" earlier in this chapter. The listing for A/D Firmware is identified as AtodM; the listing for Main Firmware is identified as Main. The remaining firmware for the display, FPGA and so forth are factory procedures only.

Firmware Diskette   5-39.

The firmware diskette contains the files shown in Table 5-16. The `*.bat` files are used for the standard installation of the firmware. If you wish to customize the installation, then do not run the batch file, but refer to Table 5-16 for the switches used for the executable file `ld26xx.exe`. Create a directory on your hard drive for this diskette and then copy the contents to the hard drive. For example, create the directory on your hard drive called `firmware` and copy the contents of the diskette into this directory. (Refer to your Windows or DOS documentation if you need information on creating directories or copying files.)

Table 5-16. Files on the Firmware Diskette

File [1]	PC COM Port	Instrument	Description
`load451.bat`	COM1	2640A/2645A	Loads Main Firmware via COM1
`load452.bat`	COM2	2640A/2645A	Loads Main Firmware via COM2
`adld401.bat`	COM1	2640A	Loads 2640A A/D Firmware via COM1
`adld402.bat`	COM2	2640A	Loads 2640 A/D Firmware via COM2
`adld451.bat`	COM1	2645A	Loads 2645A A/D Firmware via COM1
`adld452.bat`	COM2	2645A	Loads 2645 A/D Firmware via COM2
`readme.txt`			Loading instructions and hints
`fa0102.hex` [typical]			Typical A/D Firmware file loaded by `ld26xx.exe`
`mm0104.bin` [typical]			Typical Main Firmware file loaded by `ld26xx.exe`
File	**Switch**		**Switch Description**
`ld26xx.exe`			Executable file that loads the firmware into the instrument
	/B		Switch to run the program in the Batch mode. If you include this switch, you must include both the /Cn and /Fname switches
	/Cn		Switch sets the PC COM port number where /C1 is COM1 and /C2 is COM2
	/Fname		Switch specifies the firmware file to load where [name] is the file name
	/H		Switch to disable the CTS/RTS handshake; required to load the A/D Firmware
	/Mn		Switch to force detection of a particular model instrument where /M2 is for the 2640A/2645A instruments
	/Rn		Switch for baud rate where /R1 is 19200 and /R2 38400

[1] The *.bat files contain a checklist of instructions, and then launches the `ld26xx.exe` file with its appropriate switches for this loading procedure. For example, the file `load451.bat` might launch the file `ld26xx.exe /Fmm0104.bin /C1 /B /R2 /M2` where `/Fmm0104.bin` is the name of the Main Firmware file, followed `/C1` for COM1, `/B` for batch mode (notice the required `/Cn` and `/Fname` switches), `/R2` for baud rate 38400, and `/M2` for 2640A/2645A instruments.

Loading the Main Firmware 5-40.

The instrument Main Firmware is stored in an electrically erasable and programmable Flash memory (A1U21). The firmware is easily updated without opening the instrument case or replacing any parts. This procedure requires the "NetDAQ Embedded Firmware Memory Loader" diskette that contains the software loader and the latest release of Main Firmware. The Main Firmware is identical for both the 2640A and 2645A.

Complete the following procedure to load the Main Firmware. Use this procedure only if the normal defaults specified for the `*.bat` file are acceptable. If you want to customize this installation, refer to Table 5-16.

1. Set up the instrument for RS-232 communications as described in "Calibration Procedure (Manual)" in Chapter 4, only use a baud rate of 38400 instead of 19200. Note which PC COM port was used for the RS-232 connection.

2. At the PC, obtain the DOS prompt `C:\>`. (Do not shell to the DOS prompt from Windows.)

3. If you have not already done so, copy the contents of the diskette into a directory on your hard drive, e.g., `firmware`, and change to this directory (`C:\firmware>`).

4. After the DOS prompt in the directory with the diskette files, type `load451.bat` if you connected to PC COM port 1, or `load452.bat` if you connected to PC COM port 2. For example, type the command `C:\firmware>load451.bat`; then press <Enter>.

5. Observe the checklist for this installation, a pause (press <Cntl><C> to escape at this point), and then press any key to the launch the executable `ld26xx.exe` with its appropriate switches for this loading application (see Table 5-16).

6. While loading; the instrument display shows "boot." Allow several minutes for the firmware loading process to complete. The PC screen will show Loading Line as the firmware is loaded. Do not interrupt this process by touching the PC keyboard or removing power from the instrument. After the completion of the firmware, the screen shows Done Loading and the DOS prompt is returned.

7. To confirm the successful loading of the new firmware, see "Diagnostic Tool idS" earlier in this chapter and note the new version of the Main Firmware identified as Main.

Loading the A/D Firmware   5-41.

The instrument A/D Firmware is stored in an electrically erasable and programmable Flash memory (A3U6). The Program Power for A3U6 is from an external source at A3P2 (or A3J3) and the firmware loads from an internal connection at A3P1. This means you must remove the case to load the A/D firmware. The A/D Firmware is specific to the 2640A or 2645A. Be sure you are loading the correct program.

Complete the following procedure to load the A/D Firmware. Use this procedure only if the normal defaults specified for the `*.bat` file are acceptable. If you want to customize this installation, refer to Table 5-16.

1. Remove the instrument case as described in the procedure "Removing the Instrument Case" in Chapter 3.

2. Locate contacts for A3W5 and install a jumper across these contacts. This connects Vcc to the line VBOOT (for the A3U5 microprocessor) and prevents A3U5 from initializing the A3 A/D Converter PCA kernel.

⚠ **WARNING**

**To avoid electric shock, do not touch any portion of the
instrument except as described in this procedure.**

3. Turn on the instrument power and observe self test reports error 7.

4. Connect the selected PC COM port to A3P1 using the connection shown in
    Figure 5-3. This connection must be made when instrument power is on. Use
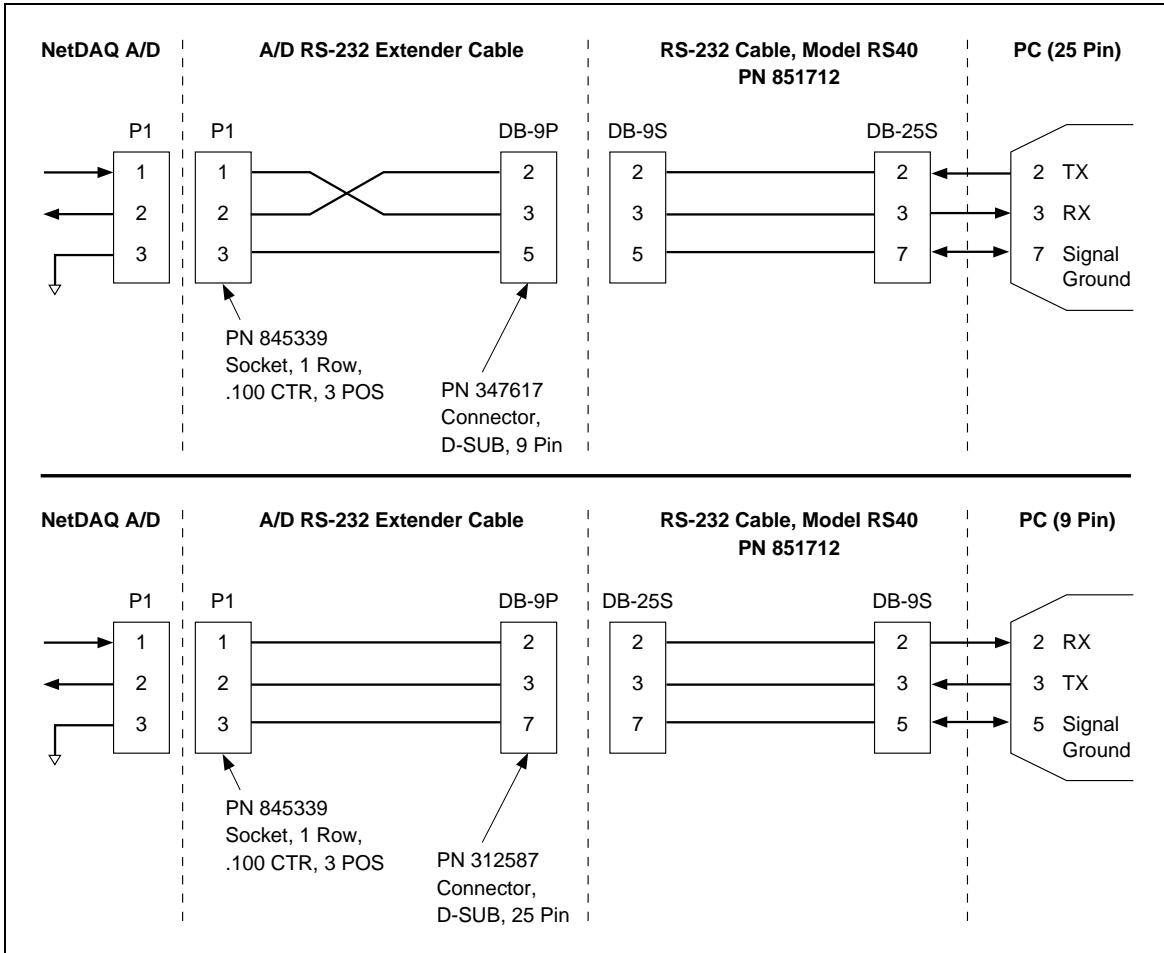   standard connector parts to assemble this custom cable.

Figure 5-3. Connection to A3P1 for Loading A/D Firmware

5. Apply +12V dc, 300 mA, programming power from an external source to A3J3 or
    A3P2. The + voltage is connected to A3P2-1 or A3J3-2. This connection must be made
    when instrument power is on.

6. At the PC, obtain the DOS prompt `C:\>`. (Do not shell to the DOS prompt from
    Windows.)

7. If you have not already done so, copy the contents of the diskette into a directory on
    your hard drive, e.g., `firmware`, and change to this directory (`C:\firmware>`).

8. **2640A** After the DOS prompt in the directory with the diskette files, type `adld401.bat` if you connected to PC COM port 1, or `adld402.bat` if you connected to PC COM port 2. For example, type the command `C:\firmware>adld401.bat`; then press <Enter>.

-or-

2645A After the DOS prompt in the directory with the diskette files, type `adld451.bat` if you connected to PC COM port 1, or `adld452.bat` if you connected to PC COM port 2. For example, type the command `C:\firmware>adld451.bat`; then press <Enter>.

9. Observe the checklist for this installation, a pause (press <Cntl><C> to escape at this point), and then press any key to the launch the executable `ld26xx.exe` with its appropriate switches for this loading application (see Table 5-16).

10. Allow several minutes for the firmware loading process to complete. The PC screen will show Loading Line as the firmware is loaded. Do not interrupt this process by touching the PC keyboard or removing power from the instrument. After the completion of the firmware, the screen shows Done Loading and the DOS prompt is returned.

11. With the instrument power still on, remove the +12V dc connection at A3J3 or A3P2.

12. Turn the instrument power off and remove the connection at A3P1.

13. IMPORTANT! Remove the jumper at A3W5.

14. Reinstall the instrument case using the procedure "Installing the Instrument Case" in Chapter 3.

15. Turn on the instrument power and verify you do not receive self-test error code 7, which would indicate you failed to remove the A3W5 jumper in Step 13.

16. To confirm the successful loading of the new firmware, see "Diagnostic Tool idS" earlier in this chapter and note the new version of the A/D Firmware identified as AtodM.

Chapter 6
List of Replaceable Parts

Introduction 6-1.

This chapter contains an illustrated list of replaceable parts for models 2640A and 2645A Data Acquisition Units. Parts are listed by assembly; alphabetized by reference designator. Each assembly is accompanied by an illustration showing the location of each part and its reference designator. The parts lists give the following information:

- Reference designator (for example, "R52").
- An indication if the part is subject to damage by static discharge.
- Description.
- Fluke stock number.
- Total quantity.
- Any special notes (i.e., factory-selected part).

CAUTION

A * symbol indicates a device that may be damaged by static discharge.

How To Obtain Parts 6-2.

Electronic components may be ordered directly from the Fluke Corporation and its authorized representatives by using the part number under the heading FLUKE STOCK NO. In the U.S., order directly from the Fluke Parts Dept. by calling 1-800-526-4731. Parts price information is available from the Fluke Corporation or its representatives.

In the event that the part ordered has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, if necessary.

To ensure prompt delivery of the correct part, include the following information when you place an order:

- Instrument model and serial number.
- Part number and revision level of the pca (printed circuit assembly) containing the part.
- Reference designator.
- Fluke stock number.
- Description (as given under the DESCRIPTION heading).
- Quantity.

Manual Status Information 6-3.

The Manual Status Information table that precedes the parts list defines the assembly revision levels that are documented in the manual. Revision levels are printed on the component side of each pca.

Newer Instruments 6-4.

Changes and improvements made to the instrument are identified by incrementing the revision letter marked on the affected pca. These changes are documented on a supplemental change/errata sheet which, when applicable, is included with the manual.

Service Centers 6-5.

A list of service centers that may be contacted for any items on the Parts Lists is located at the end of this chapter.

NOTE

This instrument may contain a Nickel-Cadmium battery. Do not mix with the solid waste stream. Spent batteries should be disposed of by a qualified recycler or hazardous materials handler. Contact your authorized Fluke service center for recycling information.

WARNING

THIS INSTRUMENT CONTAINS A FUSIBLE RESISTOR (PN 650085). TO ENSURE SAFETY, USE EXACT REPLACMENT ONLY.

MANUAL STATUS INFORMATION

Ref or Option number	Assembly name	Fluke Part Number	Revision Level
A1	Main PCA	938089	D
A2	Display PCA	814194	–
A3	2640A A/D Converter PCA	938100	C
A3	2645A A/D Converter PCA	932652	C
A4	Analog Input PCA	814210	C

Table 6-1. 2640A/2645A Final Assembly

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
A1	* MAIN PCA ASSEMBLY	938089	1	
A2	* DISPLAY PCA ASSEMBLY	814194	1	
A3	* 2640 A/D CONVERTER ASSEMBLY	938100	1	1
A3	* 2645 A/D CONVERTER ASSEMBLY	932652	1	2
A4	* ANALOG INPUT PCA ASSEMBLY	814210	1	
H51	SCREW,PH,P,LOCK,SS,6-32,.375	334458	2	
H52	SCREW,PH,P,LOCK,STL,6-32,.250	152140	12	
H53	SCREW,FHU,P,LOCK,SS,6-32,.250	320093	4	
H54	SCREW,TH,P,SS,4-40,.187	721118	2	
H65	SCREW,KNURL,SL,CAPT,STL,6-32,.500	876479	2	
H70	NUT,HEX,STL,6-32	110551	4	
MP1	BEZEL,REAR, GRAY #8	874081	1	
M2	ISOTHERMAL CASE,BOTTOM	874107	1	
MP3	ISOTHERMAL CASE,TOP	874110	1	
MP4	SEAL,CALIBRATION	735274	1	
MP5	DECAL, REAR PANEL	938142	1	
MP10	CHASSIS ASSY	938118	1	
MP11	FRONT PANEL	938134	1	
MP12	ELASTOMERIC KEYPAD	935890	1	
MP13	CASE FOOT, BLACK	824433	2	
MP15	LENS, FRONT PANEL	784777	1	
MP16	FOOT, FRONT	938126	2	
MP18	OUTER CASE	938121	1	
MP19	WIRE ASSY,GROUND	874099	1	
MP22	PWR PLUG,PANEL,10A,250V,3 WIRE,SWITCH	928627	1	
MP25	DECAL,ISOTHERMAL CASE	874131	1	
MP27	CABLE ASSY,FLAT,20 COND,MMOD,FERRITE	876185	1	
MP35	DECAL, CSA	864470	1	
MP42	CORD,LINE,5-15/IEC,3-18AWG,SVT,5.5 FT	343723	1	
MP46	HOLDER,FUSE,.25X1.25,SCREW MT,187TAB	929885	1	
MP48	CONN ACC,D-SUB,FEMALE SCREWLOCK,.250	844704	2	
MP59	DECAL,NAMEPLATE	938147	1	
MP67	TERM STRIP,SOCKET,.197CTR,10 POS	875880	1	
MP71	POWER TRANSFORMER	949602	1	
MP95	JUMPER,REC,2 POS,.100CTR,.025 SQ POST	757294	4	
MP97	DECAL, FUSE WARNING	939673	1	
MP98	WIRE ASSY, RECEPTACLE TO FUSE	939678	1	
MP99	FUSE,.25X1.25,0.15A,250V,SLOW	944629	1	
MP101	LABEL,ADHES,VINYL, 1.500, .312	844712	2	
MP111	LABEL,PAPER,ITS-90	928101	1	
MP199	T/C CABLE,ASSY	871512	1	
MP260	COVER, RELAYS	939744	1	1
MP399	LABEL,MYLAR,GROUND SYMBO	911388	1	
MP990	AC SHIELD	949669	1	
MP995	CARD,REGISTRATION,2620A DATA ACQ	896969	1	
MP997	CABLE ASSY,C0AX,BNC(M),BNC(M),4M	943600	1	
MP998	ADAPTER,COAX,BNC(M),BNC(F),BNC(F)	942813	1	
MP999	TERMINATION,COAX,BNC(M),50 OHM	942834	1	
TM1	264X SERIES USERS MANUAL	942623	1	

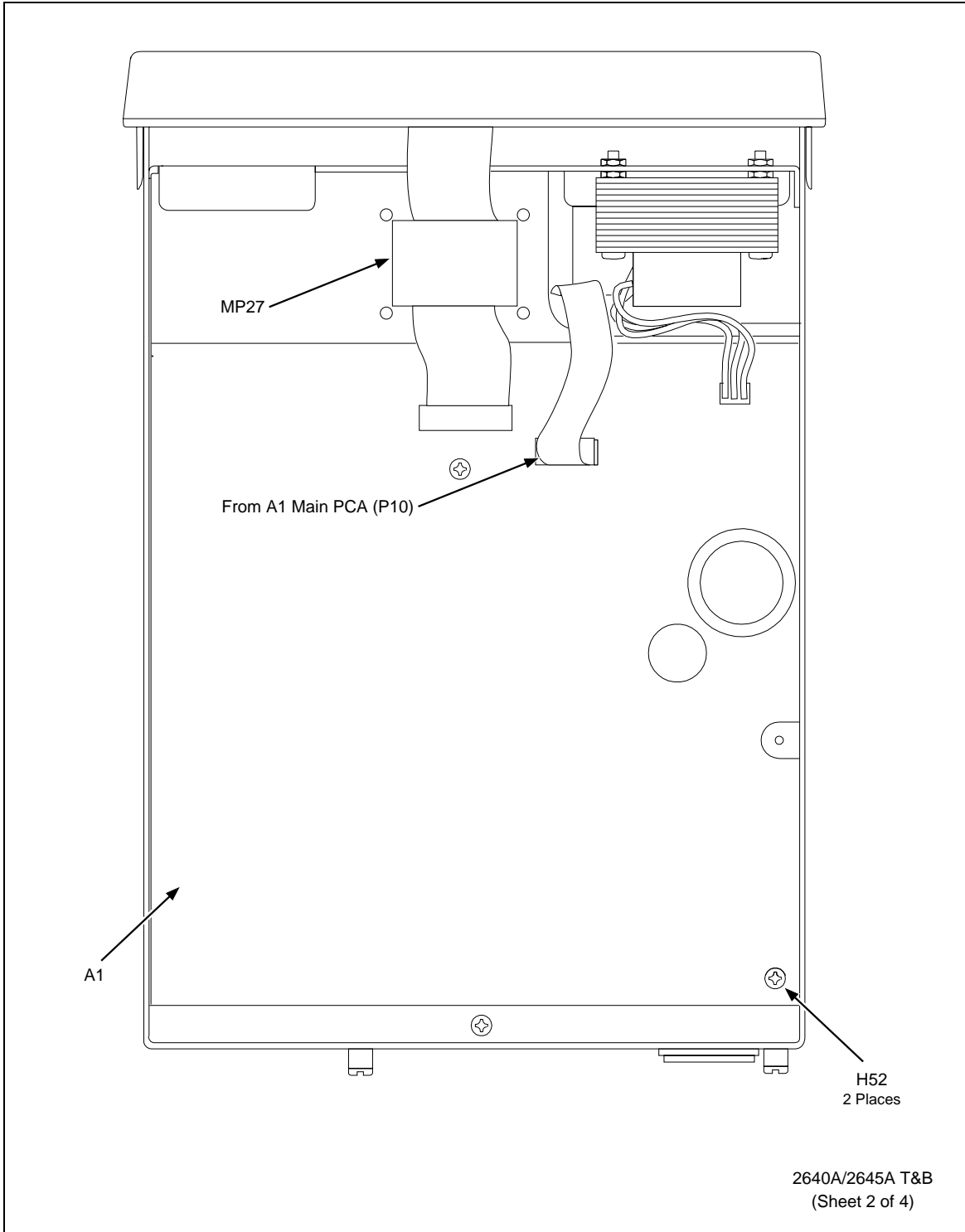1. 2640 only.

2. 2645 only.
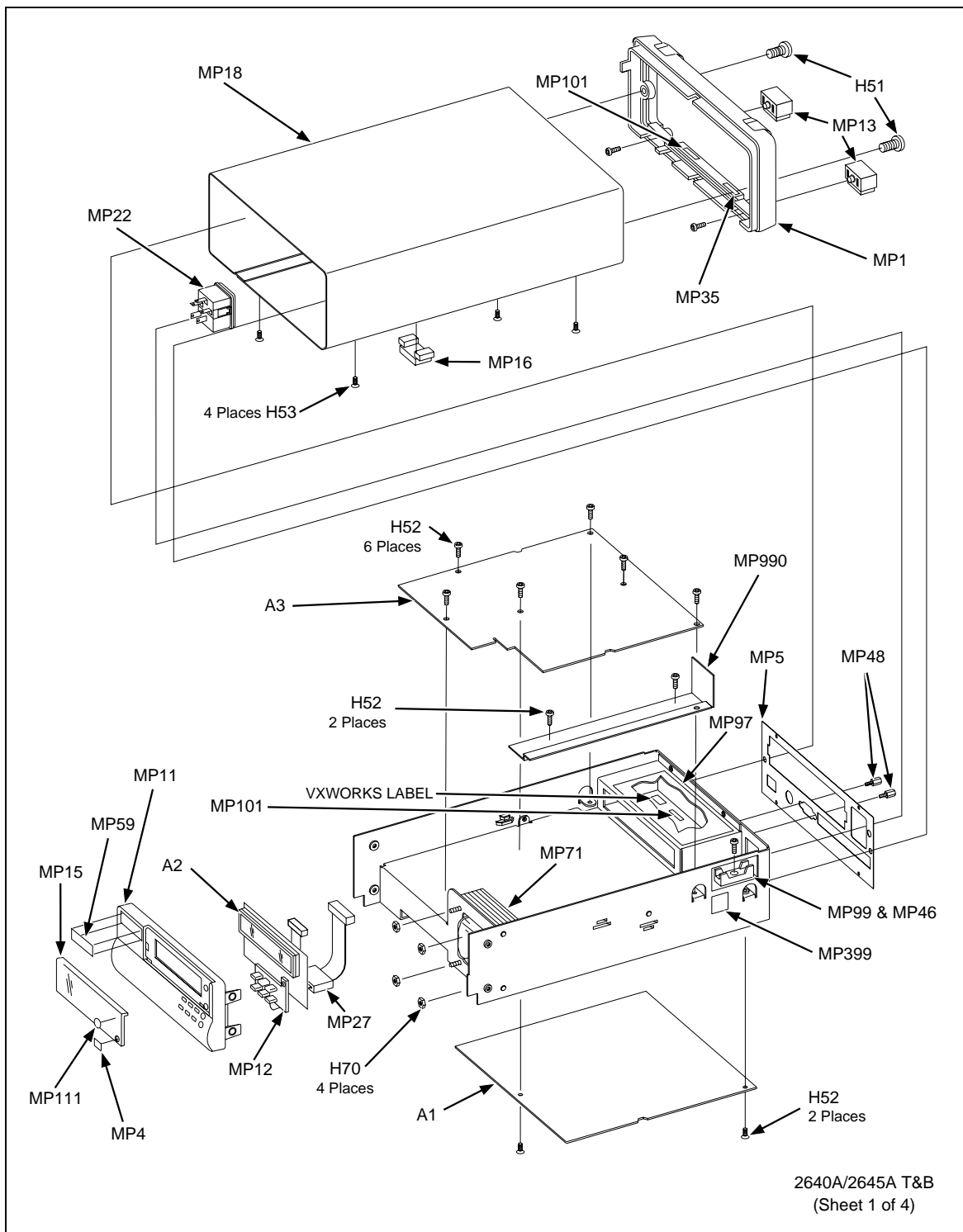
Figure 6-1. 2640A/2645A Final Assembly

MP27

From A1 Main PCA (P10)

A1

H52
2 Places

2640A/2645A T&B
(Sheet 2 of 4)

Figure 6-1. 2640A/2645A Final Assembly (cont)

MP71

From A1 Main PCA Assy (P10)

H52

H52

Black (Part
of MP71)

MP46 &
MP99

White (Part of MP71)
(N tab of MP22)

MP98
(From L tab
of MP22)

MP19
($\perp$ tab
of MP22)

2640A/2645A T&B
(Sheet 3 of 4)

Figure 6-1. 2640A/2645A Final Assembly (cont)

Red (2) from
A1 Main PCA Assy (P10)
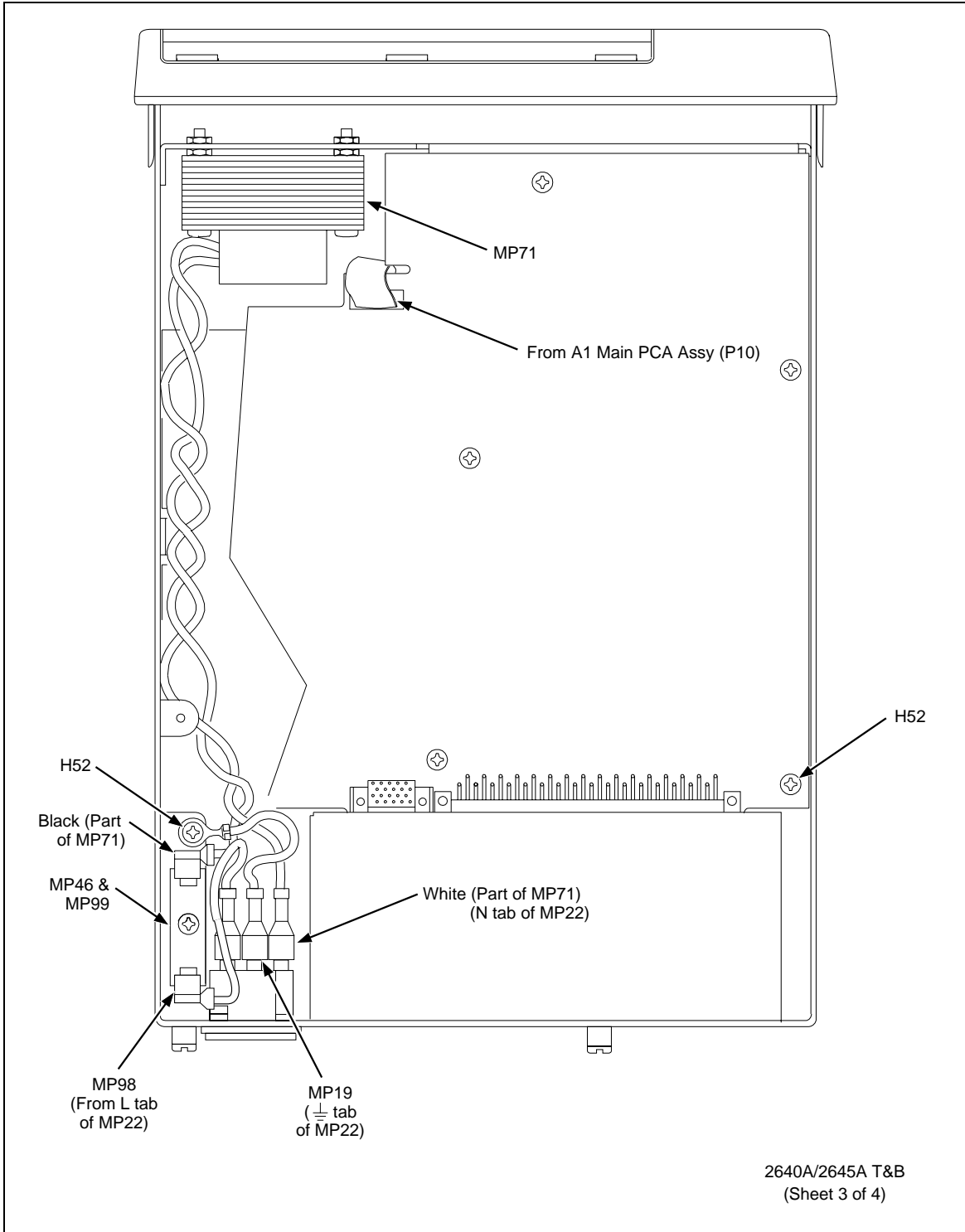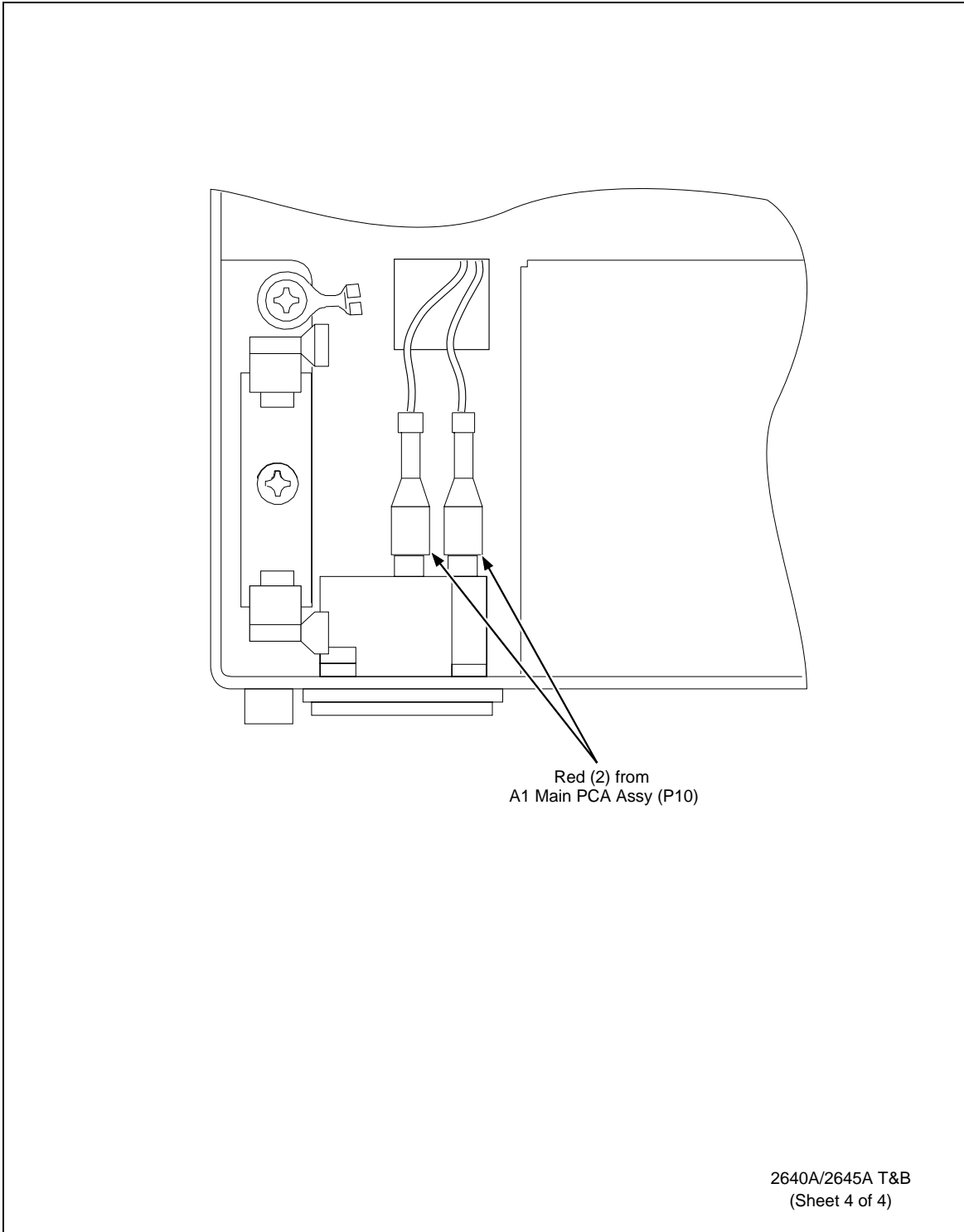
2640A/2645A T&B
(Sheet 4 of 4)

Figure 6-1. 2640A/2645A Final Assembly (cont)

Table 6-2. A1 Main PCA Assembly

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
BT1	BATTERY,LITHIUM,3.0V,0.560AH	821439	1	
C1, 18	CAP,AL,220UF,+-20%,35V,SOLV PROOF	929708	2	
C2	CAP,CER,0.033UF,+-20%,100V,X7R,1206	886655	1	
C3, 8, 38,	CAP,CER,22PF,+-10%,50V,C0G,1206	740563	4	
C89		740563		
C4- 6, 11,	CAP,AL,47UF,+-20%,50V,SOLV PROOF	822403	7	
C15, 30, 31		822403		
C7	CAP,AL,10000UF,+-20%,35V,SOLV PROOF	875203	1	
C9, 32, 34	CAP,AL,1UF,+-20%,50V,SOLV PROOF	782805	3	
C10, 35, 53,	CAP,CER,1000PF,+-5%,50V,C0G,1206	867408	4	
C81		867408		
C12, 13	CAP,AL,470UF,+-20%,16V,SOLV PROOF	772855	2	
C14	CAP,AL,2200UF,+-20%,10V,SOLV PROOF	875208	1	
C16, 19- 22	CAP,CER,0.1UF,+-10%,25V,X7R,1206	747287	40	
C24, 25, 29,		747287		
C33, 36, 40-		747287		
C42, 60, 62-		747287		
C65, 67- 69,		747287		
C71, 73, 75-		747287		
C80, 82- 84,		747287		
C86- 88, 90,		747287		
C92, 93, 95,		747287		
C96		747287		
C17	CAP,AL,2.2UF,+-20%,50V,SOLV PROOF	769687	1	
C23, 28	CAP,CER,1000PF,+-20%,3000V,Z5U	832709	2	
C26	CAP,AL,47UF,+-20%,100V,SOLV PROOF	837492	1	
C27, 37	CAP,CER,0.01UF,+-10%,50V,X7R,1206	747261	2	
C39,102	CAP,CER,0.047UF,+-10%,100V,X7R	844733	2	
C43- 52, 54-	CAP,CER,180PF,+-10%,50V,C0G,1206	769778	16	
C59		769778		
C61	CAP,CER,0.01UF,+100-0%,1600V,Z5U	106930	1	
C97	CAP,CER,4700PF,+-10%,50V,X7R,1206	832279	1	
C98-101	CAP,TA,10UF,+-20%,16V,6032	867572	4	
CR1, 10	DIODE,SI,60 PIV,3 AMP,SCHOTTKY	943097	2	
CR2, 3	DIODE,SI,600 PIV,1.5 AMP	112383	2	
CR4, 14, 15,	* DIODE,SI,BV=70V,IO=50MA,DUAL,SOT23	742544	6	
CR18, 19, 21		742544		
CR5, 6, 16	DIODE,SI,40 PIV,1 AMP,SCHOTTKY	837732	3	
CR7	* DIODE,SI,SCHOTTKY,DUAL,30V,SOT-23	942594	1	
CR8, 9, 13,	* DIODE,SI,BV=100,IO=100MA,DUAL,SOT23	821116	4	
CR17	*	821116		
CR11, 12, 20,	* DIODE,SI,BV=75V,IO=250MA,SOT23	830489	4	
CR22	*	830489		
DS1	LED,YELLOW,RIGHT ANGLE,3 MCD	914242	1	
DS2, 3	LED,RED,RIGHT ANGLE,3.0 MCD	927389	2	
J2	HEADER,1 ROW,.050CTR,20 PIN	831529	1	
J3	HEADER,1 ROW,.100CTR,3 PIN	845334	1	
J4	CONN,D-SUB,PWB,RT ANG,9 PIN	855221	1	
J5	HEADER,1 ROW,.197CTR,RT ANG,10 PIN	875695	1	
J6	HEADER,1 ROW,.197CTR,RT ANG,8 PIN	875690	1	
L1	FERRITE CHIP,95 OHMS @100 MHZ,3612	867734	1	

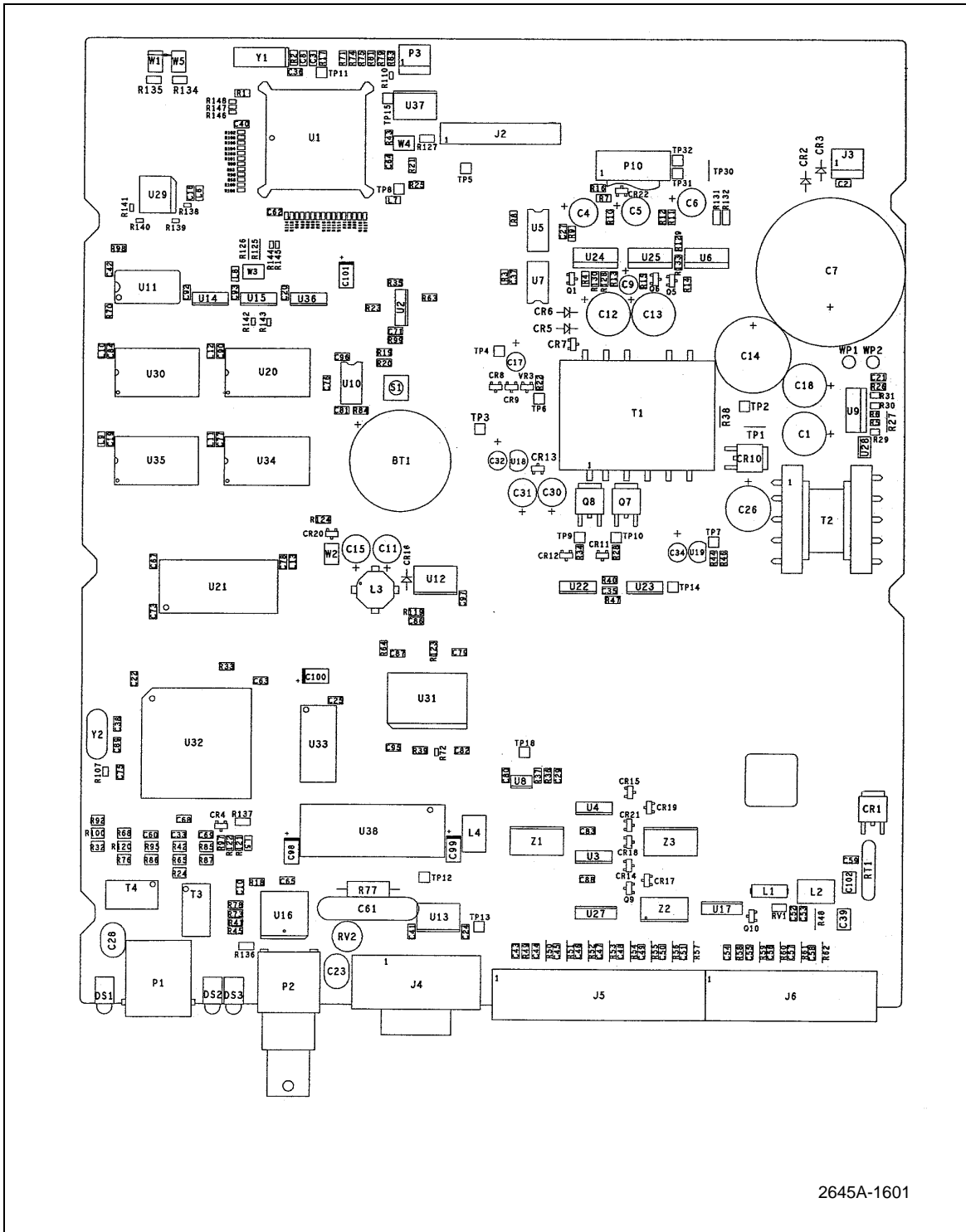**Table 6-2. A1 Main PCA Assembly (cont)**

Reference Designator		Description	Fluke Stock No	Tot Qty	Notes
L2, 4		CHOKE,6TURN	320911	2	
L3		INDUCTOR,20UH,+-20%,1.15ADC	914007	1	
L5- 13		FERRITE CHIP,600 OHM @100 MHZ,1206	943704	9	
P1		JACK,MODULAR,PWB,RT ANG,8 POS,8 PIN	929450	1	
P2		CONN,COAX,BNC(F),PWB,RT ANG	929153	1	
P10		CABLE ASSY,FLAT,10 CONDUCT,6.0"	714022	1	
Q 1	*	TRANSISTOR,SI,PNP,SMALL SIGNAL,SOT-23	742684	1	
Q5, 6	*	TRANSISTOR,SI,NPN,SMALL SIGNAL,SOT-23	742676	2	
Q7, 8	*	TRANSISTOR,SI,N-MOS,50W,D-PAK	927806	2	
Q9	*	TRANSISTOR,SI,NPN,25V,SOT-23	820902	1	
Q10	*	TRANSISTOR,SI,N-DMOS FET,SOT-23	927538	1	
R1, 14, 22,	*	RES,CERM,47K,+-5%,.125W,200PPM,1206	746685	6	
R25, 39,127	*		746685		
R2	*	RES,CERM,698K,+-1%,.125W,100PPM,1206	867296	1	
R3, 16, 97	*	RES,CERM,360,+-5%,.125W,200PPM,1206	783290	3	
R4, 15,130	*	RES,CERM,10,+-1%,.125W,100PPM,1206	867676	3	
R5, 6, 29-	*	RES,CERM,12.4K,+-1%,0.1W,100PPM,0805	928804	6	
R31,107	*		928804		
R7, 8, 28,	*	RES,CERM,470,+-5%,.125W,200PPM,1206	740506	9	
R34, 49, 58,	*		740506		
R121,122,136	*		740506		
R9, 12, 46,	*	RES,CERM,4.02K,+-1%,.125W,100PPM,1206	783266	5	
R129,131	*		783266		
R10, 44	*	RES,CERM,1.30K,+-1%,.125W,100PPM,1206	780999	2	
R11,132	*	RES,CERM,1.21K,+-1%,.125W,100PPM,1206	867189	2	
R13, 18, 84,	*	RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	4	
R128	*		783241		
R17	*	RES,CERM,33,+-5%,.125W,200PPM,1206	746248	1	
R19	*	RES,CERM,11K,+-1%,.125W,100PPM,1206	867291	1	
R20	*	RES,CERM,59K,+-1%,.125W,100PPM,1206	851803	1	
R21	*	RES,CERM,270,+-5%,.125W,200PPM,1206	746354	1	
R23, 35, 41,	*	RES,CERM,1.5K,+-5%,.125W,200PPM,1206	746438	7	
R45, 63, 73,	*		746438		
R78	*		746438		
R24	*	RES,CERM,78.7,+-1%,0.25W,100PPM,1210	929682	1	
R26	*	RES,CERM,100,+-5%,.125W,200PPM,1206	746297	1	
R27		RES,CF,220K,+-5%,0.25W	851837	1	
R32, 68, 76,	*	RES,CERM,75,+-1%,0.25W,100PPM,1210	929679	6	
R92,100,120	*		929679		
R33, 71, 83,	*	RES,CERM,4.7K,+-5%,.125W,200PPM,1206	740522	4	
R98	*		740522		
R36	*	RES,CERM,3.6K,+-5%,.125W,200PPM,1206	746537	1	
R37	*	RES,CERM,9.1K,+-5%,.125W,200PPM,1206	746602	1	
R38,126		RES JUMPER,0.02,0.25W	682575	2	
R40	*	RES,CERM,5.1K,+-5%,.125W,200PPM,1206	746560	1	
R42, 65, 85,	*	RES,CERM,39.2,+-1%,0.25W,100PPM,1210	929666	4	
R87	*		929666		
R43, 47, 64,	*	RES,CERM,10K,+-5%,.125W,200PPM,1206	746610	14	
R70, 74, 75,	*		746610		
R79, 81, 99,	*		746610		
R123,124,134,	*		746610		

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Table 6-2. A1 Main PCA Assembly (cont)

Reference Designator		Description	Fluke Stock No	Tot Qty	Notes
R135,137	*		746610		
R48		RES,CF,10K,+-5%,0.25W	697102	1	
R50- 57, 59-		RES,CF,47,+-5%,0.25W	822189	12	
R62			822189		
R66, 67, 69,	*	RES,CERM,47,+-5%,.0625W,200PPM,0603	927707	41	
R72, 80, 82,	*		927707		
R88- 91, 93,	*		927707		
R94, 96,101-	*		927707		
R106,108-118,	*		927707		
R138-148	*		927707		
R77	*	RES,CERM,1M,+-5%,1W,200PPM	912589	1	
R86, 95	*	RES,CERM,49.9,+-1%,0.25W,100PPM,1210	929674	2	
R119	*	RES,CERM,100K,+-5%,.125W,200PPM,1206	740548	1	
R133	*	RES,CERM,3.32K,+-1%,.125W,100PPM,1206	810788	1	
RT1		THERMISTOR,DISC,0.18,25C	875273	1	
RV1		VARISTOR,41.5V,+-9%,1.0MA,1206	914114	1	
RV2		VARISTOR,910,+-10%,1.0MA	876193	1	
T1		TRANSFORMER, INVERTER	939681	1	
T2		INDUCTOR,FXD,DUAL,EE24-25,0.4MH,1.2A	817379	1	
T3		TRANSF,PULSE,3/PKG,1:1,100UH	929625	1	
T4		TRANSF,PULSE,10BASE-T,RCV1:1,XMT1:1.4	929620	1	
TP1, 30		JUMPER,WIRE,NONINSUL,0.200CTR	816090	2	
U1	*	IC,INTEGR MLTIPROTOCOL MPU,16 MHZ,QFP	910831	1	
U2	*	IC,CMOS,QUAD BUS BUFFER W/3-ST,SOIC	866801	1	
U3, 4	*	IC,OP AMP,QUAD,LOW POWER,SOIC	742569	2	
U5, 7	*	ISOLATOR,OPTO,HI-SPEED,LED TO GATE	504522	2	
U6, 24	*	IC,VOLT REG,ADJ,POS,LO DROPOUT,TO-220	943931	2	
U8, 28	*	IC,OP AMP,DUAL,LOW POWER,SOIC	867932	2	
U9	*	IC,V REG,SWITCHING,100KHZ,5A,TO-220	929591	1	
U10	*	IC,CMOS,MICROPROCESSOR SUPERVISOR,DIP	913975	1	
U11	*	IC,CMOS,PARALLEL I/O CAL/CLCK W/CRYST	914036	1	
U12	*	IC,CMOS,REGULATOR,STEP-UP,PWM,SO16	914080	1	
U13	*	IC,CMOS,RS232 DRIVER/RECEIVER,SOIC	821538	1	
U14	*	IC,CMOS,HEX INVERTER,SOIC	838417	1	
U15	*	IC,CMOS,QUAD 2 INPUT OR GATE,SOIC	838276	1	
U16	*	IC,COAXIAL TRANSCEIVER,ETHERNET,PLCC	944723	1	
U17, 27	*	IC,ARRAY,7 NPN DARLINGTON PAIRS,SOIC	821009	2	
U18	*	IC,VOLT REG,FIXED,-5.0 VOLTS,0.1 AMPS	454793	1	
U19	*	IC,VOLT REG,ADJ,1.2 TO 32 V,0.1 A	810242	1	
U20, 30, 34,	*	IC,CMOS,SRAM,128K X 8,100 NS,SO32	914101	4	
U35	*		914101		
U21	*	IC,PROGRAMMED FLASH,MAIN	949677	1	
U22	*	IC,CMOS,DUAL D F/F,+EDG TRG,SOIC	782995	1	
U23	*	IC,CMOS,HEX INVERTER,UNBUFFERED,SOIC	806893	1	
U25	*	IC,VOLT REG,ADJ,NEG,LO DROPOUT,TO-220	943936	1	
U29	*	IC,16V8,PROGRAMMED,2645A-90130,PLCC20	943159	1	
U31	*	IC,PROG GATE ARRAY,3000 G,70 MHZ,PQFP	887138	1	
U32	*	IC,ETHERCOUPLER CONTROLLER,PQFP160	929612	1	
U33	*	IC,CMOS,SRAM,32K X 8,70 NS,SO28	929609	1	
U36	*	IC,CMOS,QUAD INPUT NAND GATE,SOIC	830703	1	
U38		PWR SUP,5VIN,9VOUT,1.8W	929583	1	

Table 6-2. A1 Main PCA Assembly (cont)

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
VR3	* ZENER,UNCOMP,6.8V,5%,20MA,0.2W,SOT-23	837195	1	
W2, 3	HEADER,1 ROW,.100CTR,2 PIN	643916	2	
WP1, 2	DC POWER WIRE	938139	2	
Y1	CRYSTAL,15.36MHZ,50PPM,SURFACE MT	943167	1	
Y2	CRYSTAL,20.00MHZ,+-30PPM,HC-49M	867051	1	
Z1	RES,CERM,NET,CUSTOM	821157	1	
Z2	RES,CERM,SOIC,16 PIN,15 RES,22K,+-2%	867841	1	
Z3	RES,CERM,SOIC,20 PIN,10 RES,47K,+-2%	867846	1	

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Figure 6-2. A1 Main PCA Assembly

Table 6-3. A2 Display PCA Assembly

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
C1, 3- 6	CAP,CER,0.1UF,+-10%,25V,X7R,1206	747287	5	
C2	CAP,TA,4.7UF,+-20%,16V,3528	745976	1	
CR3	* DIODE,SI,BV=75V,IO=250MA,SOT23	830489	1	
DS1	TUBE,DISPLAY,VAC FLUOR,7 SEG,10 CHAR	783522	1	
J1	HEADER,1 ROW,.050CTR,20 PIN	831529	1	
LS1	AF TRANSD,PIEZO,22 MM	602490	1	
MP321	WIRE,JUMPER,TEF,22AWG,WHT,.300	528257	1	
R1, 10, 12	* RES,CERM,10K,+-5%,.125W,200PPM,1206	746610	3	
R2	* RES,CERM,2.2M,+-5%,.125W,200PPM,1206	811778	1	
R3	* RES,CERM,1.2M,+-5%,.125W,200PPM,1206	806240	1	
R11	* RES,CERM,1K,+-5%,.125W,200PPM,1206	745992	1	
U1	* IC,CMOS,4-BIT MPU,FLUKE 45-90002	820993	1	
U4	* IC,CMOS,DUAL DIV BY 16 BIN CNTR,SOIC	837054	1	
U5	* IC,CMOS,DUAL MONOSTB MULTIVBRTR,SOIC	806620	1	
U6	* IC,CMOS,QUAD 2 IN NAND W/SCHMT,SOIC	837245	1	
Z1	RES,CERM,SOIC,16 PIN,15 RES,10K,+-2%	836296	1	
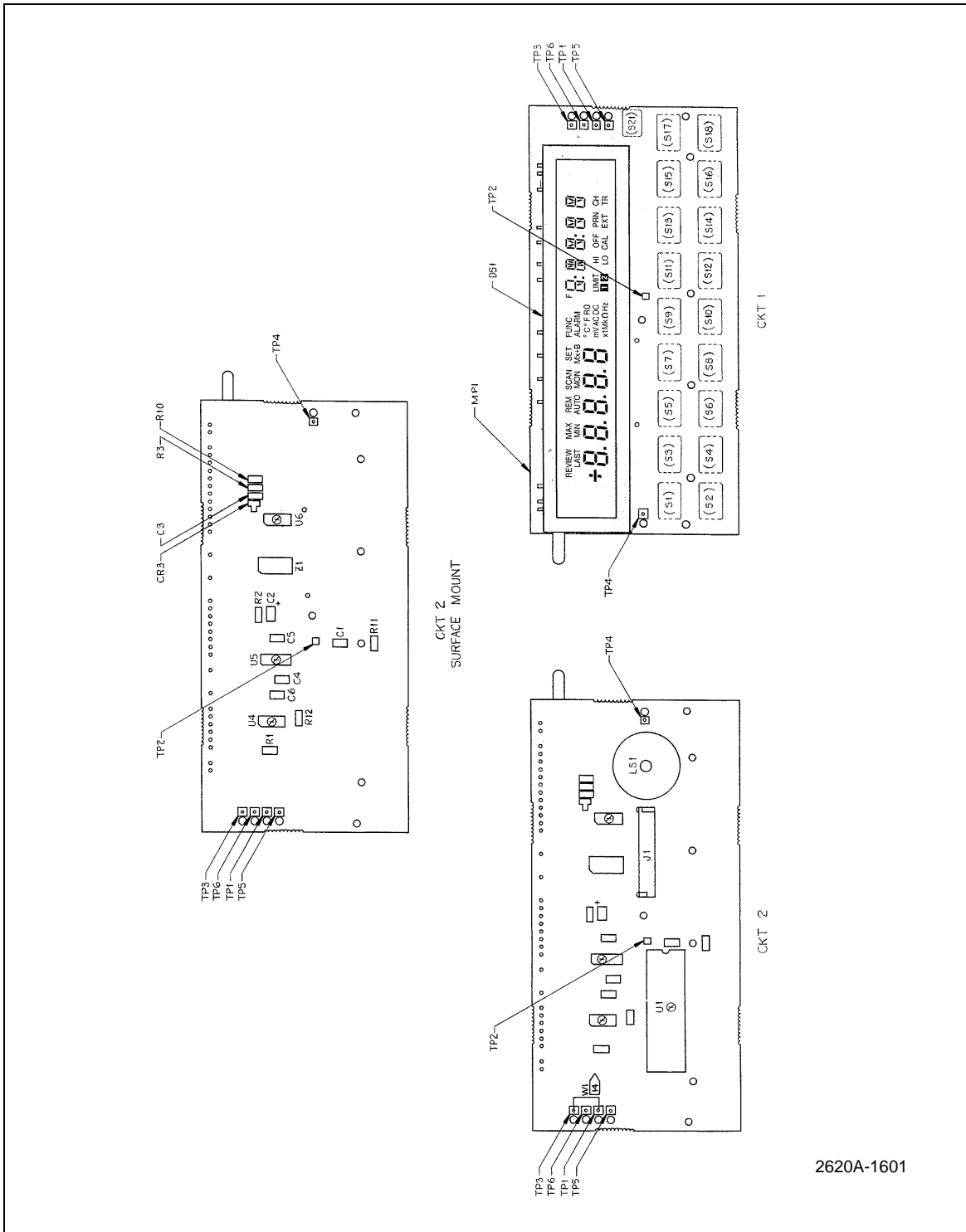
2620A-1601

Figure 6-3. A2 Display PCA Assembly

Table 6-4. 2640A A3 A/D Converter PCA Assembly

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
C1- 4, 6-	CAP,CER,0.1UF,+-10%,25V,X7R,1206	747287	60	
C12, 16- 24,		747287		
C28- 30, 32,		747287		
C34, 36- 42,		747287		
C47, 49- 55,		747287		
C61- 63, 69,		747287		
C70, 75, 77,		747287		
C78, 81, 86-		747287		
C96		747287		
C5, 13- 15,	CAP,TA,10UF,+-20%,16V,6032	867572	10	
C31, 33, 45,		867572		
C46, 67, 68		867572		
C25, 48	CAP,CER,0.01UF,+-10%,50V,X7R,1206	747261	2	
C26, 27	CAP,CER,27PF,+-10%,50V,C0G,1206	800508	2	
C35, 56	CAP,CER,1000PF,+-10%,50V,C0G,1206	747378	2	
C43	CAP,CER,3.3PF,+-0.5PF,50V,C0G,0805	514208	1	
C44	CAP,POLYPR,1500PF,+-2.5%,100V	854641	1	
C57- 59	CAP,POLYPR,0.1UF,+-10%,160V	446781	3	
C60	CAP,POLYES,0.47UF,+-10%,50V	697409	1	
C64, 65	CAP,AL,470UF,+-20%,10V,SOLV PROOF	822387	2	
C66	CAP,POLYES,1UF,+-10%,50V	733089	1	
C71, 72	CAP,TA,33UF,+-10%,6V	866897	2	
C73	CAP,POLYPR,2200PF,+-5%,100V	854505	1	
C74	CAP,CER,1000PF,+-5%,50V,C0G,1206	867408	1	
C76	CAP,CER,4.3PF,+-0.5PF,50V,C0G,0805	514216	1	
C79	CAP,CER,0.047UF,+-20%,50V,X7R,1206	782615	1	
C80	CAP,POLYES,0.1UF,+-10%,1000V	837518	1	
C82	CAP,CER,2500PF,+-20%,250V,X7R	485680	1	
C83, 84	CAP,CER,15PF,+-10%,50V,C0G,1206	837393	2	
C85	CAP,CER,68PF,+-2%,50V,C0G	715300	1	
C97, 98	CAP,CER,180PF,+-2%,50V,C0G	820522	2	
CR1- 6	* DIODE,SI,BV=70V,IO=50MA,DUAL,SOT23	742320	6	
CR7, 21	* DIODE,SI,SCHOTTKY,DUAL,30V,SOT-23	942594	2	
CR8- 14, 17-	* DIODE,SI,DUAL,BV=50V,IO=100MA,SOT23	851659	10	
CR19	*	851659		
CR15	* DIODE,SI,BV=100,IO=100MA,DUAL,SOT23	821116	1	
J1	CONN,DIN41612,TYPE C,RT ANG,48 PIN	867333	1	
J2	CONN,MICRO-RIBBON,PLUG,RT ANG,20 POS	876107	1	
J3	JACK,PWB,RT ANG,1.3MM PIN	943113	1	
J10	HEADER,2 ROW,.100CTR,10 PIN	756858	1	
K1- 20, 23,	RELAY,REED,2 FORM A,5VDC,LOW THERM,HV	929711	22	
K24		929711		
K21, 22	RELAY,REED,2 FORM A,5VDC,LOWTHERM,1UV	944488	2	
K25, 26	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	836486	2	
K27	RELAY,ARMATURE,4 FORM C,5V,LATCH	715078	1	
L1- 49, 51	FERRITE CHIP,600 OHM @100 MHZ,1206	943704	50	
L50, 53- 71	INDUCTOR,33UH,+-10%,0.115ADC	944509	20	
L52	INDUCTOR,15MH,+-5%,0.021ADC	944251	1	
MP200	INSUL PT,TRANSISTOR MOUNT,DAP,TO-5	152207	1	
MP813,815	RIVET,S-TUB,OVAL,STL,.087,.343	838458	2	
P1, 2	HEADER,1 ROW,.100CTR,3 PIN	845334	2	

Table 6-4. 2640A A3 A/D Converter PCA Assembly (cont)

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
Q1	* TRANSISTOR,SI,N-DMOS FET,SOT-23	927538	1	
Q2, 4	* TRANSISTOR,SI,N-JFET,SOT-23	929588	2	
Q3	* TRANSISTOR,SI,P-CHAN,SOT-23	832477	1	
Q5	REF AMP SET	936047	1	
Q6- 9, 19,	* TRANSISTOR,SI,N-JFET,SOT-23	876263	10	
Q20, 23- 26	*	876263		
Q10- 16	* TRANSISTOR,SI,N-JFET,SOT-23	820860	7	
Q17, 18, 21,	* TRANSISTOR,SI,NPN,SELECT IEBO,SOT-23	821637	4	
Q22	*	821637		
Q33	* TRANSISTOR,SI,PNP,SMALL SIGNAL,SOT-23	742684	1	
R1, 6, 23,	* RES,CERM,10K,+-1%,0.1W,100PPM,0805	928791	22	
R38- 42, 46,	*	928791		
R47, 49- 57,	*	928791		
R60,144,145	*	928791		
R2, 3	* RES,CERM,470K,+-5%,.125W,200PPM,1206	746792	2	
R4, 20, 44,	* RES,CERM,10K,+-1%,.125W,100PPM,1206	769794	11	
R45, 75, 78,	*	769794		
R95, 98,149,	*	769794		
R150,152	*	769794		
R5, 61, 65,	* RES,CERM,1.07K,+-1%,.125W,100PPM,1206	876011	5	
R101,147	*	876011		
R7- 14, 17-	* RES,CERM,47,+-5%,.0625W,200PPM,0603	927707	34	
R19, 24- 37,	*	927707		
R43, 59,109,	*	927707		
R115,118,153,	*	927707		
R166-168	*	927707		
R15,102-104,	* RES,CERM,100K,+-1%,.125W,100PPM,1206	769802	7	
R126,134,139	*	769802		
R16,108,136,	* RES,CERM,30.1K,+-1%,.125W,100PPM,1206	801258	4	
R137	*	801258		
R21	* RES,CERM,1.5K,+-1%,.125W,100PPM,1206	810630	1	
R22, 62,106,	* RES,CERM,10,+-1%,.125W,100PPM,1206	867676	12	
R107,129,131,	*	867676		
R154,158,160,	*	867676		
R164,165,184	*	867676		
R48, 85- 92,	* RES,CERM,47,+-5%,.125W,200PPM,1206	746263	11	
R148,151	*	746263		
R58	* RES,CERM,698K,+-1%,.125W,100PPM,1206	867296	1	
R66, 68, 70,	* RES,CERM,200,+-1%,.125W,100PPM,1206	772798	7	
R72, 73, 81,	*	772798		
R84	*	772798		
R67	* RES,CERM,7.5K,+-1%,.125W,100PPM,1206	811463	1	
R69, 96	* RES,CERM,2K,+-5%,.125W,200PPM,1206	746461	2	
R71	RES,MF,28.7K,+-1%,0.125W,50PPM	335315	1	
R74, 97,105,	* RES,CERM,47K,+-5%,.125W,200PPM,1206	746685	10	
R120-124,142,	*	746685		
R143	*	746685		
R76,112-114	* RES,CERM,33,+-5%,.125W,200PPM,1206	746248	4	
R77	* RES,CERM,26.1K,+-1%,.125W,100PPM,1206	807685	1	
R79	* RES,CERM,110K,1%,.125W,100PPM,1206	887208	1	
R80	* RES,CERM,100,+-5%,.125W,200PPM,1206	746297	1	

Table 6-4. 2640A A3 A/D Converter PCA Assembly (cont)

Reference Designator		Description	Fluke Stock No	Tot Qty	Notes
R82		RES,MF,10K,+-1%,0.125W,25PPM	328120	1	
R83		RES,MF,402,+-1%,0.125W,25PPM	658401	1	
R93	*	RES,CERM,91K,+-5%,.125W,200PPM,1206	811828	1	
R94	*	RES,CERM,45.3K,+-1%,0.1W,100PPM,0805	930201	1	
R99		RES,MF,29.4K,+-1%,0.125W,25PPM	929690	1	
R100,140	*	RES,CERM,4.02K,+-1%,.125W,100PPM,1206	783266	2	
R110,111		RES,MF,1K,+-1%,100PPM,FLMPRF,FUSIBLE	650085	2	1
R116,146		RES,CF,270,+-5%,0.25W	810424	2	
R117,125	*	RES,CERM,22,+-5%,.125W,200PPM,1206	746230	2	
R119,127,133	*	RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	3	
R128		RNET, MF, FRIT, SIP, LO V I SOURCE	926691	1	
R130,132	*	RES,CERM,100K,+-5%,3W	820811	2	
R135	*	RES,CERM,24.9K,+-1%,.125W,100PPM,1206	867689	1	
R138		THERMISTOR,DISC,POS,1K,+-40%,25 C	820878	1	
R141	*	RES,CERM,1M,+-1%,.125W,100PPM,1206	836387	1	
R155	*	RES,CERM,510,+-5%,.125W,200PPM,1206	746388	1	
R156		RES,CF,6.2K,+-5%,0.25W	714337	1	
R183	*	RES,CERM,59K,+-1%,.125W,100PPM,1206	851803	1	
TP1, 2		JUMPER,WIRE,NONINSUL,0.200CTR	816090	2	
U1, 3, 23	*	IC,COMPARATOR,DUAL,LOW PWR,SOIC	837211	3	
U2	*	IC,CMOS,SRAM,128K X 8,100 NS,SO32	914101	1	
U4	*	IC,CMOS,RS232 DRIVER/RECEIVER,SOIC	821538	1	
U5	*	IC,INTEGR MLTIPROTOCOL MPU,16 MHZ,QFP	910831	1	
U6	*	PROGRAMMED FLASH, PFE	949685	1	
U7, 10	*	IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	838029	2	
U8	*	IC,VOLT REG,5 V,LO DO/IQ,500MA,SOT223	929641	1	
U9, 34	*	IC,CMOS,QUAD 2 INPUT OR GATE,SOIC	838276	2	
U11	*	IC,COMPARATOR,HI-SPEED,PRECISION	822197	1	
U12, 27, 31	*	IC,OP AMP,DUAL,PICOAMP IB,SO8	910836	3	
U13, 15	*	IC,ARRAY,7 NPN DARLINGTON PAIRS,SOIC	821009	2	
U14, 33	*	IC,LSTTL,BCD-DEC,DECODER/DRIVER,SOIC	742007	2	
U16	*	IC,CMOS,QUAD 2 INPUT AND GATE,SOIC	853317	1	
U17, 2	*	IC,CMOS,HEX INVERTER,UNBUFFERED,SOIC	806893	2	
U18	*	IC,EPLD,PR0GRAMMED,2645A-90220,PLCC84	929695	1	
U19	*	IC,OP AMP,DUAL,LO POWR,SNGL SUP,8PDIP	929604	1	
U20	*	IC,OP AMP,DUAL,RAIL-RAIL VOUT,SO8	929596	1	
U22, 24, 25	*	IC,CMOS,TRIPLE 2-1 LINE ANLG MUX,SOIC	929013	3	
U26	*	IC,BPLR,TRUE RMS TO DC CONVERTER	707653	1	
U28	*	IC,OP AMP,PRECISION,SINGLE SUPPLY,SO8	905315	1	
U29	*	IC,OP AMP,JFET INPUT,DECOMP,SOIC	837237	1	
U30		IC TWIN WELL STALLION ASSEMBLY TESTED	933502	1	
U32	*	IC,OP AMP,DUAL,HIGH BW,SNGL SUP,SO8	929075	1	
VR1	*	ZENER,UNCOMP,15V,5%,8.5MA,0.2W,SOT-23	837187	1	
VR2- 4	*	ZENER,UNCOMP,6.0V,5%,20MA,0.2W,SOT-23	837161	3	
W5, 6, 8		HEADER,1 ROW,.100CTR,2 PIN	643916	3	
Y1		CRYSTAL,15.36MHZ,50PPM,SURFACE MT	943167	1	
Y2		CRYSTAL,10MHZ,+-0.01%,HC-18/U	520239	1	
Z1		RNET, MF, FRIT, SIP, A TO D CONV	926688	1	
Z2		RNET,CERM,SIP,2620 LO V DIVIDER	849984	1	
Z3, 4		RNET,MF,POLY,SIP,1752 LO V DIVIDER	645341	2	
Z5		RNET,MF,POLY,SIP,8840 LO V DIVIDER	655811	1	

Table 6-4. 2640A A3 A/D Converter PCA Assembly (cont)

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
Z6	RNET,CERM,SIP,2620 HI V AMP GAIN	847363	1	
Z7	RNET, MF, FRIT, SIP, HI V DIVIDER	926733	1	
Z8	RNET,MF,POLY,SIP,2280 LO V DIVIDER	611186	1	
1. FUSIBLE RESISTOR. USE EXACT REPLACEMENT ONLY.				
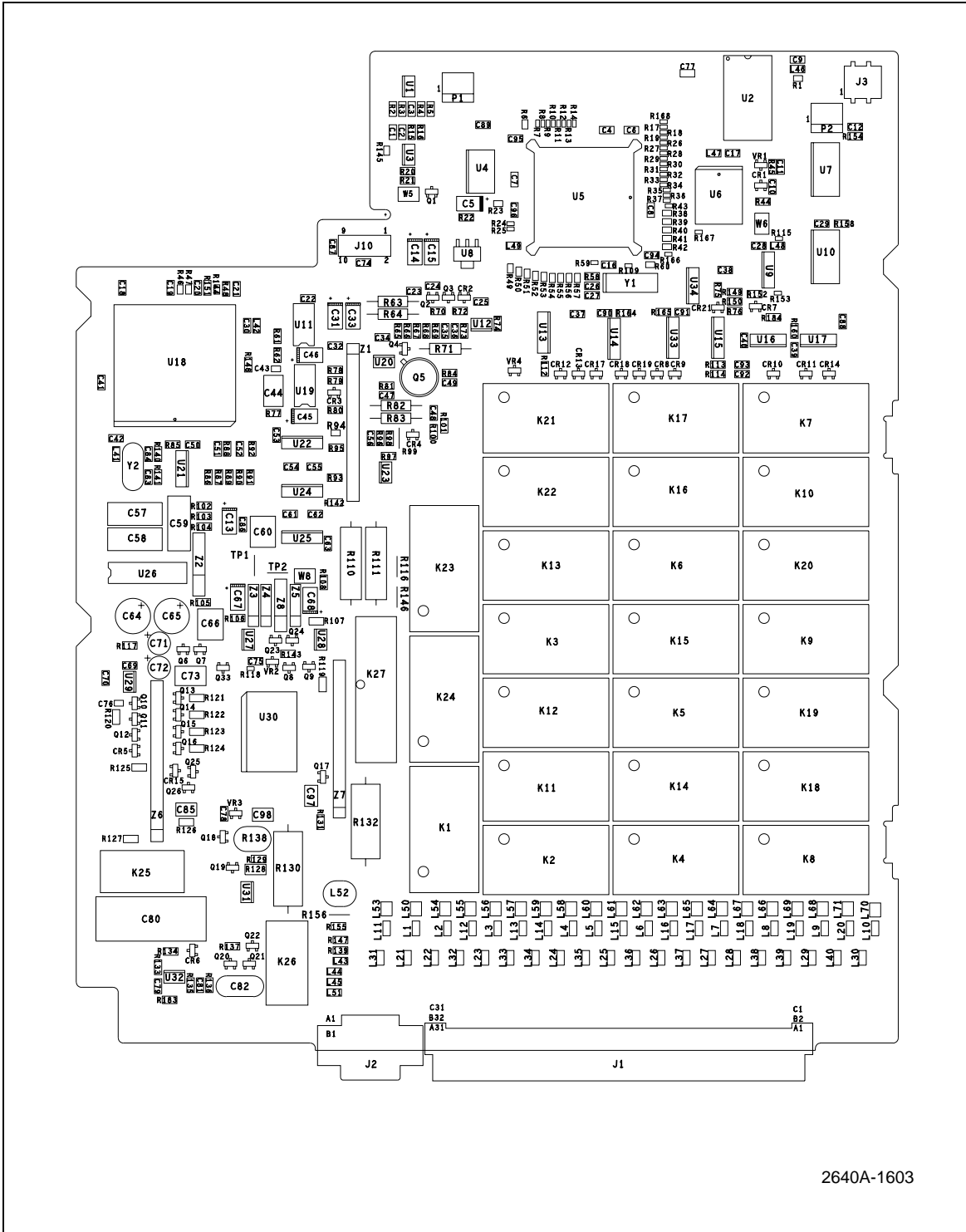
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Figure 6-4. 2640A A3 A/D Converter PCA Assembly

Table 6-5. 2645A A3 A/D Converter PCA Assembly

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
C1- 4, 6-203	CAP,CER,0.1UF,+-10%,25V,X7R,1206	747287	58	
C12, 16- 24,		747287		
C28- 30, 32,		747287		
C34, 36- 42,		747287		
C47, 49- 55,		747287		
C61- 63, 69,		747287		
C70, 75, 77,		747287		
C78, 81, 86,		747287		
C88- 91, 94-		747287		
C97		747287		
C5, 13- 15,	CAP,TA,10UF,+-20%,16V,6032	867572	10	
C31, 33, 45,		867572		
C46, 67, 68		867572		
C25, 48	CAP,CER,0.01UF,+-10%,50V,X7R,1206	747261	2	
C26, 27	CAP,CER,27PF,+-10%,50V,C0G,1206	800508	2	
C35, 56	CAP,CER,1000PF,+-10%,50V,C0G,1206	747378	2	
C43	CAP,CER,3.3PF,+-0.5PF,50V,C0G,0805	514208	1	
C44	CAP,POLYPR,1500PF,+-2.5%,100V	854641	1	
C57- 59	CAP,POLYPR,0.1UF,+-10%,160V	446781	3	
C60	CAP,POLYES,0.47UF,+-10%,50V	697409	1	
C64, 65	CAP,AL,470UF,+-20%,10V,SOLV PROOF	822387	2	
C66	CAP,POLYES,1UF,+-10%,50V	733089	1	
C71, 72	CAP,TA,33UF,+-10%,6V	866897	2	
C73	CAP,POLYPR,1000PF,+-1%,100V	844816	1	
C74, 87	CAP,CER,1000PF,+-5%,50V,C0G,1206	867408	2	
C76	CAP,CER,4.3PF,+-0.5PF,50V,C0G,0805	514216	1	
C79	CAP,CER,0.047UF,+-20%,50V,X7R,1206	782615	1	
C80	CAP,POLYES,0.1UF,+-10%,1000V	837518	1	
C82	CAP,CER,2500PF,+-20%,250V,X7R	485680	1	
C83, 84	CAP,CER,15PF,+-10%,50V,C0G,1206	837393	2	
C85	CAP,CER,68PF,+-2%,50V,C0G	715300	1	
CR1- 6, 8,	* DIODE,SI,BV=70V,IO=50MA,DUAL,SOT23	742320	8	
CR9	*	742320		
J1	CONN,DIN41612,TYPE C,RT ANG,48 PIN	867333	1	
J2	CONN,MICRO-RIBBON,PLUG,RT ANG,20 POS	876107	1	
J3	JACK,PWB,RT ANG,1.3MM PIN	943113	1	
J10	HEADER,2 ROW,.100CTR,10 PIN	756858	1	
K1- 24	RELAY,SOLID STATE,DUAL 1FA,400V,20MA	929703	24	
K25, 26	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	836486	2	
K27	RELAY,ARMATURE,4 FORM C,5V,LATCH	715078	1	
L1- 49, 51	FERRITE CHIP,600 OHM @100 MHZ,1206	943704	50	
L50, 52	INDUCTOR,15MH,+-5%,0.021ADC	944251	2	
L61-100	INDUCTOR,33UH,+-10%,0.115ADC	944509	40	
MP200	INSUL PT,TRANSISTOR MOUNT,DAP,TO-5	152207	1	
MP813,815	RIVET,S-TUB,OVAL,STL,.087,.343	838458	2	
P1, 2	HEADER,1 ROW,.100CTR,3 PIN	845334	2	
Q1	* TRANSISTOR,SI,N-DMOS FET,SOT-23	927538	1	
Q2, 4	* TRANSISTOR,SI,N-JFET,SOT-23	929588	2	
Q3	* TRANSISTOR,SI,P-CHAN,SOT-23	832477	1	
Q5	REF AMP SET	936047	1	
Q6- 10, 13,	* TRANSISTOR,SI,N-JFET,SOT-23	876263	10	

Table 6-5. 2645A A3 A/D Converter PCA Assembly (cont)

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
Q19, 20, 23,	*	876263		
Q24	*	876263		
Q11, 12, 14-	* TRANSISTOR,SI,N-JFET,SOT-23	820860	5	
Q16	*	820860		
Q17, 18, 21,	* TRANSISTOR,SI,NPN,SELECT IEBO,SOT-23	821637	4	
Q22	*	821637		
Q33	* TRANSISTOR,SI,PNP,SMALL SIGNAL,SOT-23	742684	1	
R1, 6, 23,	* RES,CERM,10K,+-1%,0.1W,100PPM,0805	928791	22	
R38- 42, 46,	*	928791		
R47, 49- 57,	*	928791		
R60,144,145	*	928791		
R2, 3	* RES,CERM,470K,+-5%,.125W,200PPM,1206	746792	2	
R4, 20, 44,	* RES,CERM,10K,+-1%,.125W,100PPM,1206	769794	7	
R45, 78, 95,	*	769794		
R98	*	769794		
R5, 61, 65,	* RES,CERM,1.07K,+-1%,.125W,100PPM,1206	876011	5	
R101,147	*	876011		
R7- 14, 17-	* RES,CERM,47,+-5%,.0625W,200PPM,0603	927707	34	
R19, 24- 37,	*	927707		
R43, 59,109,	*	927707		
R115,118,153,	*	927707		
R167-169	*	927707		
R15,102-104,	* RES,CERM,100K,+-1%,.125W,100PPM,1206	769802	6	
R126,134	*	769802		
R16,108,136,	* RES,CERM,30.1K,+-1%,.125W,100PPM,1206	801258	4	
R137	*	801258		
R21	* RES,CERM,1.5K,+-1%,.125W,100PPM,1206	810630	1	
R22, 62,106,	* RES,CERM,10,+-1%,.125W,100PPM,1206	867676	13	
R107,129,131,	*	867676		
R149,150,154,	*	867676		
R158,160,164,	*	867676		
R165	*	867676		
R48, 85- 92,	* RES,CERM,47,+-5%,.125W,200PPM,1206	746263	11	
R121,148	*	746263		
R58	* RES,CERM,698K,+-1%,.125W,100PPM,1206	867296	1	
R66, 68, 70,	* RES,CERM,200,+-1%,.125W,100PPM,1206	772798	7	
R72, 73, 81,	*	772798		
R84	*	772798		
R67	* RES,CERM,7.5K,+-1%,.125W,100PPM,1206	811463	1	
R69, 96	* RES,CERM,2K,+-5%,.125W,200PPM,1206	746461	2	
R71	RES,MF,28.7K,+-1%,0.125W,50PPM	335315	1	
R74, 97,105,	* RES,CERM,47K,+-5%,.125W,200PPM,1206	746685	9	
R120,122-124,	*	746685		
R142,143	*	746685		
R75, 76	* RES,CERM,33,+-5%,.125W,200PPM,1206	746248	2	
R77	* RES,CERM,26.1K,+-1%,.125W,100PPM,1206	807685	1	
R79	* RES,CERM,110K,1%,.125W,100PPM,1206	887208	1	
R80	* RES,CERM,100,+-5%,.125W,200PPM,1206	746297	1	
R82	RES,MF,10K,+-1%,0.125W,25PPM	328120	1	
R83	RES,MF,402,+-1%,0.125W,25PPM	658401	1	
R93	* RES,CERM,91K,+-5%,.125W,200PPM,1206	811828	1	

Table 6-5. 2645A A3 A/D Converter PCA Assembly (cont)

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
R94	* RES,CERM,45.3K,+-1%,0.1W,100PPM,0805	930201	1	
R99	RES,MF,29.4K,+-1%,0.125W,25PPM	929690	1	
R100,140	* RES,CERM,4.02K,+-1%,.125W,100PPM,1206	783266	2	
R110,111	RES,MF,1K,+-1%,100PPM,FLMPRF,FUSIBLE	650085	2	1
R112-114,138	* RES,CERM,150,+-5%,.125W,200PPM,1206	746313	4	
R116,146	RES,CF,270,+-5%,0.25W	810424	2	
R117,125	* RES,CERM,22,+-5%,.125W,200PPM,1206	746230	2	
R119,127,133	* RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	3	
R128	RNET, MF, FRIT, SIP, LO V I SOURCE	926691	1	
R130,132	* RES,TINOX,39K,+-5%,2W	615435	2	
R135	* RES,CERM,24.9K,+-1%,.125W,100PPM,1206	867689	1	
R139	* RES,CERM,39K,+-5%,.125W,200PPM,1206	746677	1	
R141	* RES,CERM,1M,+-1%,.125W,100PPM,1206	836387	1	
R183	* RES,CERM,43.2K,+-1%,.125W,100PPM,1206	887109	1	
TP1, 2	JUMPER,WIRE,NONINSUL,0.200CTR	816090	2	
U1, 3, 23	* IC,COMPARATOR,DUAL,LOW PWR,SOIC	837211	3	
U2	* IC,CMOS,SRAM,128K X 8,100 NS,SO32	914101	1	
U4	* IC,CMOS,RS232 DRIVER/RECEIVER,SOIC	821538	1	
U5	* IC,INTEGR MLTIPROTOCOL MPU,16 MHZ,QFP	910831	1	
u6	* PROGRAMMED FLASH, FFE	949680	1	
U7, 10	* IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	838029	2	
U8	* IC,VOLT REG,5 V,LO DO/IQ,500MA,SOT223	92964	1	
U9, 34	* IC,CMOS,QUAD 2 INPUT OR GATE,SOIC	838276	2	
U11	* IC,COMPARATOR,HI-SPEED,PRECISION	822197	1	
U12, 27, 31	* IC,OP AMP,DUAL,PICOAMP IB,SO8	910836	3	
U13	* IC,ARRAY,7 NPN DARLINGTON PAIRS,SOIC	821009	1	
U14, 33	* IC,LSTTL,BCD-DEC,DECODER/DRIVER,SOIC	742007	2	
U15	* IC,CMOS,OCTAL BUFFER/LINE DRVR,SOIC	853671	1	
U16	* IC,CMOS,QUAD INPUT NAND GATE,SOIC	830703	1	
U17, 21	* IC,CMOS,HEX INVERTER,UNBUFFERED,SOIC	806893	2	
U18	* IC,EPLD,PR0GRAMMED,2645A-90220,PLCC84	929695	1	
U19	* IC,OP AMP,DUAL,LO POWR,SNGL SUP,8PDIP	929604	1	
U20	* IC,OP AMP,DUAL,RAIL-RAIL VOUT,SO8	929596	1	
U22, 24, 25	* IC,CMOS,TRIPLE 2-1 LINE ANLG MUX,SOIC	929013	3	
U26	* IC,BPLR,TRUE RMS TO DC CONVERTER	707653	1	
U28	* IC,OP AMP,PRECISION,SINGLE SUPPLY,SO8	905315	1	
U29	* IC,OP AMP,JFET INPUT,DECOMP,SOIC	837237	1	
U30	IC TWIN WELL STALLION ASSEMBLY TESTED	933502	1	
U32	* IC,OP AMP,DUAL,HIGH BW,SNGL SUP,SO	929075	1	
VR1	* ZENER,UNCOMP,15V,5%,8.5MA,0.2W,SOT-23	837187	1	
VR2, 3	* ZENER,UNCOMP,6.0V,5%,20MA,0.2W,SOT-2	837161	2	
W5, 6, 8	HEADER,1 ROW,.100CTR,2 PIN	643916	3	
Y1	CRYSTAL,15.36MHZ,50PPM,SURFACE MT	943167	1	
Y2	CRYSTAL,10MHZ,+-0.01%,HC-18/U	520239	1	
Z1	RNET, MF, FRIT, SIP, A TO D CONV	926688	1	
Z2	RNET,CERM,SIP,2620 LO V DIVIDER	849984	1	
Z3, 4	RNET,MF,POLY,SIP,1752 LO V DIVIDER	645341	2	
Z5	RNET,MF,POLY,SIP,8840 LO V DIVIDER	655811	1	
Z6	RNET,CERM,SIP,2620 HI V AMP GAIN	847363	1	
Z7	RNET, MF, FRIT, SIP, HI V DIVIDER	926733	1	

Table 6-5. 2645A A3 A/D Converter PCA Assembly (cont)

Reference Designator	Description	Fluke Stock No	Tot Qty	Notes
Z8	RNET,MF,POLY,SIP,2280 LO V DIVIDER	611186	1	
1. FUSIBLE RESISTOR. USE EXACT REPLACEMENT ONLY.				

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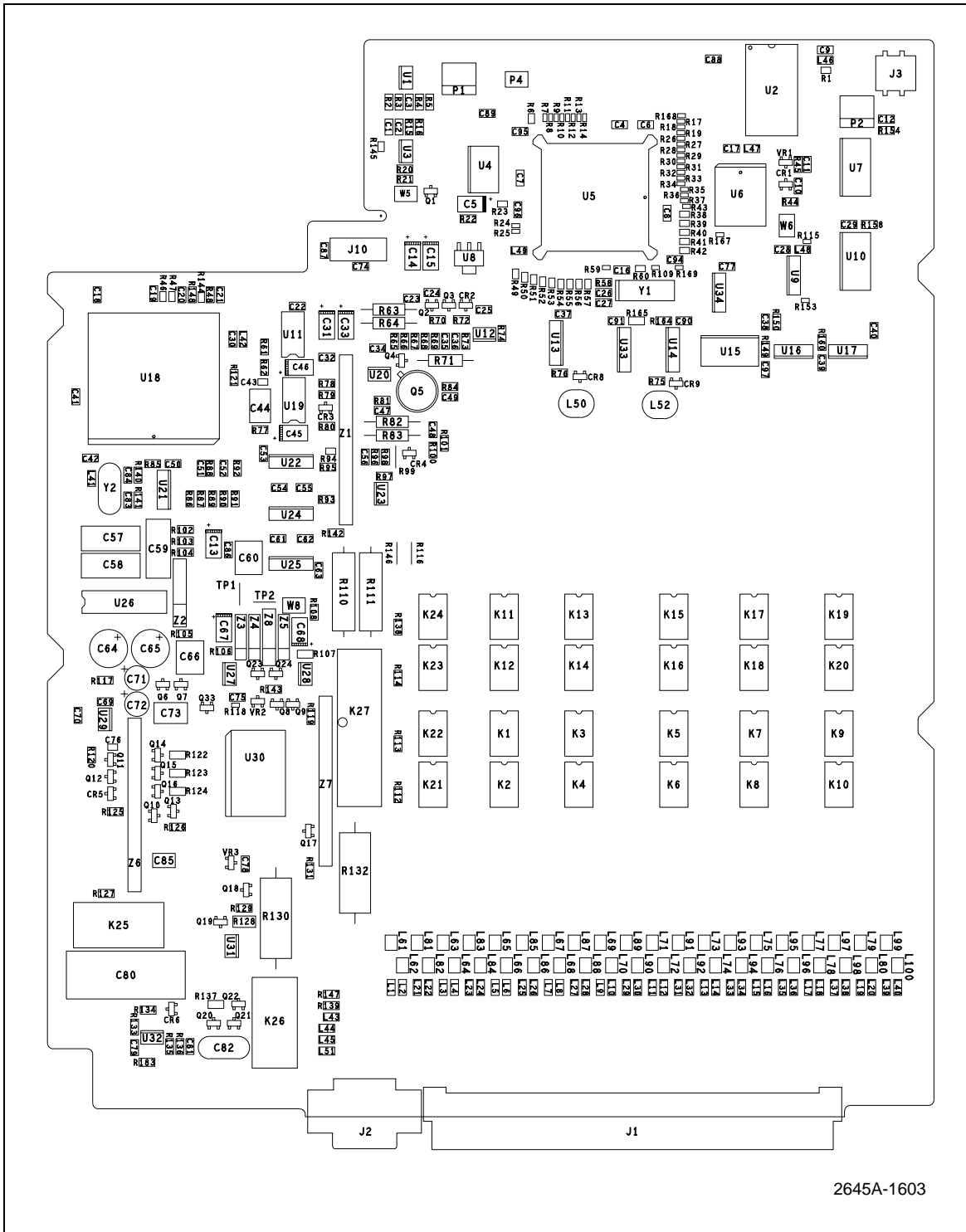
Figure 6-5. 2645A A3 A/D Converter PCA Assembly

Table 6-6. A4 Analog Input PCA Assembly

Reference Designator		Description	Fluke Stock No	Tot Qty	Notes
C1		CAP,CER,1000PF,+-5%,50V,C0G,1206	867408	1	
H55		RIVET,S-TUB,OVAL,STL,.087,.375	106473	2	
L1		CORE,BALUN,FERRITE,.136,.079,.093	106184	1	
M1, 2		HEADER,1 ROW,.156CTR,15 PIN	414458	2	
MP2		ISOTHERMAL CASE,BOTTOM	874107	1	
MP3		ISOTHERMAL CASE,TOP	874110	1	
MP25		DECAL,ISOTHERMAL CASE	874131	1	
P1		CONN,DIN41612,TYPE R,RT ANG,48 SCKT	867338	1	
P2		CONN,MICRO-RIBBON,REC,RT ANG,20 POS	876102	1	
Q1	*	TRANSISTOR,SI,NPN,TEMP SENSOR TO-92	741538	1	
R1		RES,MF,5.49K,+-1%,0.125W,100PPM	334565	1	
R2		RES,MF,10K,+-1%,0.125W,25PPM	328120	1	
R3		RES,VAR,CERM,50K,+-10%,0.5W	876573	1	
RV1- 4		VARISTOR,910,+-10%,1.0MA	876193	4	
TB1, 2		TERM STRIP,PWB,45 ANG,.197CTR,20 POS	875195	2	
VR1	*	IC, 2.5V,100 PPM T.C.,BANDGAP REF	723478	1	
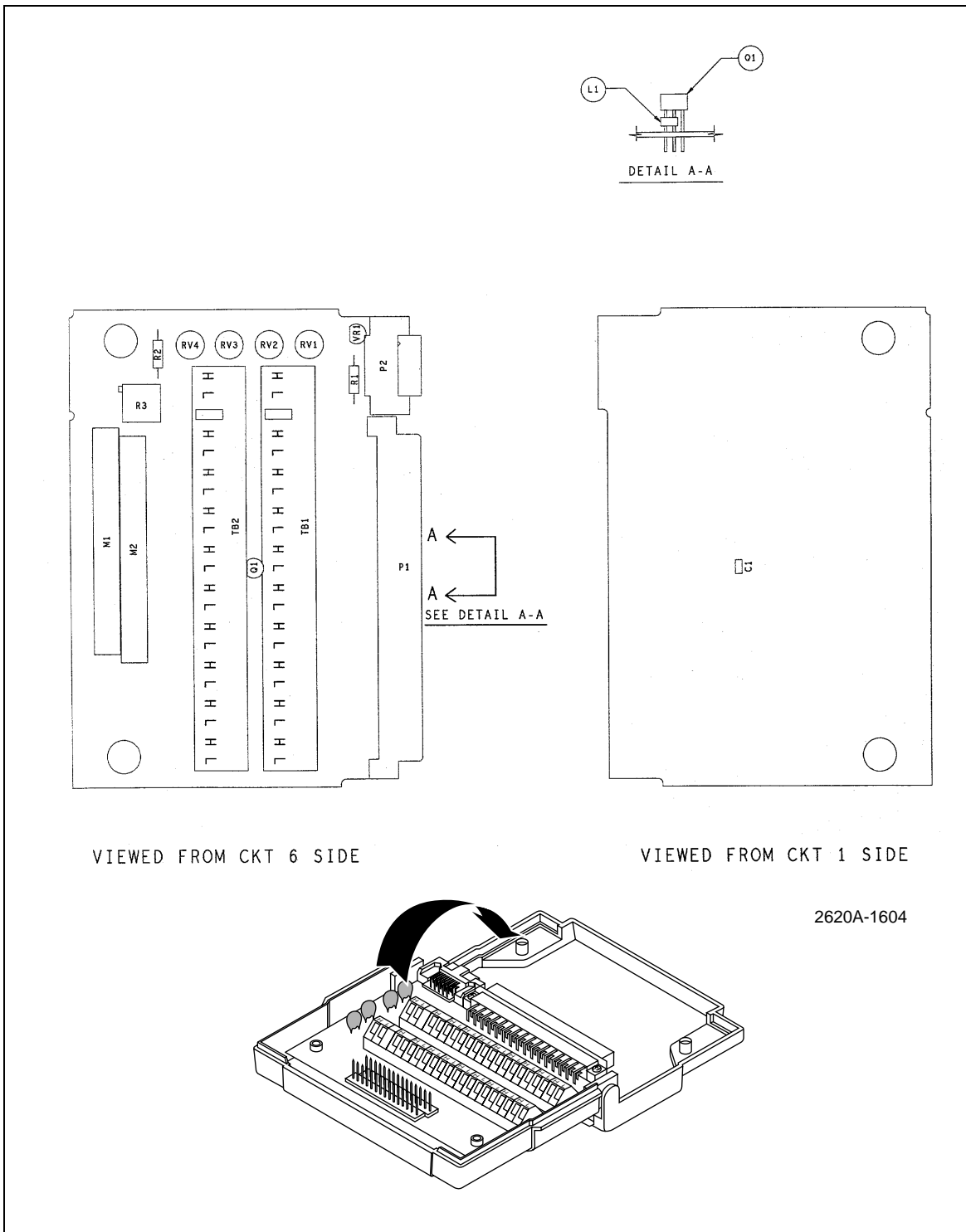
Figure 6-6. A4 Analog Input PCA Assembly

Chapter 7
Schematic Diagrams
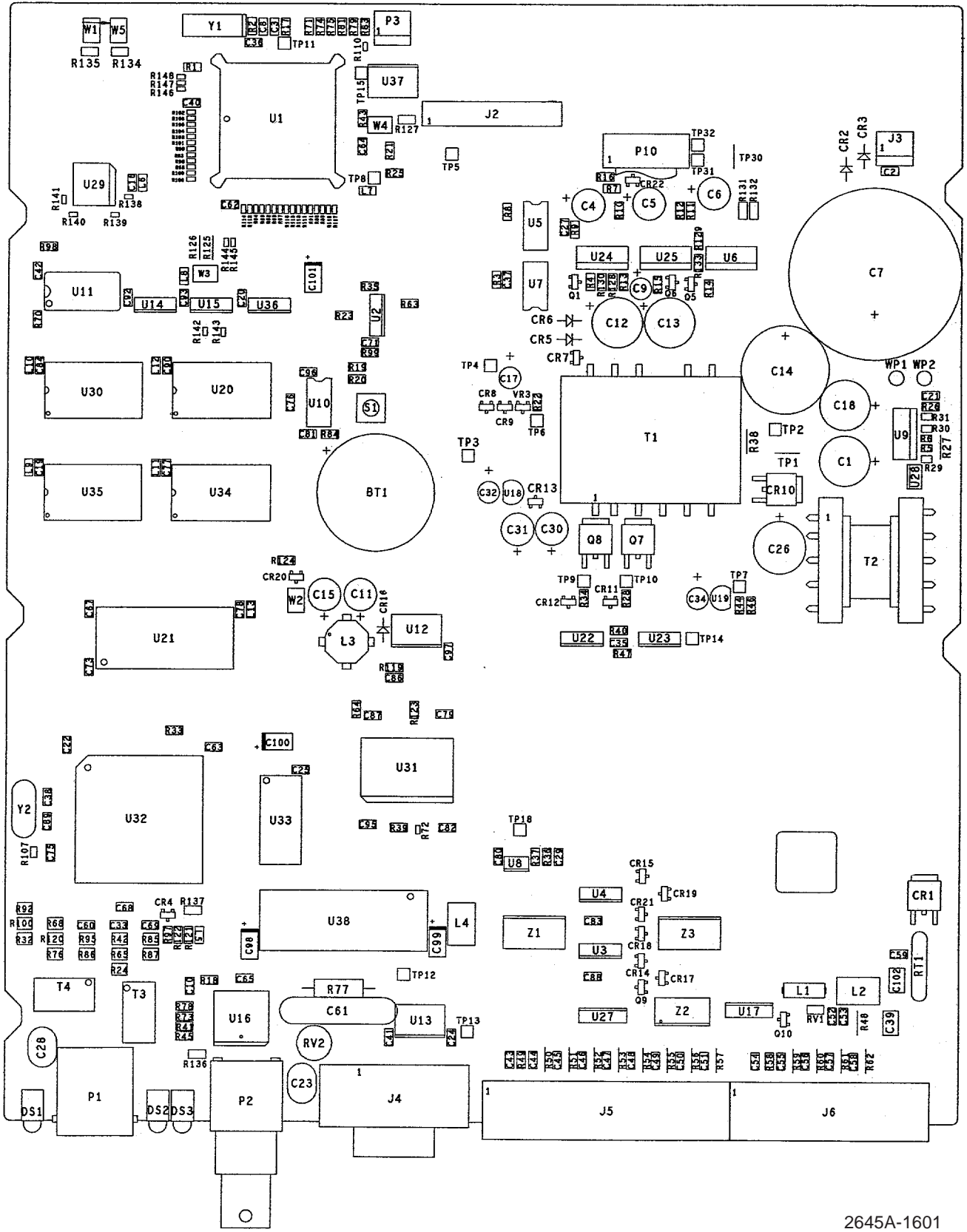
NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL CAPACITOR VALUES ARE IN MICROFARADS.
2. ALL RESISTOR VALUES ARE IN OHMS.
3. ALL RESISTORS ARE 1/8W, 5% UNLESS OTHERWISE NOTED.

REF DES	DO_GND	GND	GND1	IBIAS	M9V	VBB	VCC	VCC1	VCC15	VCC20	VCC21	VCC29	VCC30	VCC34	VCC35
U36		7				14									
U2		7					14								
U22		7		14											
U23		7		14											
U14		7					14								
U15		7							14						
U29		10								32					
U20		16										20			
U30		16											32		
U34		16												32	
U35		16													32
U10		3					2								
U32		16, 20, 29, 30, 37, 56, 61, 65, 80, 99, 120, 127, 140, 143, 144, 145, 146, 147, 148, 149, 150, 160					1, 19, 31, 32, 52, 53, 62, 81, 116, 121								
U13		9					16								
U37		9					16								
U1		4, 13, 23, 29, 34, 44, 57, 67, 84, 102, 107, 116, 126						18, 28, 39, 62, 83, 99, 112, 131							
U16			16, 17		5, 6, 7, 8, 9, 10, 11, 20, 21, 22, 23, 24, 25										
U21		13, 32										23			
U11		1, 12, 21				24									
U17, U27	8														
U33		14					28								
U31		16, 28, 53, 66, 77, 4					27, 41, 55 79, 91, 3								

Reference Designations		
Last Used		Not Used
BT	BT1	
C	C102	C66, 70, 72, 74, 85, 91, 94
CR	CR22	
DS	DS3	
J	J6	J1
L	L13	
P	P10	P4-9
Q	Q10	Q2-4
R	R148	
RT	RT1	
RV	RV2	
S	S1	
T	T4	
TP	TP32	TP16-17, 19-29
U	U38	U26
VR	VR3	VR1-2
W	W5	
WP	WP2	
Y	Y2	
Z	Z3	

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2645A-1001
(Sheet 1 of 7)

Figure 7-1. A1 Main PCA Assembly
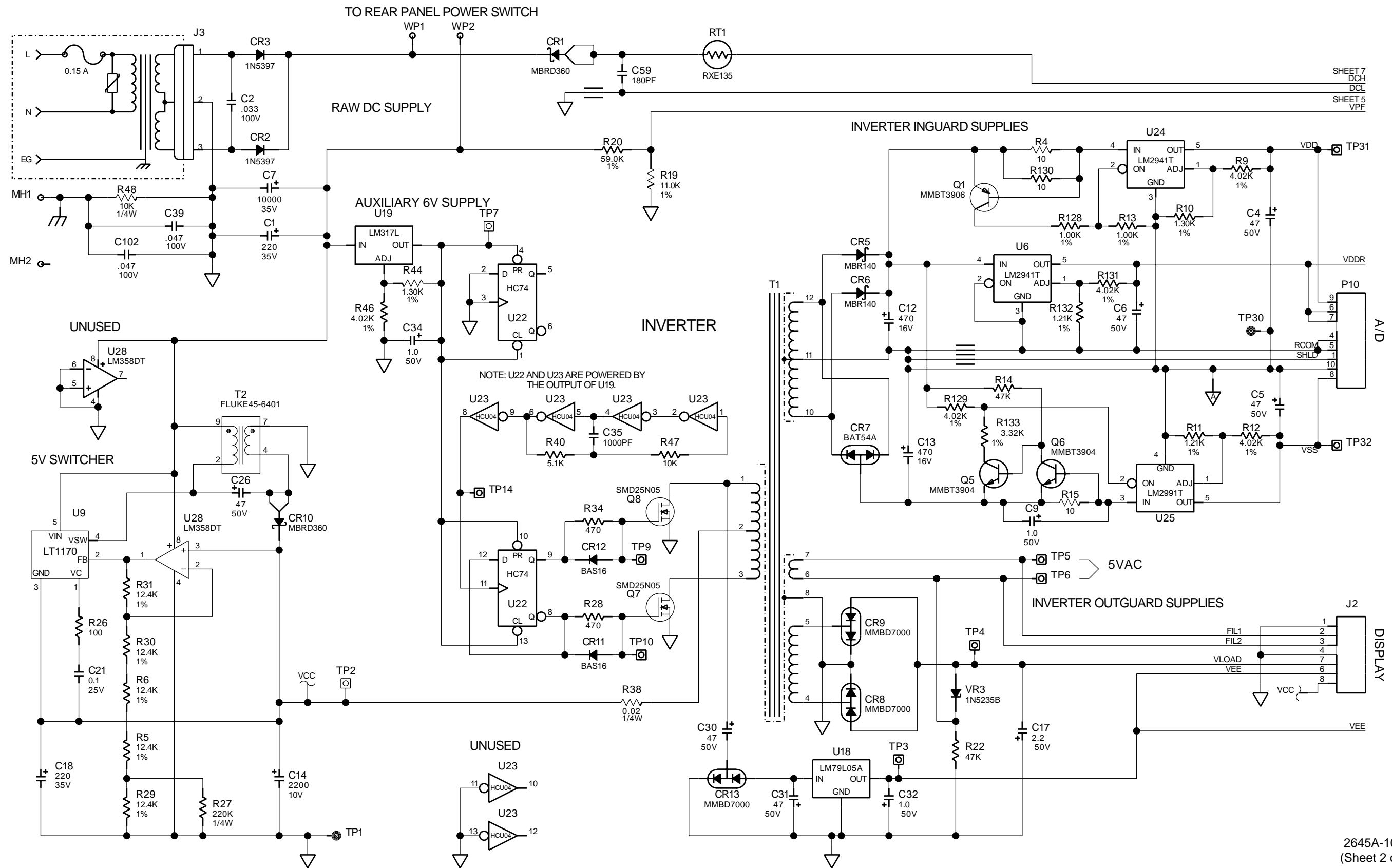
Figure 7-1. A1 Main PCA Assembly (cont)

2645A-1001
(Sheet 2 of 7)

Figure 7-1. A1 Main PCA Assembly (cont)
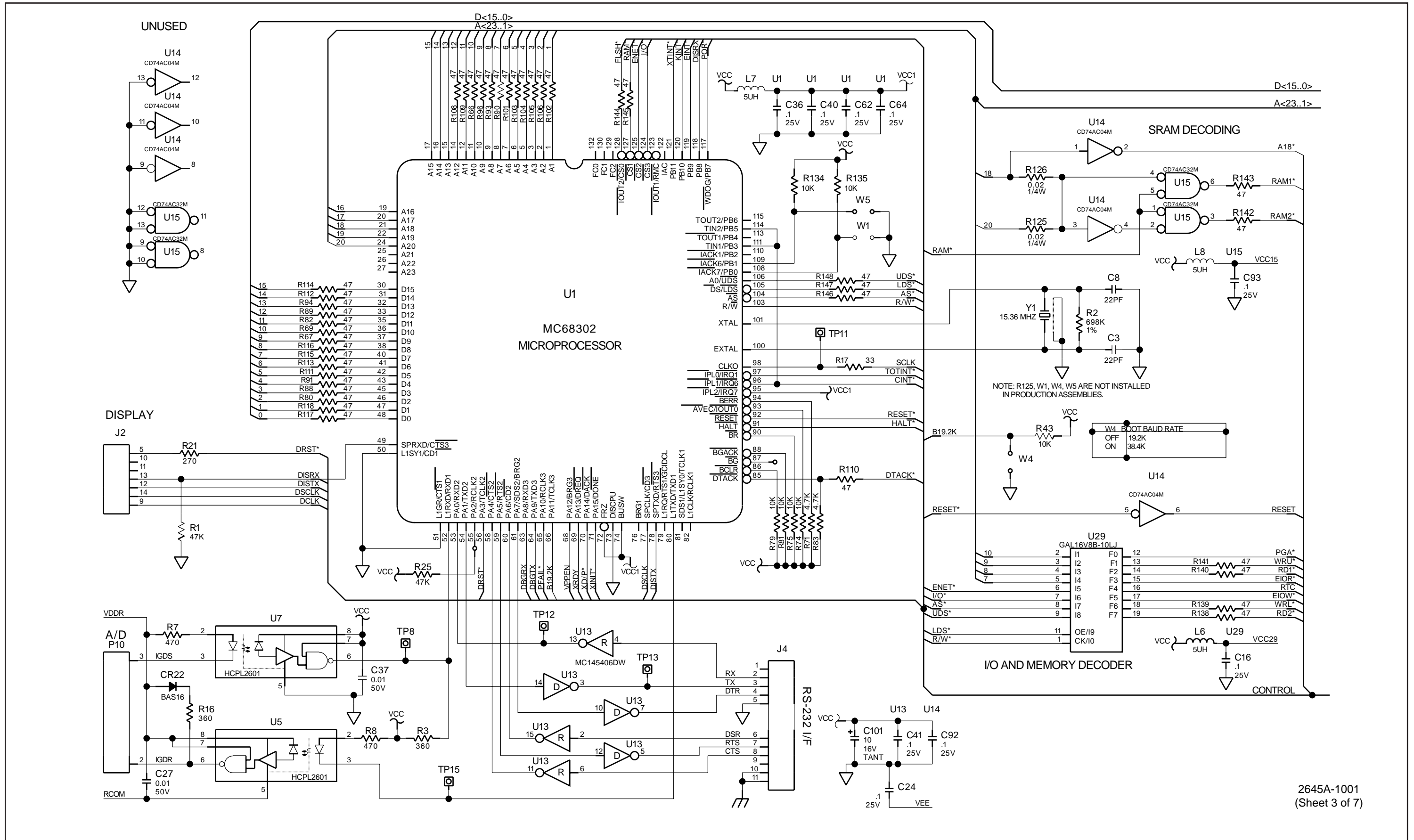
2645A-1001
(Sheet 3 of 7)

ETHERNET INTERFACE

Figure 7-1. A1 Main PCA Assembly (cont)

2640A-1001
(Sheet 4 of 7)
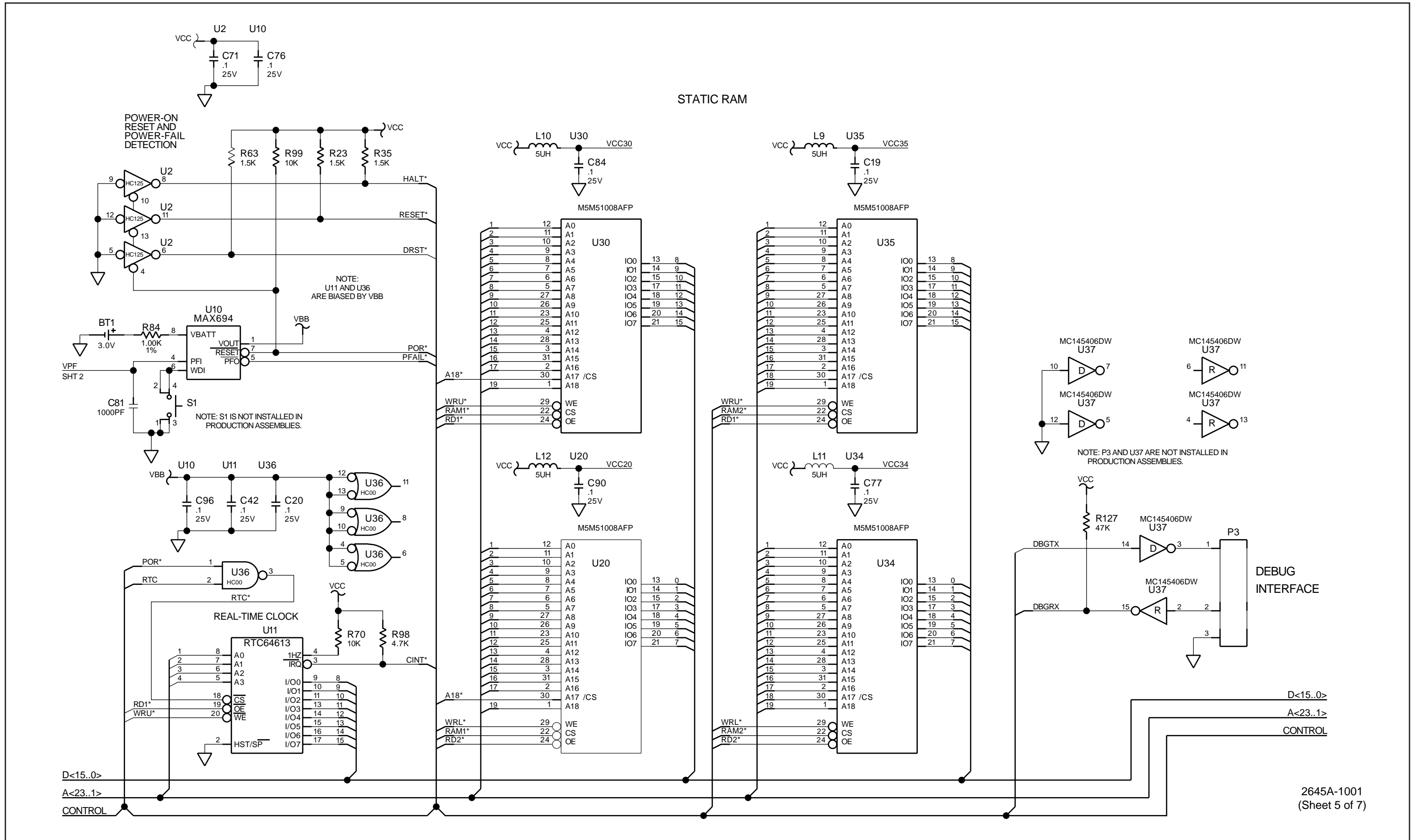
STATIC RAM

POWER-ON
RESET AND
POWER-FAIL
DETECTION

NOTE:
U11 AND U36
ARE BIASED BY VBB

NOTE: S1 IS NOT INSTALLED IN
PRODUCTION ASSEMBLIES.

NOTE: P3 AND U37 ARE NOT INSTALLED IN
PRODUCTION ASSEMBLIES.

REAL-TIME CLOCK

DEBUG
INTERFACE

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(Sheet 5 of 7)

Figure 7-1. A1 Main PCA Assembly (cont)

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Figure 7-1. A1 Main PCA Assembly (cont)

Figure 7-1. A1 Main PCA Assembly (cont)
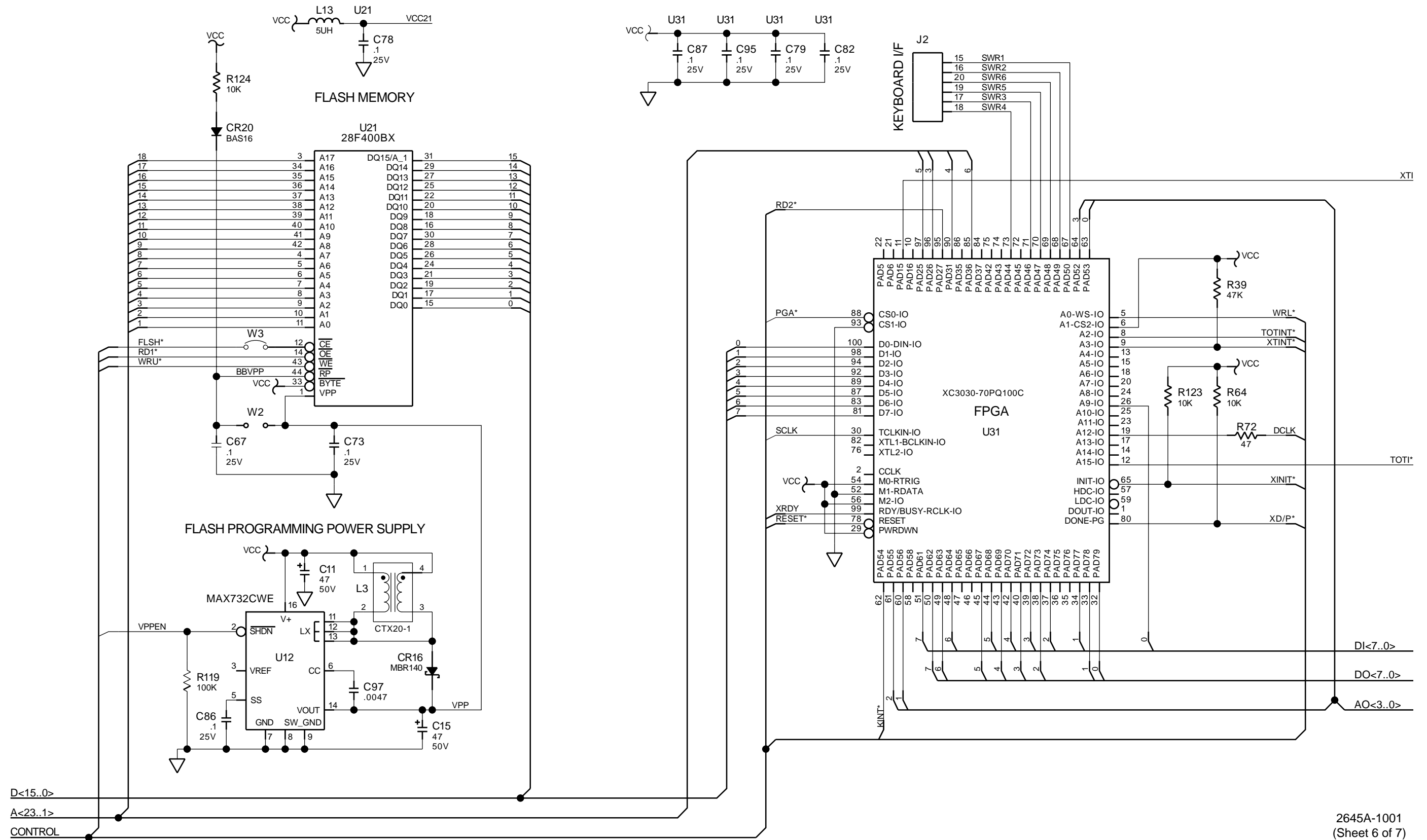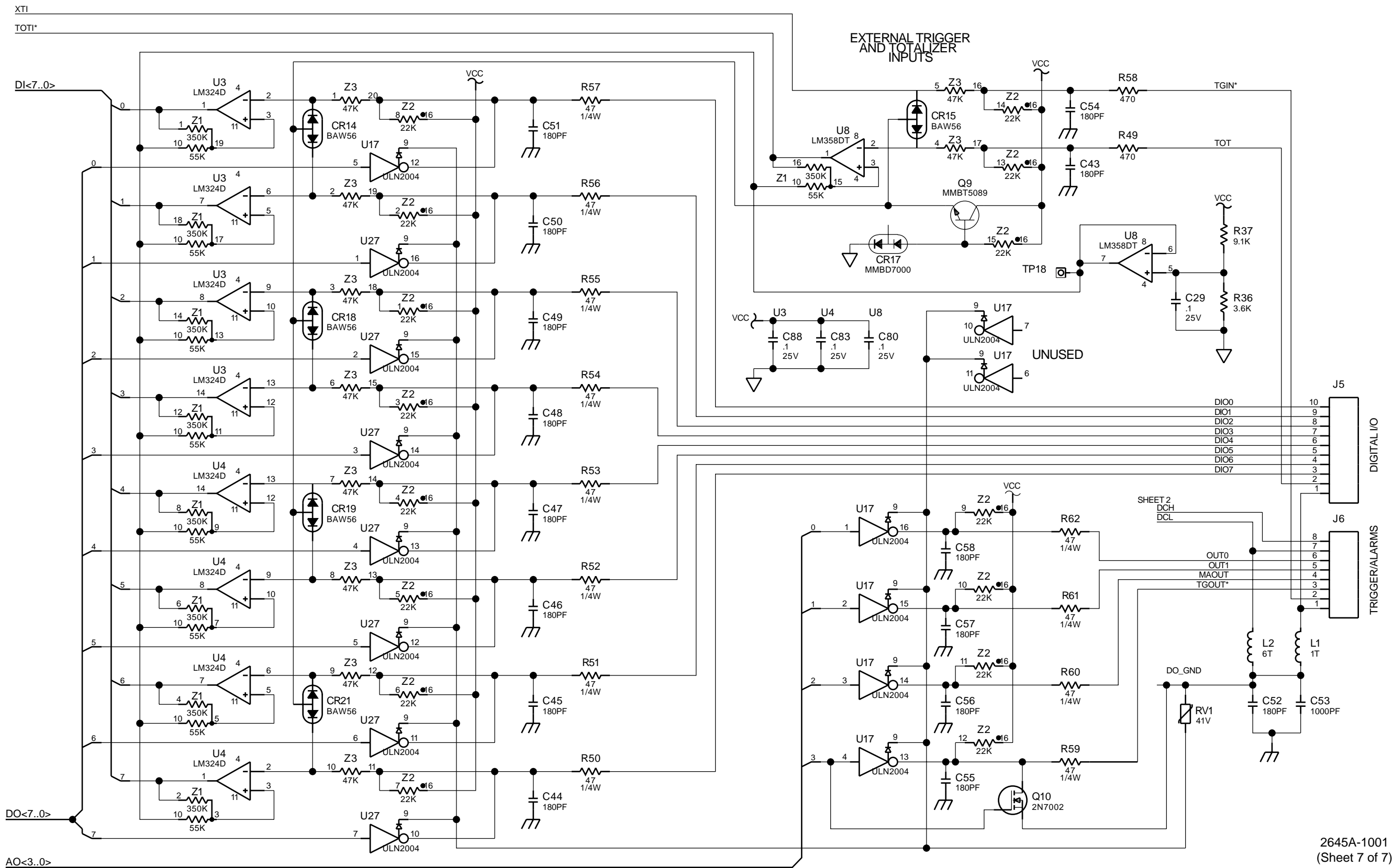
2645A-1001
(Sheet 7 of 7)
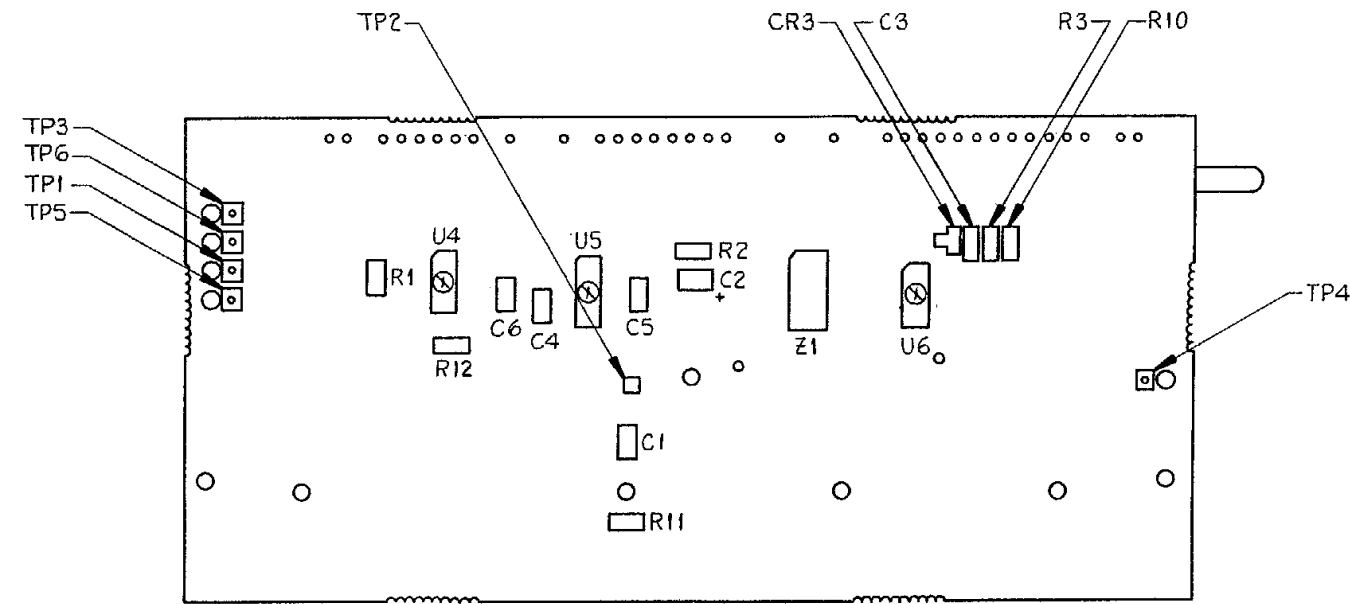
CKT 2
SURFACE MOUNT

CKT 2

CKT 1

2620A-1602

Figure 7-2. A2 Display PCA Assembly

Figure 7-2. A2 Display PCA Assembly (cont)

2620A-1002

Figure 7-3. 2640A A3 A/D Converter PCA Assembly

2640A-1603

2640A-1003
(Sheet 1 of 6)

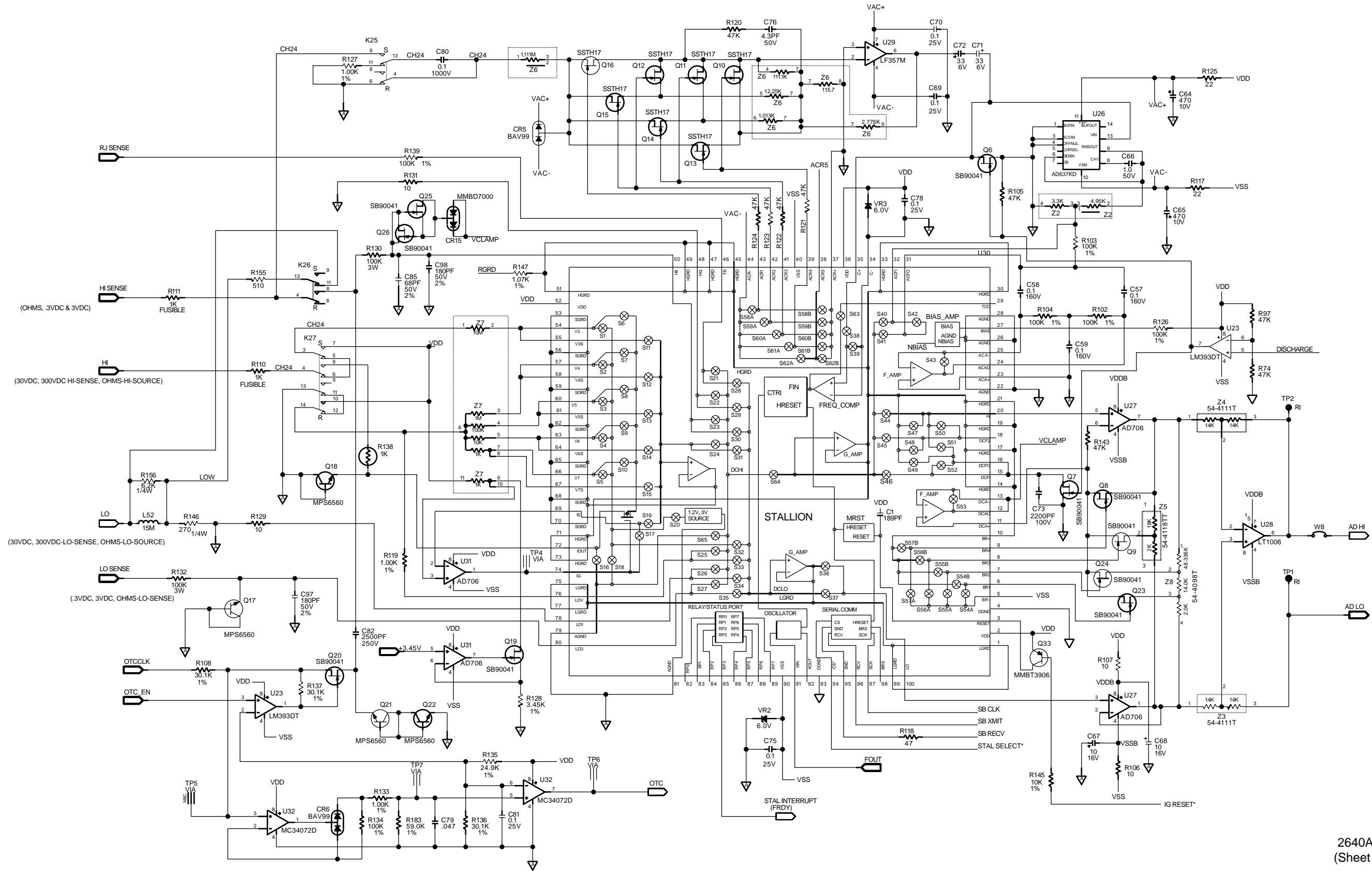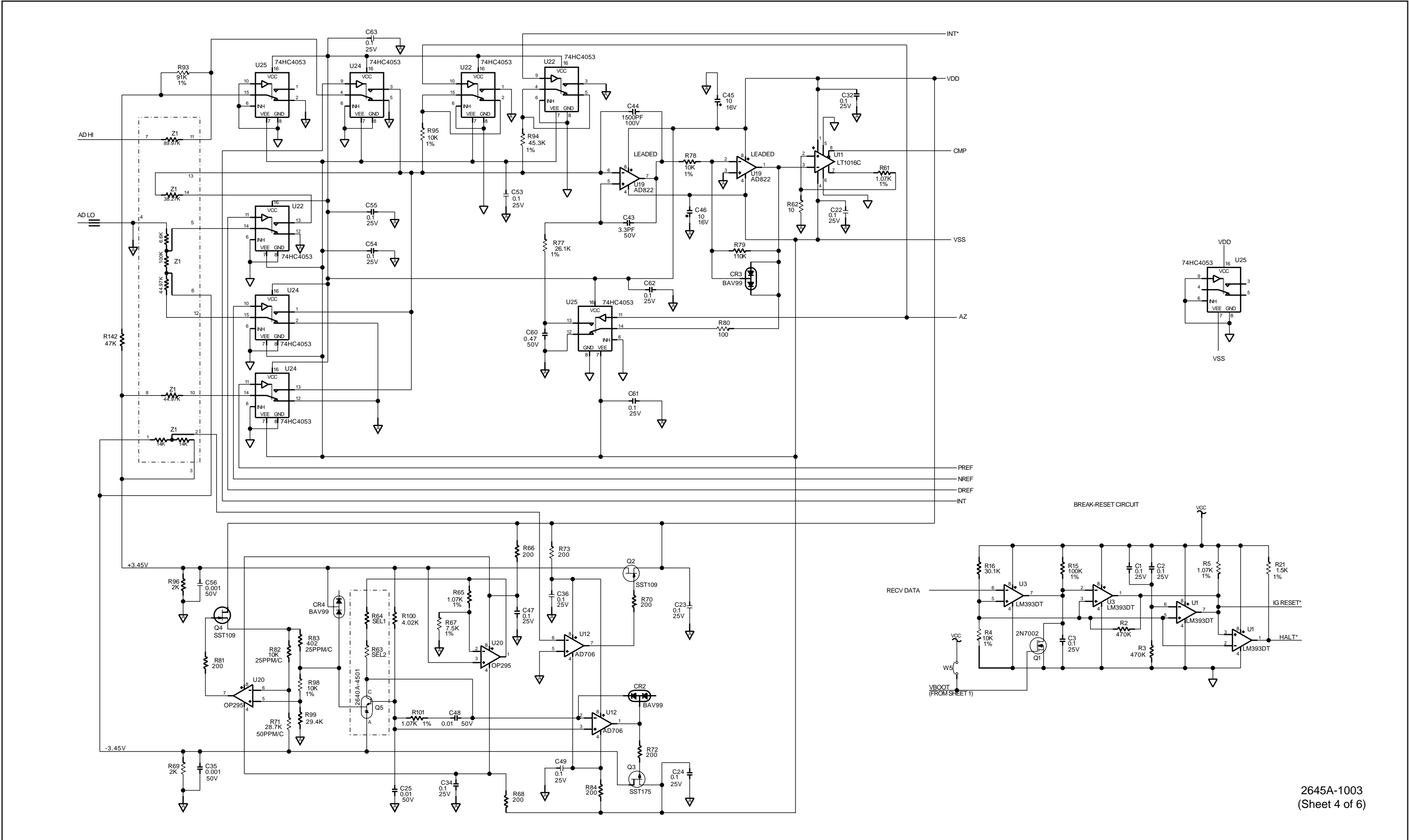**Figure 7-3. 2640A A3 A/D Converter PCA Assembly (cont)**

Figure 7-3. 2640A A3 A/D Converter PCA Assembly (cont)

2640A-1003
(Sheet 2 of 6)

2640A-1003
(Sheet 3 of 6)

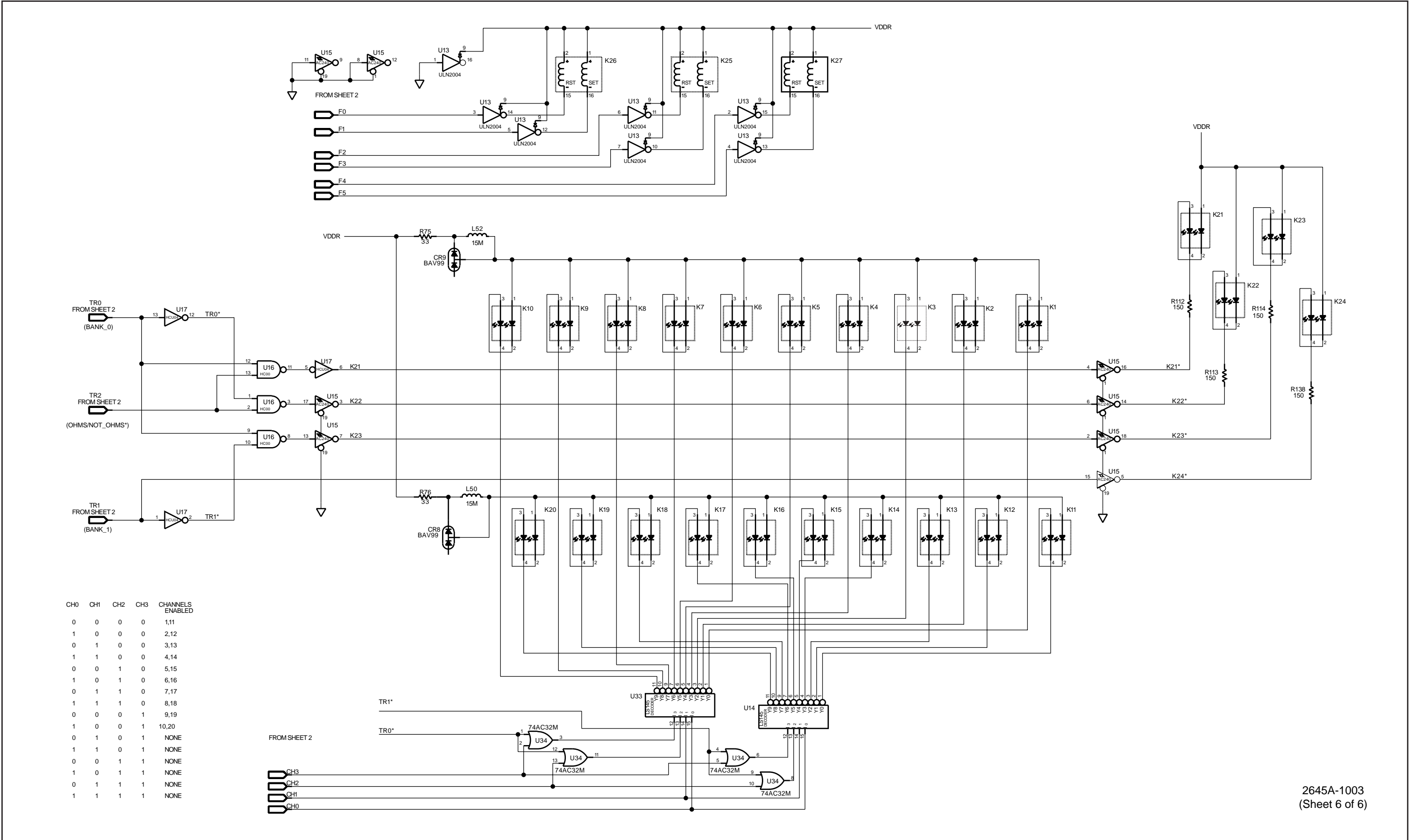**Figure 7-3. 2640A A3 A/D Converter PCA Assembly (cont)**
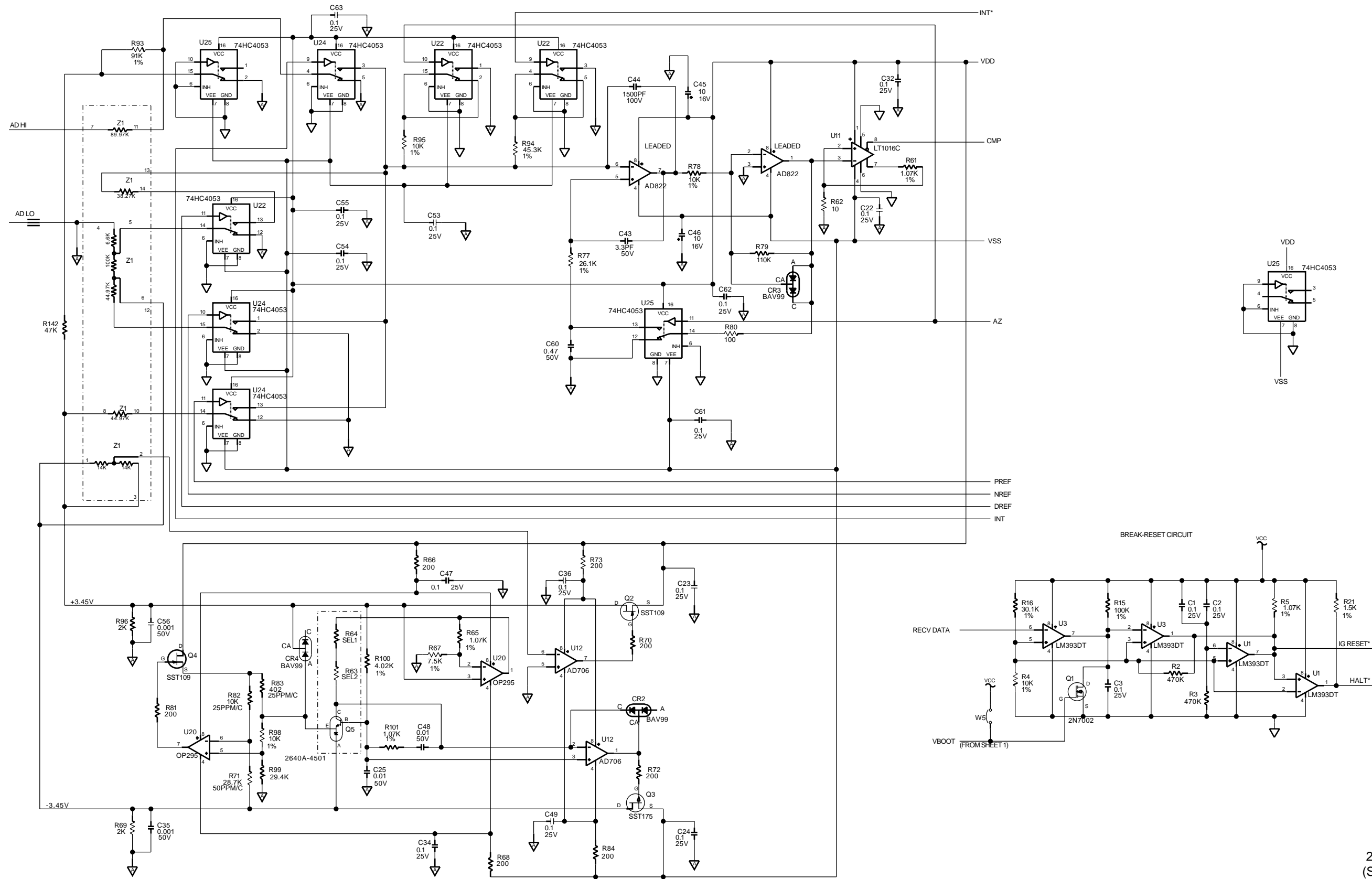
2640A-1003
(Sheet 4 of 6)

**Figure 7-3. 2640A A3 A/D Converter PCA Assembly (cont)**
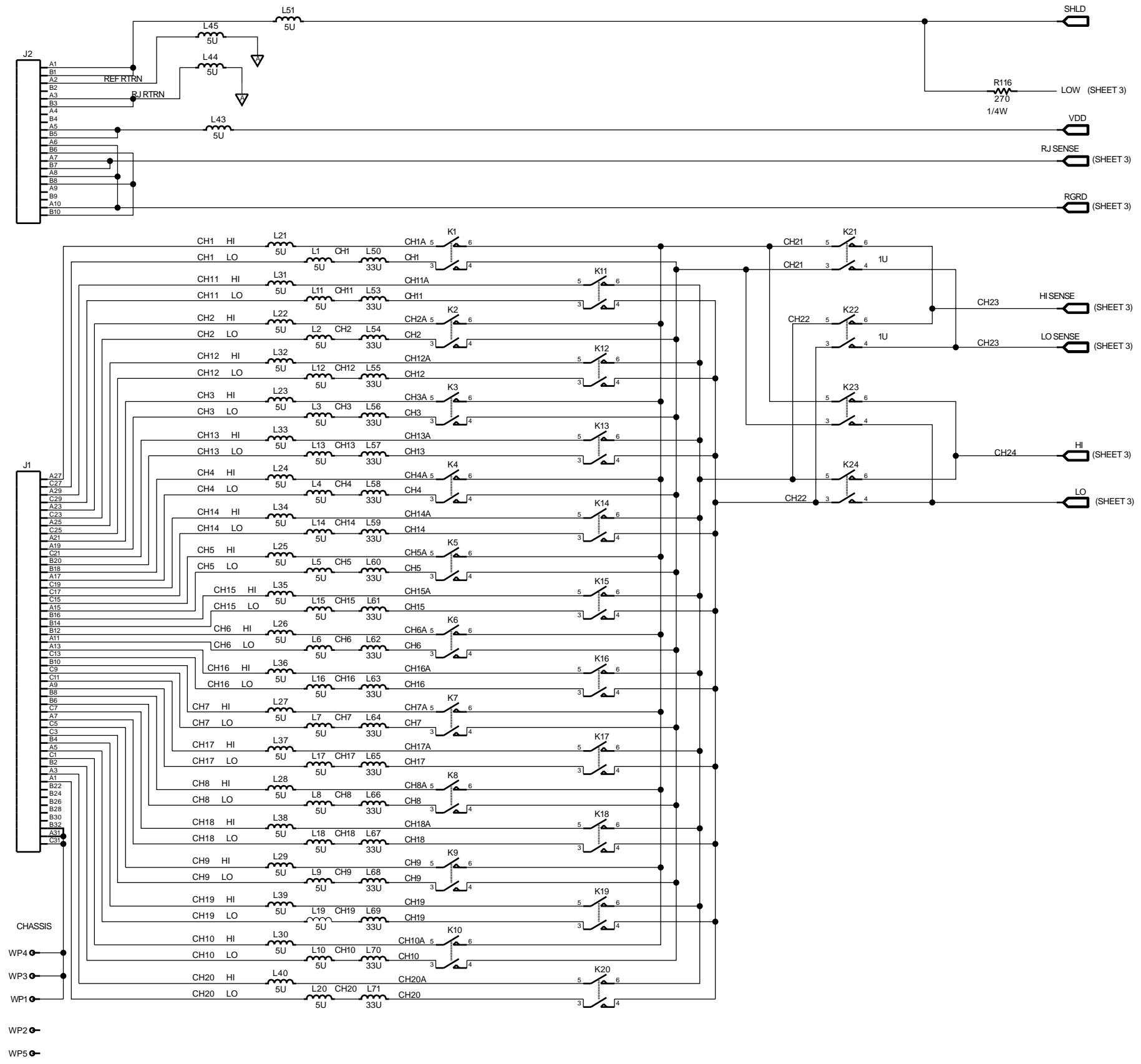
2640A-1003
(Sheet 5 of 6)

Figure 7-3. 2640A A3 A/D Converter PCA Assembly (cont)

Figure 7-3. 2640A A3 A/D Converter PCA Assembly (cont)

2640A-1003
(Sheet 6 of 6)

CH0	CH1	CH2	CH3	CHANNELS ENABLED
0	0	0	0	1,11
1	0	0	0	2,12
0	1	0	0	3,13
1	1	0	0	4,14
0	0	1	0	5,15
1	0	1	0	6,16
0	1	1	0	7,17
1	1	1	0	8,18
0	0	0	1	9,19
1	0	0	1	10,20
0	1	0	1	NONE
1	1	0	1	NONE
0	0	1	1	NONE
1	0	1	1	NONE
0	1	1	1	NONE
1	1	1	1	NONE
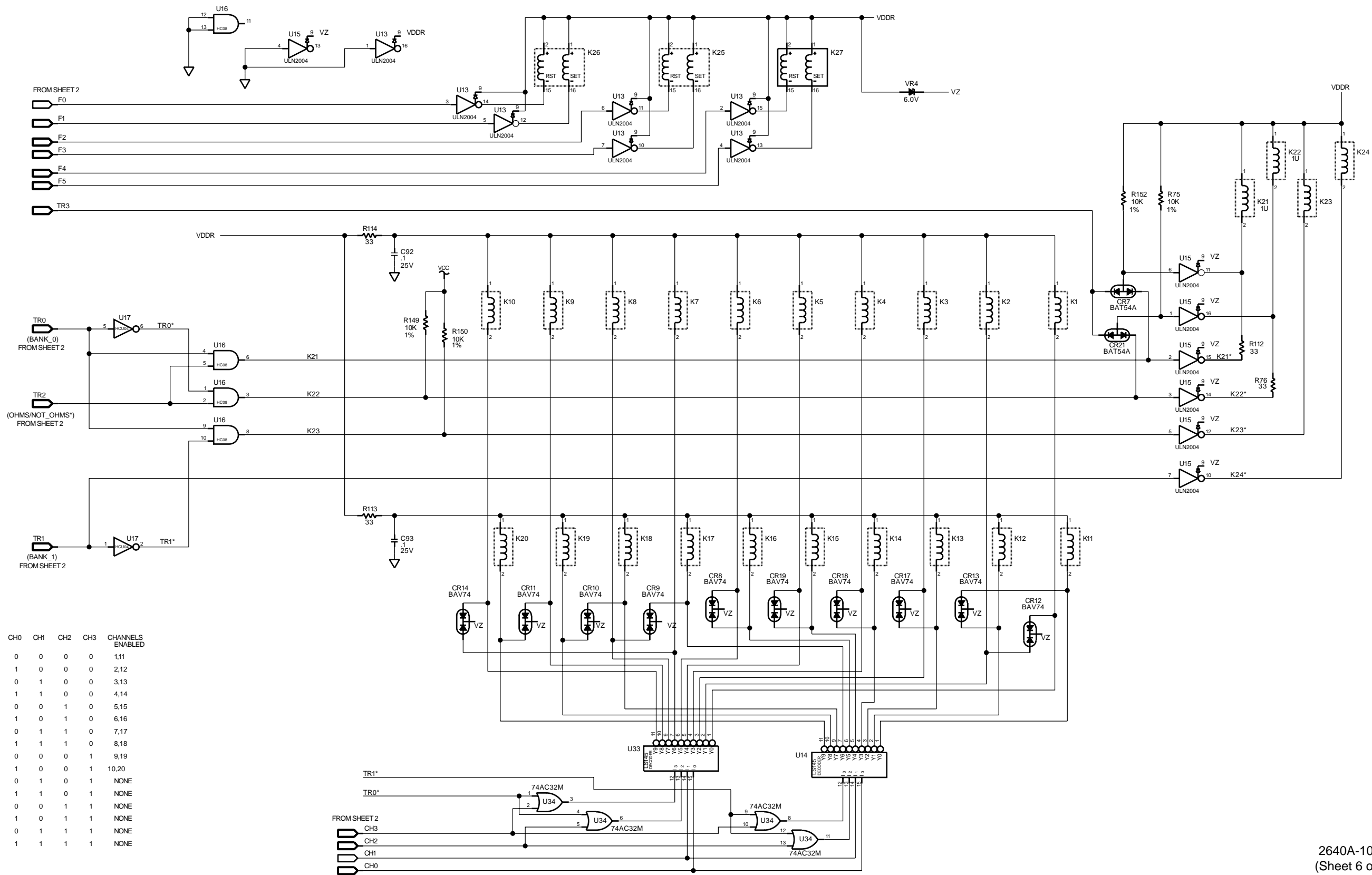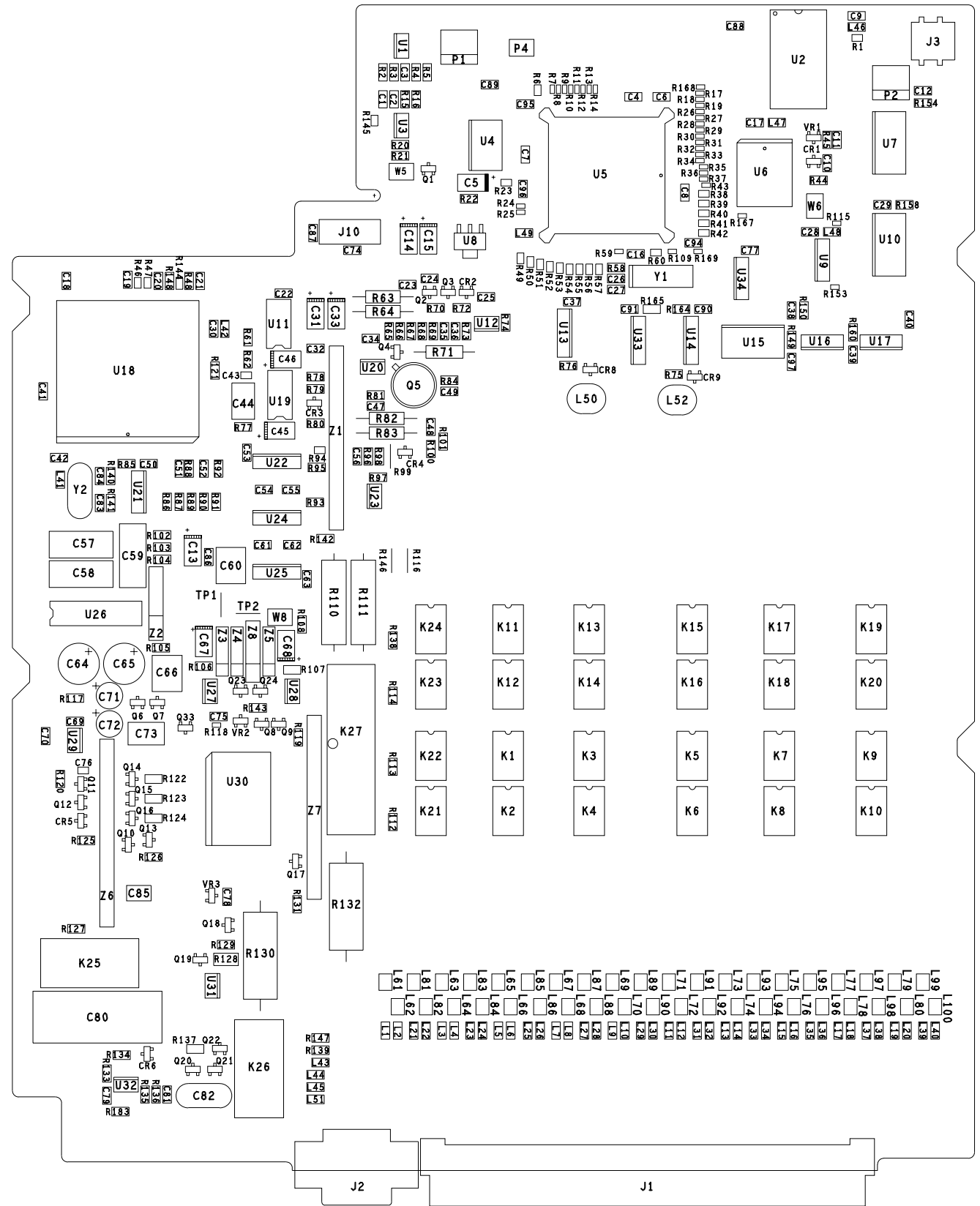
2645A-1603

Figure 7-4. 2645A A3 A/D Converter PCA Assembly

Figure 7-4. 2645A A3 A/D Converter PCA Assembly (cont)

2645A-1003
(Sheet 1 of 6)

2645A-1003
(Sheet 2 of 6)

Figure 7-4. 2645A A3 A/D Converter PCA Assembly (cont)

Figure 7-4. 2645A A3 A/D Converter PCA Assembly (cont)

2640A-1003
(Sheet 3 of 6)

2645A-1003
(Sheet 4 of 6)

Figure 7-4. 2645A A3 A/D Converter PCA Assembly (cont)

Figure 7-4. 2645A A3 A/D Converter PCA Assembly (cont)
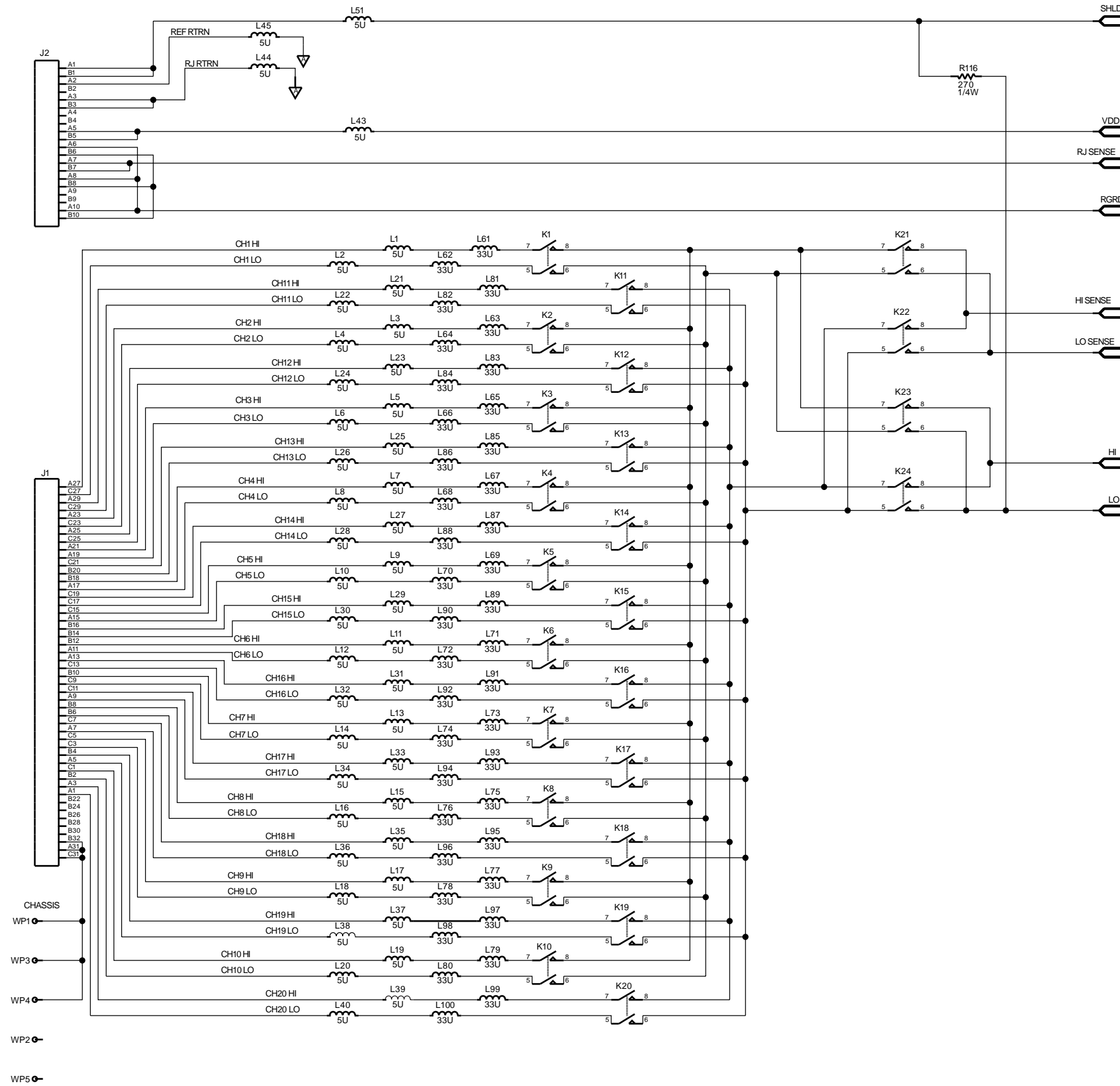
2645A-1003
(Sheet 5 of 6)

Figure 7-4. 2645A A3 A/D Converter PCA Assembly (cont)

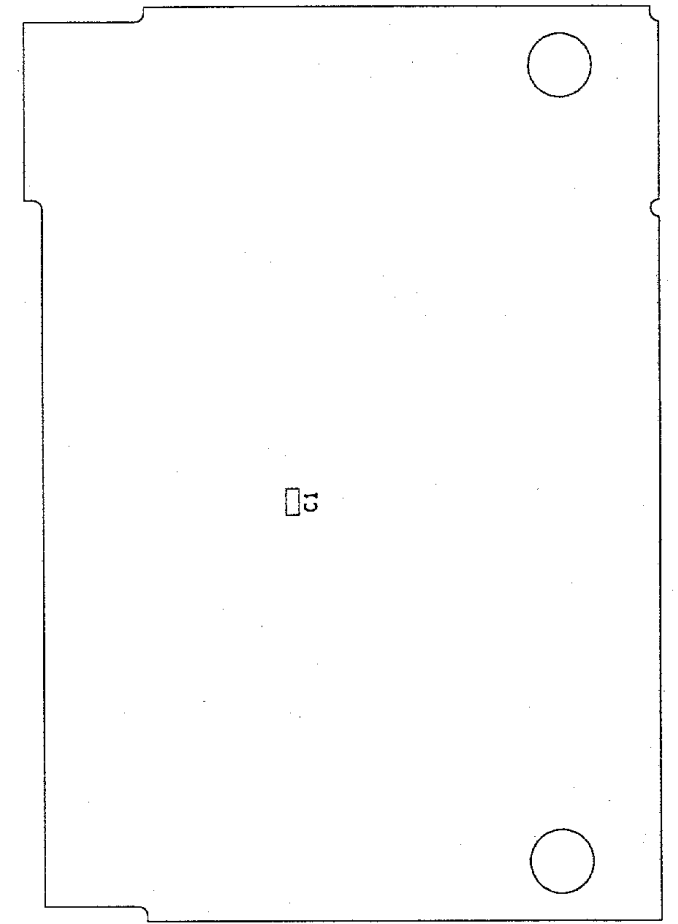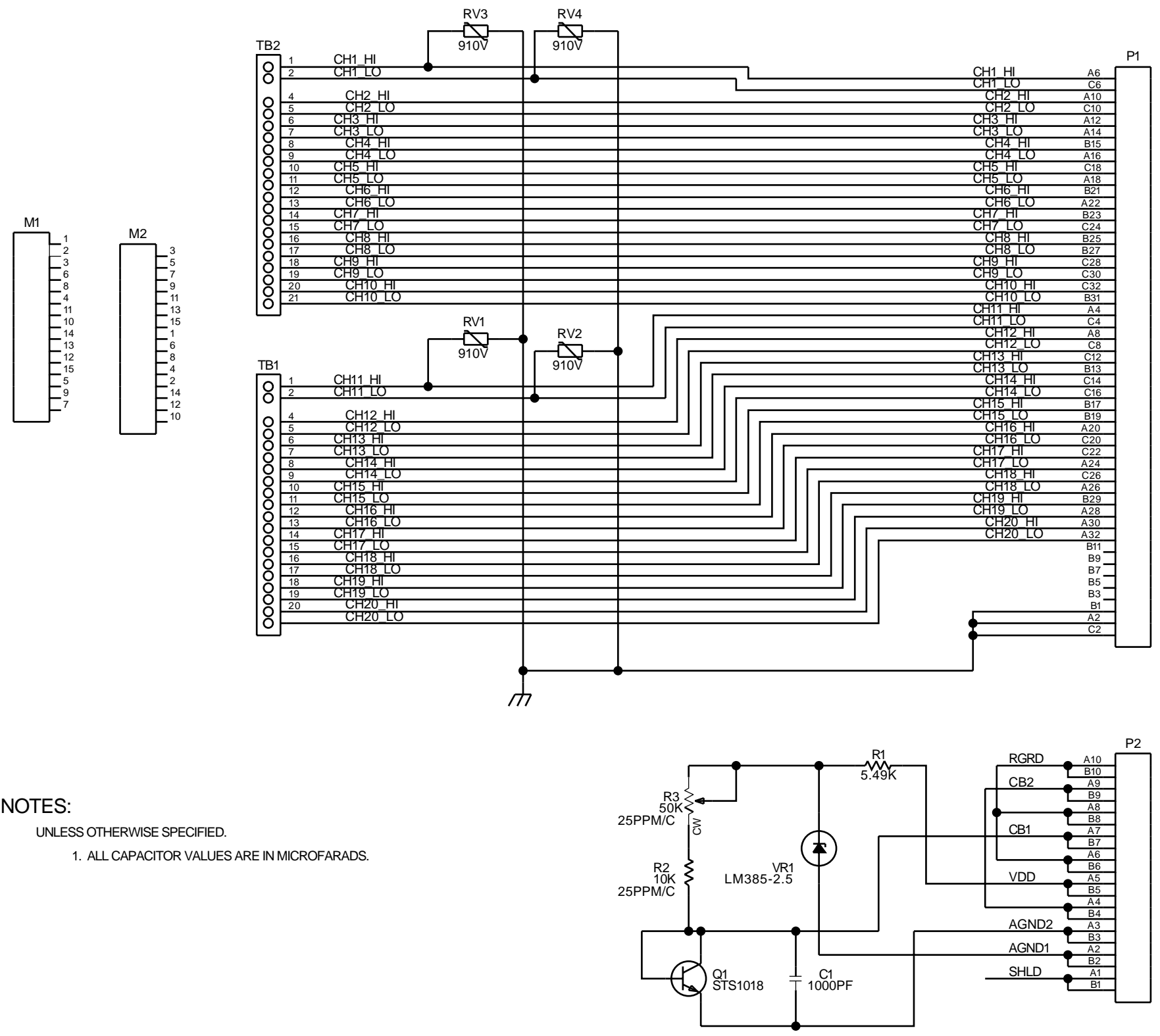2645A-1003
(Sheet 6 of 6)

DETAIL A-A
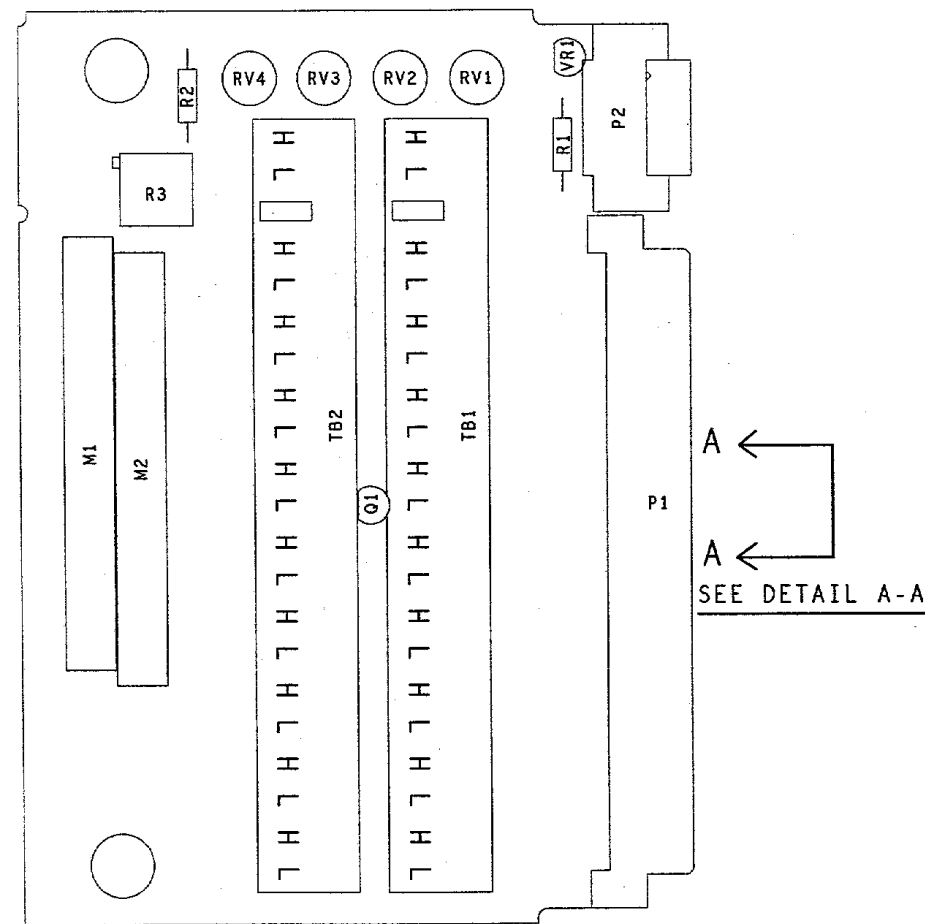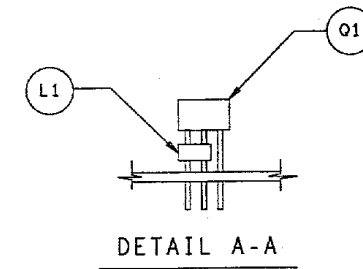
VIEWED FROM CKT 6 SIDE

VIEWED FROM CKT 1 SIDE

2620A-1604

Figure 7-5. A4 Analog Input PCA Assembly

NOTES:

UNLESS OTHERWISE SPECIFIED.

1. ALL CAPACITOR VALUES ARE IN MICROFARADS.

2620A-1004

Figure 7-5. A4 Analog Input PCA Assembly (cont)