FLUKE ®

57LFC/AN

System Calibrator

Service Manual

March 2004

LIMITED WARRANTY AND LIMITATION OF LIABILITY

Each Fluke product is warranted to be free from defects in material and workmanship under normal use and service. The warranty period is one year and begins on the date of shipment. Parts, product repairs, and services are warranted for 90 days. This warranty extends only to the original buyer or end-user customer of a Fluke authorized reseller, and does not apply to fuses, disposable batteries, or to any product which, in Fluke's opinion, has been misused, altered, neglected, contaminated, or damaged by accident or abnormal conditions of operation or handling. Fluke warrants that software will operate substantially in accordance with its functional specifications for 90 days and that it has been properly recorded on non-defective media. Fluke does not warrant that software will be error free or operate without interruption.

Fluke authorized resellers shall extend this warranty on new and unused products to end-user customers only but have no authority to extend a greater or different warranty on behalf of Fluke. Warranty support is available only if product is purchased through a Fluke authorized sales outlet or Buyer has paid the applicable international price. Fluke reserves the right to invoice Buyer for importation costs of repair/replacement parts when product purchased in one country is submitted for repair in another country.

Fluke's warranty obligation is limited, at Fluke's option, to refund of the purchase price, free of charge repair, or replacement of a defective product which is returned to a Fluke authorized service center within the warranty period.

To obtain warranty service, contact your nearest Fluke authorized service center to obtain return authorization information, then send the product to that service center, with a description of the difficulty, postage and insurance prepaid (FOB Destination). Fluke assumes no risk for damage in transit. Following warranty repair, the product will be returned to Buyer, transportation prepaid (FOB Destination). If Fluke determines that failure was caused by neglect, misuse, contamination, alteration, accident, or abnormal condition of operation or handling, including overvoltage failures caused by use outside the product's specified rating, or normal wear and tear of mechanical components, Fluke will provide an estimate of repair costs and obtain authorization before commencing the work. Following repair, the product will be returned to the Buyer transportation prepaid and the Buyer will be billed for the repair and return transportation charges (FOB Shipping Point).

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Since some countries or states do not allow limitation of the term of an implied warranty, or exclusion or limitation of incidental or consequential damages, the limitations and exclusions of this warranty may not apply to every buyer. If any provision of this Warranty is held invalid or unenforceable by a court or other decision-maker of competent jurisdiction, such holding will not affect the validity or enforceability of any other provision.

Fluke Corporation
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Everett, WA 98206-9090
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5602 BD Eindhoven
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11/99

To register your product online, visit register.fluke.com

Claims

Immediately upon arrival, purchaser shall check the packing container against the enclosed packing list and shall, within thirty (30) days of arrival, give Fluke notice of shortages or any nonconformity with the terms of the order. If purchaser fails to five notice, the delivery shall be deemed to conform with the terms of the order.

The purchaser assumes all risk of loss or damage to instruments upon delivery by Fluke to the carrier. If an instrument is damaged in transit, PURCHASER MUST FILE ALL CLAIMS FOR DAMAGE WITH THE CARRIER to obtain compensation. Upon request by purchaser, Fluke will submit an estimate of the cost to repair shipment damage.

Fluke will be happy to answer all questions to enhance the use of this instrument. Please address your requests or correspondence to: Fluke Corporation, P.O. Box 9090, Everett, WA 98206-9090.

Interference Information

This equipment generates and uses radio frequency energy and if not installed and used in strict accordance with the manufacturer's instructions, may cause interference to radio and television reception. It has been type tested and found to comply with the limits for a Class A computing device in accordance with the specifications in Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of more of the following measures:

- Reorient the receiving antenna
- Relocate the equipment with respect to the receiver
- Move the equipment away from the receiver
- Plug the equipment into a different outlet so that the computer and receiver are on different branch circuits

If necessary, the user should consult the dealer or an experienced radio/television technician for additional suggestions. The user may find the following booklet prepared by the Federal Communications Commission helpful: How to Identify and Resolve Radio-TV Interference Problems. This booklet is available from the U.S. Government Printing Office, Washington, D.C. 20402. Stock No. 004-000-00345-4.

OPERATOR SAFETY SUMMARY

⚠⚠WARNING

HIGH VOLTAGE

is used in the operation of this equipment

LETHAL VOLTAGE

may be present on the terminals, observe all safety precautions!

To avoid electrical shock hazard, the operator should not electrically contact the output hi or sense hi binding posts. During operation, lethal voltages of up to 2200 V ac or dc may be present on these terminals.

Whenever the nature of the operation permits, keep one hand away from equipment to reduce the hazard of current flowing thought vital organs of the body.

Terms in this Manual

This instrument has been designed and tested in accordance with the safety standards listed in the General Specifications, which are located in Chapter 1 of this manual. This manual contains information and warnings which have to be followed by the user to ensure safe operation and to retain the instrument in safe condition.

⚠⚠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 the equipment or other property.

Symbols Marked on Equipment

⚠	Caution, risk of electric shock.
⏚	Protective ground (earth) terminal.
⏚	Functional earth terminal.
⚠	Caution, risk of danger. Refer to the manual to maintain the safety provided by the equipment.

⚠⚠Warning

- **Do not operate this calibrator in a position where it is difficult to operate the power switch.**
- **Do not operate this calibrator in a manner not specified in the manual or the protection provided by the equipment may be impaired.**
- **Do not operate the calibrator if it shows signs of damage or malfunction, the protection provided by the equipment may be impaired.**
- **Do not use hook-up wire on the calibrator with an insulation or current rating of less than the calibrator output.**

Power Source

The 57LFC is intended to operate from a power source that will not apply more than 246 V 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 essential for safe operation.

Use the Proper Fuse

To avoid fire hazard, use only the fuse specified on the line voltage selection switch label, and which is identical in type voltage rating, and current rating.

Grounding the 57LFC

The 57LFC is Safety Class I (grounded enclosure) instruments as defined in IEC 61010 2nd Edition. The enclosure is grounded through the grounding conductor of the power cord. To avoid electrical shock, plug the power cord into a properly wired earth grounded receptacle before connecting anything to any of the 57LFC terminals. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Use the Proper Power Cord

- Use only the power cord and connector appropriate for proper operation of a 57LFC.
- Use only a power cord that is in good condition.
- Refer cord and connector changes to qualified service personnel.

Do Not Operate in Explosive Atmospheres

To avoid explosion, do not operate the 57LFC in an atmosphere of explosive gas.

Do Not Remove Cover

To avoid personal injury, do not remove the cover from the 57LFC. Do not operate the 57LFC without the cover properly installed. There are no user-serviceable parts inside the 57LFC, so there is no need for the operator to ever remove the cover.

SERVICING SAFETY SUMMARY

FOR QUALIFIED SERVICE PERSONNEL ONLY

Also refer to the preceding Operator Safety Summary

Do Not Service Alone

Do not perform internal service or adjustment of this product unless another person capable of rendering first aid and resuscitation is present.

Use Care When Servicing With Power On

Dangerous voltage exist at many points inside this product. To avoid personal injury, do not touch exposed connections and components while power is on.

Whenever the nature of the operation permits, keep one hand away from equipment to reduce the hazard of current flowing through vital organs of the body.

Do not wear a grounded wrist strap while working on this product. A grounded wrist strap increase the risk of current flowing through the body.

Disconnect power before removing protective panels, soldering, or replacing components.

High voltage may still be present even after disconnecting power.

FIRST AID FOR ELECTRIC SHOCK

Free the Victim From the Live Conductor

Shut off high voltage at once and ground the circuit. If high voltage cannot be turned off quickly, ground the circuit.

If the circuit cannot be broken or grounded, use a board, dry clothing, or other nonconductor to free the victim.

Get Help!

Yell for help. Call an emergency number. Request medical assistance.

Never Accept Ordinary and General Tests for Death

Symptoms of electric shock may include unconsciousness, failure to breathe, absence of pulse, pallor, and stiffness, and severe burns.

Treat the Victim

If the victim is not breathing, begin CPR or mouth-to-mouth resuscitation if you are certified.

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Introduction and Specifications

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Introduction

The Fluke Model 57LFC System Calibrator (hereafter called the Calibrator) is a precise instrument that calibrates a wide variety of electrical measuring instruments. This calibrator maintains a high accuracy over a wide ambient temperature range, and is able to test instruments in harsh environments, eliminating the restriction of calibrating only in a temperature-controlled standards laboratory. With a 57LFC, you can calibrate precision multimeters that measure ac or dc voltage, ac or dc current, and resistance. The Calibrator operates in a similar manner to the 57XXA series calibrators.

Specifications are provided at the end of this chapter. The Calibrator is a fully-programmable precision source of the following:

- DC voltage to 220 V.
- AC voltage to 220 V rms, with output available from 10 Hz to 100 kHz.
- AC and DC current to 2.2 A, with AC output available from 10 Hz to 20 kHz.
- Resistance in values from 0 Ω to 19 MΩ in 1 and 1.9x.

Features of the calibrator include the following:

- Automatic meter error calculation obtained through using a simple remote adjust.
- Programmable entry limits used for restricting the levels that can be remotely keyed into the calibrator, preventing access to levels that may be harmful to equipment or personnel.
- Real-time clock and calendar.
- Offset and scaling modes that simplify linearity testing of multimeters.
- Standard IEEE-488 (GPIB) interface, complying with ANSI/IEEE Standards 488.1-1987 and 488.2-1987.
- Internal self-testing and diagnostics of analog and digital functions.
- Status LEDs on front panel to indicate standby (yellow), operate (green), high voltage (red), and fault (red and yellow).

Service Information

Each calibrator is warranted to the original purchaser for a period of one year beginning on the date received. The warranty is located at the front of this manual.

Service and technical advice for the calibrator is available at Fluke Service Centers. For a complete list of Fluke Service Centers, visit **www.fluke.com.**

A worldwide network of Fluke service centers supports Fluke instruments and assists customers in many ways. Most service centers have standards and calibration laboratories certified by local national standards organizations. The following is a partial list of the services provided by most service centers:

- Repair and certified traceable calibration of all Fluke products.
- Certified traceable calibration of many non-Fluke standards and calibrators.
- Worldwide exchange of calibrator internal modules. Delivery inside the U.S.A. is typically within 48 hours.
- Service agreements with the flexibility to suit your needs. These can be a simple warranty extension or an agreement that includes on-site support. Calibration service agreements are also available in many areas.

- Training programs and seminars, including laboratory metrology, system applications, and product maintenance.
- Application help and consulting, including system design, hardware selection, custom software, site evaluation and installation.
- Replacement parts inventory, including recommended spare parts and module kits.

Visit **www.fluke.com** for locations and phone numbers of authorized Fluke service centers.

Accessories

Table 1-1 summarizes the accessories available for the Calibrator. Following the table is a brief description of each accessory.

Table 1-1. 57LFC Accessories

Model	Description
5440A-7002	Low Thermal EMF Test Lead Set with Banana Plugs: One 4 ft. cable (122 cm) and two 2 ft. (61 cm) cables.
5440A-7003	Low Thermal EMF Test Lead Set with Spade Lugs. Two 4 ft. (122 cm) cables and One 2 ft. (61 cm) cable.
Y8021	IEEE-488 Shielded Interface Cable, 1 Meter
Y8022	IEEE-488 Shielded Interface Cable, 2 Meters
Y5537	Rack Mount Kit for 57LFC and 5500A

Low Thermal EMF Test Leads

Two types of low thermal test leads are available. These cables are designed to exhibit low thermal emfs. The types available are:

- Model 5440A-7002. Low Thermal Test Lead cables with banana plugs.

  Set includes one 4 ft. (122 cm) cable and two 2 ft. (61 cm) cables. Each cable includes two conductors and a shield lead.

- Model 5440A-7003. Low Thermal Test Lead cables with spade lugs.

  Set includes two 4 ft. (122 cm) cables and one 2 ft. (61 cm) cable. Each cable includes two conductors and a shield lead. Shield lead has a banana plug connector.

Rack Mount Kit

The rack mount kit provides all the hardware necessary to mount the 57LFC. Rack mount instructions are included with each kit.

Shielded IEEE-488 Cables (Y8021, Y8022, and Y8023)

Shielded IEEE-488 cables are available in two lengths (See Table 1-1). The cables attach the calibrator to any other IEEE-488 device. Each cable has double 24-pin connectors at both ends to allow stacking. Metric threaded mounting screws are provided with each connector. Figure 4-2 in Chapter 4 shows the pinout for the IEEE-488 connector.

Contacting Fluke

All Calibrators delivered to the Navy, contractors and subcontractors for the RTCASS program will be repaired and calibrated at the Fluke Technical Support Center in Everett, Washington. Contact Fluke Technical Support at 1-888-993-5853 or by sending a fax to 1-425-446-6390. The address for the Fluke Technical Support

Center address is:

Fluke Technical Support Center
1420 75th ST SW
Everett, WA 98203-6256
U. S. A.

Once full production is started the following service centers will also maintain and calibrate the Calibrator in Europe.

FLUKE NEDERLAND B.V.
Customer Support Services
Science Park Eindhoven 5108
5692 EC Son
Netherlands

FLUKE DEUTSCHLAND GMBH
Customer Support Services
Heinrich Hertz Straße 11
D-34123 Kassel
Germany

and in Asia,

FLUKE SOUTH EAST ASIA PTE LTD.
Service Center
83 Clemenceau Avenue
#15-15/06 Ue Square
239920
Singapore

Specifications

The 57LFC System Calibrators are verified and calibrated at the factory prior to shipment to ensure they meet the accuracy standards required for all certified calibration laboratories. By calibrating to the specifications in this chapter, you can maintain the high performance level throughout the life of your calibrator.

Specifications are valid after a warm-up period of twice the time the calibrator has been turned off, up to a maximum of 30 minutes. For example, if the calibrator has been turned off for five minutes, the warm-up period is ten minutes.

To ensure the validity of the specifications, a dc zeros calibration must be performed at least every 15 days. If more than 15 days elapse without a dc zeros calibration a warning message appears. This procedure does not require any external equipment or connections and takes approximately 5 minutes to complete.

General Specifications

Factory set IEEE488 address	4
Warm-up Time	Twice the time since last warmed up, to a maximum of 30 minutes
Temperature Performance	Operating: 0 to 50 °C Calibration: 15 to 37.7 °C Storage: -40 to 75 °C
Temperature Coefficient	Temperature Coefficient for temperatures outside tcal ±5 °C is 10% of the 1-year spec per °C.
Relative Humidity	
Operating:	<95% to 43 °C (non-condensing), <40% to 50 °C.
Storage:	<95%, non-condensing
Altitude	
Operating:	3,050 m (10,000 ft) maximum
Non-operating:	12,200 m (40,000 ft) maximum
Safety	Designed to comply with IEC 61010-1 2000-1; ANSI/ISA-S82.01-1994; CAN/CSA-C22.2 No. 1010.1-92
Analog Low Isolation	20 V
EMC	Designed to comply with IEC 61326-1 2000-11 (EMC) Class A Criteria C
Line Power	
Line Voltage (selectable):	100 V, 120 V, 208 V, and 230 V
Line Frequency:	47 to 63 Hz
Line Voltage Variation:	±7% about line voltage setting
Maximum VA:	200
Settling Time	≤ 3 to 10 seconds, similar to 5700A.
Chassis Dimensions, H x W x D	178 mm x 432 mm x 457 mm (7 in x 17 in x 18 in) maximum
Weight	Less than 18.15 kg (40 pounds)
Electrical/Signal Interface	Fluke 5700A/LP equivalent signal interface, AC Mains, IEEE-488, and RS-232 connectors, AC power switch, and Line Voltage selection all on front panel
Cooling	1.42 cubic meters (50 cubic feet) per minute

⚠⚠Caution

Internal damage may occur if excessive external power is applied to the binding posts while the instrument is operating in current, voltage, or ohms. In voltage and current, exceeding 30 V may cause damage. In ohms, do not exceed the maximum specified current.

Accuracy Specifications

DC Voltage Accuracy

Ranges	Absolute Uncertainty, tcal ±5 °C ±(% output + V) 1 Year		Resolution	Maximum Burden [1]
0 mV to 220 mV	0.004%	3 µV	0.1 µV	50 Ω output impedance
0 V to 2.2 V	0.0025%	3 µV	1 µV	50 mA
0 V to 11 V	0.0025%	30 µV	10 µV	50 mA
0 V to 22 V	0.0025%	30 µV	10 µV	50 mA
0 V to 220 V	0.004%	300 µV	100 µV	20 mA

[1] Remote sensing provided on all but 220 mV range.

Note: minimum output 0 V for all ranges.

DC Current Accuracy

Ranges	Absolute Uncertainty, tcal ±5°C± (% of output + A) 1 year		Resolution	Maximum Compliance Voltage	Maximum Inductive Load
0 µA to 220 µA	0.05%	0.02 µA	1 ηA	10 V	400 µH
0 mA to 2.2 mA	0.05%	0.05 µA	0.01 µA	10 V	400 µH
0 mA to 22 mA	0.05%	0.25 µA	0.1 µA	10 V	400 µH
0 mA to 220 mA	0.05%	2.5 µA	1 µA	10 V	400 µH
0 A to 2.2 A	0.07%	40 µA	10 µA	4 V	400 µH

Resistance Accuracy

Nominal Resistance Value [1]	Absolute Uncertainty of Characterized Value, tcal ± 5 °C ± (Ω) 1 Year	Full Specification Current	Maximum Peak Current	Two-Wire Active Compensation Adder (ohms) [2]
0 Ω	0.001 Ω	8 mA to 200 mA	220 mA	0.001
1 Ω	0.001 Ω	8 mA to 100 mA	220 mA	0.001
1.9 Ω	0.002 Ω	8 mA to 100 mA	220 mA	0.001
10 Ω	0.004 Ω	8 mA to 11 mA	220 mA	0.001
19 Ω	0.008 Ω	8 mA to 11 mA	160 mA	0.001
100 Ω	0.01 Ω	8 mA to 11 mA	70 mA	0.001
190 Ω	0.02 Ω	8 mA to 11 mA	50 mA	0.001
1 kΩ	0.1 Ω	1 mA to 2 mA	22 mA	0.010
1.9 kΩ	0.2 Ω	1 mA to 1.5 mA	16 mA	0.010
10 kΩ	1 Ω	0.1 mA to 0.5 mA	3 mA	0.100
19 kΩ	2 Ω	0.05 mA to 0.25 mA	1.6 mA	0.200
100 kΩ	10 Ω	0.01 mA to 0.1 mA	0.3 mA	1.000
190 kΩ	20 Ω	5 µA to 50 µA	0.16 mA	2.000
1 MΩ	100 Ω	5 µA to 20 µA	30 µA	NA
1.9 MΩ	200 Ω	2.5 µA to 10 µA	16 µA	NA
10 MΩ	4 kΩ	0.5 µA to 2 µA	3 µA	NA
19 MΩ	10 kΩ	0.25 µA to 1 µA	1.6 µA	NA

[1] Discrete resistors with characterized values stored in non-volatile memory. Specifications apply to the characterized value using 4-wire connections.

[2] Active two-wire compensation may be selected for values up to 190 kΩ. Active compensation is 11 mA load and 2 V burden minimum.

AC Voltage Accuracy

Ranges	Frequency	Absolute Uncertainty, tcal ±5 °C ± (% output + V) 1 year		Resolution	Maximum Burden [1] [2]
10 mV to 22 mV	10 Hz to 45 Hz	0.15%	20 µV	1 µV	50 Ω output impedance
	45 Hz to 20 kHz	0.08%	20 µV		
	20 kHz to 50 kHz	0.25%	20 µV		
	50 kHz to 100 kHz	0.5%	50 µV		
22 mV to 220 mV	10 Hz to 45 Hz	0.15%	50 µV	1 µV	50 Ω output impedance
	45 Hz to 20 kHz	0.05%	50 µV		
	20 kHz to 50 kHz	0.25%	50 µV		
	50 kHz to 100 kHz	0.4%	200 µV		
0.22 V to 2.2 V	10 Hz to 45 Hz	0.1%	250 µV	10 µV	50 mA
	45 Hz to 20 kHz	0.05%	100 µV		
	20 kHz to 50 kHz	0.1%	320 µV		
	50 to 100 kHz	0.25%	2000 µV		
2.2 V to 22 V	10 Hz to 45 Hz	0.1%	1 mV	100 µV	50 mA
	45 Hz to 20 kHz	0.05%	1 mV		
	20 kHz to 50 kHz	0.1%	1 mV		
	50 kHz to 100 kHz	0.25%	2 mV		
22 V to 220 V [2]	10 Hz to 45 Hz	0.1%	10 mV	1 mV	20 mA
	45 Hz to 20 kHz	0.05%	10 mV		
	20 kHz to 50 kHz	0.25%	20 mV		
	50 kHz to 100 kHz	0.5%	50 mV		

[1] Remote sensing provided on all but 22 mV and 220 mV ranges. Maximum output current is reduced by 50% above 40 °C. Maximum load capacitance is 500 pF.

[2] V x Hz limited to 11.8e6.

Note: Frequency uncertainty is specified to be 0.01% of frequency setting.

AC Voltage Distortion

Ranges	Frequency	Max Distortion and noise 10 Hz to 10 MHz Bandwidth ±(% output + V) [1]	
10 mV to 22 mV	10 Hz to 45 Hz	0.15%	90 μV
	45 Hz to 20 kHz	0.035%	90 μV
	20 kHz to 50 kHz	0.15%	90 μV
	50 kHz to 100 kHz	0.25%	90 μV
22 mV to 220 mV	10 Hz to 45 Hz	0.15%	90 μV
	45 Hz to 20 kHz	0.035%	90 μV
	20 kHz to 50 kHz	0.15%	90 μV
	50 kHz to 100 kHz	0.20%	90 μV
0.22 V to 2.2 V	10 Hz to 45 Hz	0.15%	200 μV
	45 Hz to 20 kHz	0.035%	200 μV
	20 kHz to 50 kHz	0.15%	200 μV
	50 kHz to 100 kHz	0.20%	200 μV
2.2 V to 22 V	10 Hz to 45 Hz	0.15%	2 mV
	45 Hz to 20 kHz	0.035%	2 mV
	20 kHz to 50 kHz	0.2%	2 mV
	50 kHz to 100 kHz	0.5%	2 mV
22 V to 220 V	10 Hz to 45 Hz	0.15%	10 mV
	45 Hz to 20 kHz	0.05%	10 mV
	20 kHz to 50 kHz	0.8%	10 mV
	50 kHz to 100 kHz	1.0%	10 mV

[1] For larger resistive loads, multiply uncertainty specifications by (actual load/maximum full load for accuracy)^{2}.

AC Current Accuracy

Ranges [3]	Frequency	Absolute Uncertainty, tcal ±5 °C ±(% of output + A) 1 year		Resolution	Maximum Compliance Voltage (rms) [2]	Maximum Inductive Load [1]
30 µA to 220 µA	10 Hz to 20 Hz	0.3%	0.2 µA	0.01 µA	7 V	50 µH
	20 Hz to 45 Hz	0.15%	0.2 µA			
	45 Hz to 1 kHz	0.125%	0.2 µA			
	1 kHz to 5 kHz	0.4%	0.3 µA			
	5 kHz to 10 kHz	1.5%	0.4 µA			
0.22 mA to 2.2 mA	10 Hz to 20 Hz	0.2%	0.3 µA	0.1 µA	7 V	50 µH
	20 Hz to 45 Hz	0.15%	0.3 µA			
	45 Hz to 1 kHz	0.1%	0.3 µA			
	1 kHz to 5 kHz	0.2%	0.3 µA			
	5 kHz to 10 kHz	0.8%	0.5 µA			
2.2 mA to 22 mA	10 Hz to 20 Hz	0.2%	3 µA	1 µA	7 V	50 µH
	20 Hz to 45 Hz	0.1%	3 µA			
	45 Hz to 1 kHz	0.1%	3 µA			
	1 kHz to 5 kHz	0.2%	3 µA			
	5 kHz to 10 kHz	0.4%	5 µA			
	10 kHz to 20 kHz	0.8%	5 µA			
22 mA to 220 mA	10 Hz to 20 Hz	0.18%	30 µA	10 µA	7 V	50 µH
	20 Hz to 45 Hz	0.1%	30 µA			
	45 Hz to 1 kHz	0.1%	30 µA			
	1 kHz to 5 kHz	0.3%	50 µA			
	5 kHz to 10 kHz	0.4%	100 µA			
	10 kHz to 20 kHz	0.8%	200 µA			
0.22 A to 2.2 A	10 Hz to 45 Hz	0.18%	300 µA	100 µA	4 V	2.5 µH
	45 Hz to 1 kHz	0.1%	300 µA			
	1 kHz to 5 kHz	1%	3000 µA			
	5 kHz to 10 kHz	5%	5000 µA			

[1] 400 µH with inductive compensation ON.

[2] See AC Current Compliance Adder and Distortion Table for impact of compliance voltage on specification.

[3] I-guard, (as on the 5700A rear panel), required when sourcing low-level currents through a long cable.

Note: Frequency uncertainty is specified to be 0.01% of frequency setting.

AC Current Distortion

Ranges	Frequency	Maximum Resistive Load For Full Accuracy Ω[1]	Max Distortion & Noise 10 Hz to 50 kHz BW <0.5V Burden ±(%output + A)	
30 μA to 220 μA	10 Hz to 20 Hz	20 kΩ	0.15%	0.5 μA
	20 Hz to 45 Hz		0.1%	0.5 μA
	45 Hz to 1 kHz		0.05%	0.5 μA
	1 kHz to 5 kHz		0.5%	0.5 μA
	5 kHz to 10 kHz		1.0%	0.5 μA
0.22 mA to 2.2 mA	10 Hz to 20 Hz	10 kΩ	0.15%	1.5 μA
	20 Hz to 45 Hz		0.06%	1.5 μA
	45 Hz to 1 kHz		0.05%	1.5 μA
	1 kHz to 5 kHz		0.5%	1.5 μA
	5 kHz to 10 kHz		1.0%	1.5 μA
2.2 mA to 22 mA	10 Hz to 20 Hz	3.18 kΩ	0.15%	5 μA
	20 Hz to 45 Hz		0.05%	5 μA
	45 Hz to 1 kHz		0.07%	5 μA
	1 kHz to 5 kHz		0.3%	5 μA
	5 kHz to 10 kHz		0.7%	5 μA
	10 kHz to 20 kHz		1.0%	5 μA
22 mA to 220 mA	10 Hz to 20 Hz	318 Ω	0.15%	50 μA
	20 Hz to 45 Hz		0.05%	50 μA
	45 Hz to 1 kHz		0.07%	50 μA
	1 kHz to 5 kHz		0.30%	50 μA
	5 kHz to 10 kHz		0.70%	50 μA
	10 kHz to 20 kHz		1.0%	50 μA
0.22 A to 2.2 A	10 Hz to 45 Hz	18 Ω	0.2%	500 μA
	45 Hz to 1 kHz		0.07%	500 μA
	1 kHz to 5 kHz		1.0%	500 μA
	5 Hz to 10 kHz		2.0%	500 μA

[1] For larger resistive loads, multiply uncertainty specifications by actual load/maximum full load for accuracy.

Note: Current times Load cannot exceed the maximum compliance voltage.

Chapter 2
Theory of Operation

Title	Page

Introduction

This Chapter is intended to provide a detailed description and analysis, where appropriate, of the printed circuit board assemblies (PCAs) used in the 57LFC System Calibrator. The Calibrator contains the following PCAs.

- A1 LED PCA
- A3 Motherboard PCA
- A5 Ohms PCA
- A6 Digital Synthesis PCA
- A7 Current PCA
- A8 High Voltage PCA
- A9 Out-Guard CPU PCA

See Figure 2-1 for a block diagram of the 57LFC System Calibrator.

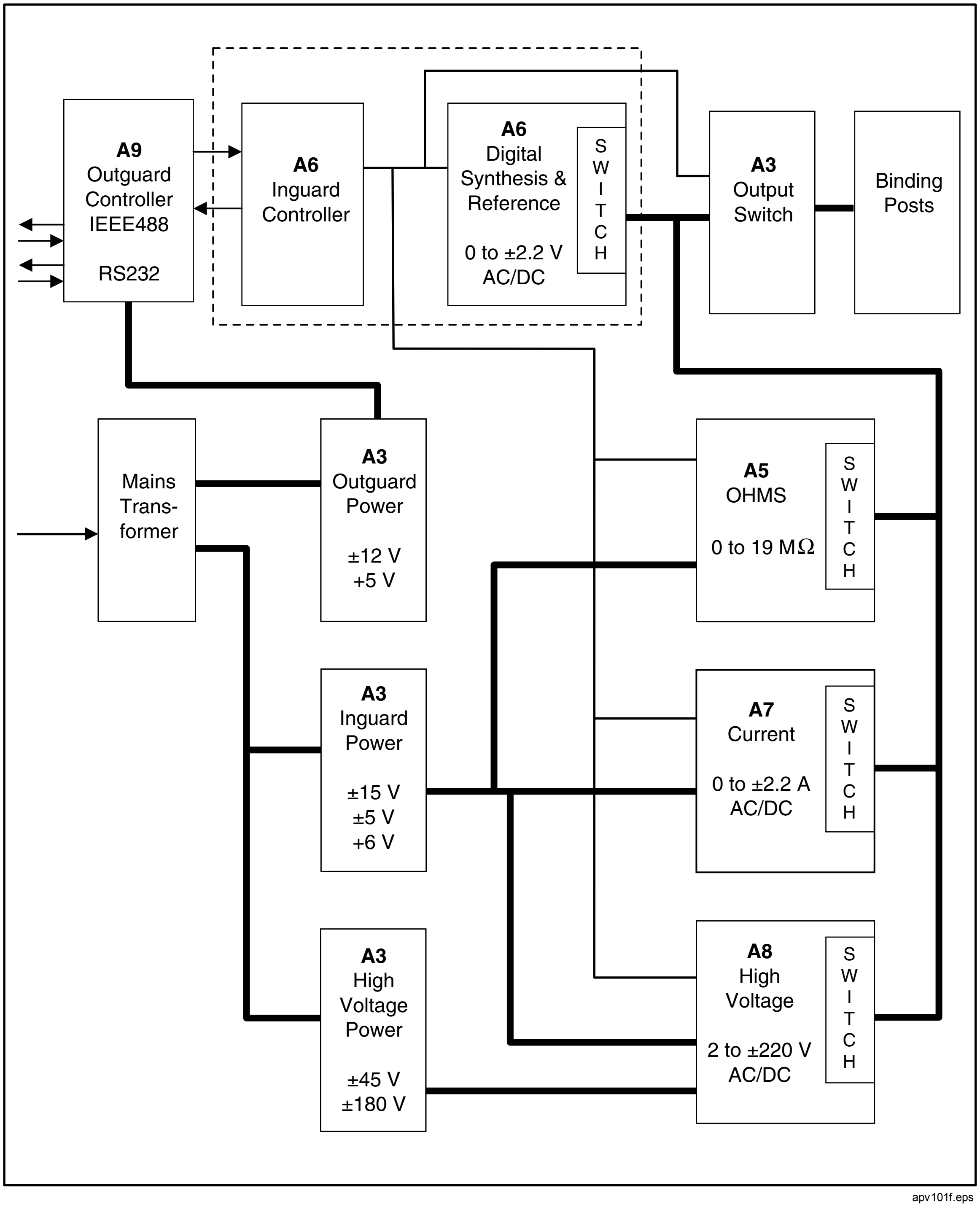

Figure 2-1. 57LFC Block Diagram

A1 LED PCA

The Calibrator front panel A1 LED PCA provides the only visual indication of the instrument operation. These LEDs provide a color-coded scheme for the instrument status.

⚠⚠Warning

This instrument is capable of outputting lethal voltages. Observe all safety precautions.

While the LEDs should provide years of operation, they are subject to wear out like any other component. Never touch the binding posts without first checking the output with a multimeter.

The front panel A1 LED PCA is connected to and controlled by the A3 Motherboard PCA. A cable is used to connect the A3 Motherboard PCA to the A1 LED PCA. On power up, the yellow LED will light indicating that the instrument has moved into a standby state. The green LED is used to indicate that the instrument is in operate and there may be live voltages on the binding posts. The red LED is used to indicate that the instrument may be outputting hazardous voltages greater than 30 V rms. If diagnostic failures occur during power-up, both the yellow and red LEDs light. If all three LEDs are lit, the instrument is broken and must be sent to a qualified technician for repair.

A3 Motherboard PCA

The following discussion covers the theory of operations for the A3 Motherboard PCA circuits. This A3 Motherboard PCA generally carries power as well as system signal buses to the circuit cards. The A3 Motherboard PCA can be divided into several areas: 1) relay control and switch matrix, 2) LED control and output cables, 3) analog and digital buses, 4) low volt buffer, 5) in-guard power supplies, 6) out-guard power supplies, 7) miscellaneous circuits, and 8) list of fuses. Please refer to the A3 Motherboard PCA schematics for this discussion.

⚠⚠Warning

The A3 Motherboard PCA contains lethal voltages. Only qualified technicians should do troubleshooting.

Relay Control and Switch Matrix

The relay matrix is shown on Sheet 1 of the A3 Motherboard PCA schematic, and the relay control is shown on Sheet 5. Some of the purposes of the relay matrix are to provide isolation between the output binding posts and the internal circuitry during standby, and provide isolation when running zero calibration or diagnostics. The functions of the relays are shown in Table 2-1. The relay control circuits consist of U3, U5, U6, U8, and U9. For U3 (74HC138), the IG_CS1 signal is generated on the A6 Digital Synthesis PCA. U8 selects the driver latch used to set or reset the latching relays.

Table 2-1. Functional Description of A3 Motherboard PCA Relays

Relay	Functional Description
K1	Reset: connect LO's to the A6 Digital Synthesis PCA; connect OUT_LO to the A6 Digital Synthesis PCA RET_LO, and connects IN_SNS_LO to the A6 SNS_LO Set: disconnect LO's from the A6 Digital Synthesis PCA; disconnect the A6 Digital Synthesis PCA RET_LO and SNS_LO from the LO input terminals
K2	Reset: select internal sensing; connect OSNS_HI to IN_SNS_HI and OSNS_LO to IN_SNS_LO Set: select remote sensing; connect SNS_HI to IN_SNS_HI and SNS_LO to IN_SNS_LO
K3	Reset: connect the Digital Synthesis PCA divider; connect IN_SNS_HI to the A6 VDIV Set: disconnect the Digital Synthesis PCA divider; disconnect IN_SNS_HI from VDIV
K4	Reset: select VMID for output; connect VMID to OUT_HI Set: disconnect VMID from output; disconnect VMID from OUT_HI
K5	Reset: select external guard; disconnect GUARD from SCOM Set: select internal guard; connect GUARD to SCOM
K6	Reset: select the 2 V buffer amp; connect V3BUF to VMID for output Set: disconnect the 2 V buffer amp; disconnect V3BUF from VMID
K7	Reset: disconnect the A8 High Voltage PCA output; disconnect OUT_220V from OUT_HI Set: select the A8 High Voltage PCA output; connect OUT_220V to OUT_HI
K8	Reset: disconnect HIGUARD (IGUARD) from GUARD (VGUARD) Set: connect HIGUARD to GUARD
K9	Reset: connect A6 Digital Synthesis PCA LO return; connect OUT_LO to A6_RET_LO Set: disconnect the A6 Digital Synthesis PCA LO return, disconnect OUT_LO from A6_RET_LO
K10	Reset: provide an internal VMID sense path, connect VMID to the A6 VDIV Set: normal operation; disconnect VMID from VDIV
K11	Reset: provide an internal 220 V sense path; connect OUT_220V to VMID Set: normal operation; disconnect OUT_220V from VMID

On power up, the relays are forced into a benign setting to protect circuitry and the customer. Table 2-2 shows the state of the A3 Motherboard PCA relays after power up. Table 2-3 shows the A3 Motherboard PCA relay states when in several states (power up and standby). Table 2-4 shows the status of control lines for all modes of A3 Motherboard PCA operation.

Table 2-2. A3 Motherboard PCA Power-up and Fault Relay States

Relay	State on Power-up or after Fault
K1	Set: disconnect A6 Digital Synthesis PCA LO sense
K2	Reset: select internal sensing
K3	Set: disconnect the A6 Digital Synthesis PCA divider
K4	Set: disconnect VMID from output
K5	Reset: select external guard
K6	Undefined
K7	Reset: disconnect the A8 High Voltage PCA output
K8	Undefined
K9	Set: disconnect the A6 Digital Synthesis PCA LO return
K10	Undefined
K11	Undefined

Table 2-3. A3 Motherboard PCA Final Relay States by Instrument State

											Guard:	ext	Int	ext	int
											Sense:	int	int	rem	rem
Relay (Virtual) Register:	**MBRLY**											g=0	g=1	g=0	g=1
Relay:	**K11**	**K10**	**K9**	**K8**	**K7**	**K6**	**K5**	**K4**	**K3**	**K2**	**K1**	d=0	d=0	d=1	d=1
Instrument State\Bit Weight:	4	2	1	8	4	2	1	8	4	2	1	hex	hex	hex	hex
Power Up	r	s	s	s	r	s	r	s	s	r	s	03ad			
Dormant	r	s	s	s	r	s	r	s	s	r	s	03ad			
External Guard (mod mask 0010h)	x	x	x	x	x	x	r	x	x	x	x	0000		0000	
Internal Guard	x	x	x	x	x	x	s	x	x	x	x		0010		0010
Internal Sense (mod mast 002h)	x	x	x	x	x	x	x	x	x	r	x	0000	0000		
External Sense	x	x	x	x	x	x	x	x	x	s	x			0002	0002
22 mV A6 Output	r	s	r	s	r	s	g	r	s	r	r	02a4	02b4	-	-
Standby 22 mV A6 Output	r	s	s	s	r	s	r	s	s	r	s	03ad			
220 mV A6 Output	r	s	r	s	r	s	g	r	s	r	r	02a4	02b4	-	-
Standby 220 mV A6 Output	r	s	s	s	r	s	r	s	s	r	s	03ad			
Optt 3.3 V A6 Output using LO Comp Amp	r	s	s	s	r	s	g	r	r	d	r	03a0	03b0	03a2	03a2
Opt 3.3 V A6 Output	r	s	r	s	r	s	g	r	r	d	r	0210	02b0	02a2	02b2
Standby Opt 3.3 A6 Output	r	s	s	s	r	s	r	s	s	r	s	03ad			
2.2 V Buffer Out using LO Comp Amp	r	s	s	s	r	r	g	r	r	d	r	0380	0390	0382	0392
2.2 V Buffer Output	r	s	r	s	r	r	g	r	r	d	r	0280	0290	0282	0292
Standby 2.2 V Buffer Output		r	s	s	r	r	r	s	s	r	s	038d			
22 V A8 Output using LO Comp Amp	r	s	s	s	r	s	g	r	r	d	r	03a0	03b0	03a2	03b2
22 V A8 Output	r	s	r	s	r	s	g	r	r	d	r	02a0	02b0	02a2	02b2
Standby 22 V A8 Output	r	s	s	s	r	s	r	s	s	r	s	03ad			
220 V A8 Output Using LO Comp Amp	r	s	s	s	s	s	g	s	r	d	r	03e8	03f8	03ea	03fa
220 V A8 Output	r	s	r	s	s	s	g	s	r	d	r	02e8	02f8	02ea	02fa
Standby 220 V A8 Output	r	s	s	s	r	s	r	s	s	r	s	03ad			
Ohms A5 Output 4-Wire	r	s	s	r	r	s	g	s	s	s	s	-	-	032f	033f
Standby Ohms A5 4W	r	s	s	r	r	s	r	s	s	r	s	032d			
Ohms A5 Output 2-Wire	r	s	s	r	r	s	g	s	s	r	s	032d	033d	-	-
Standby Ohms A5 2W	r	s	s	r	r	s	r	s	s	r	s	032d			
Ohms A5 Out 2W Comp	r	s	s	r	r	s	g	s	s	d	s	032d	033d	032f	033f
Standby A5 2W Comp	r	s	s	r	r	s	r	s	s	r	s	032d			
Current A7 Output	r	s	s	r	r	s	g	s	s	s	s	032f	033f	-	-
Standby Current A7 Output	r	s	s	r	r	s	r	s	s	r	s	032d			
TC A10 Output	r	s	s	s	r	s	g	s	s	r	s	03ad	03bd	-	-
Standby TC A10 Output	r	s	s	s	r	s	r	s	s	r	s	03ad			
Internal Measure Opt 3.3 V A6 Output	r	r	s	s	r	s	r	s	s	r	s	01ad			
Internal Measure 2.2 V Buffer Output	r	r	s	s	r	r	r	s	s	r	s	018d			
Internal Measure 22 V A8 Output	r	r	s	s	r	s	r	s	s	r	s	01ad			
Internal Measure 220 V A8 Output	s	r	s	s	r	s	r	s	s	r	s	05ad			

Key: x = don't care, r = reset, s = set, d = reset (0) for internal sense or set (1) for remote sense, g = reset (0) for external guard or set (1) for internal guard

Notes:

- An over-voltage detection or other serious problem should trip the instrument to the fault state.
- An over-compliance or over-current detection should trip the instrument to the appropriate overload fault.
- A hardware fault causes the instrument to enter the fault state.

Table 2-4. Control Register States by Instrument State

Control Register	MBSW								
Signal:	-	-	CKIT*	CKHVCUR*	-	WARNING*	OPERATE*	STANDBY*	
Instrument State \ Bit Weight:	8	4	2	1	8	4	2	1	**hex**
Dormant	x	x	H	H	x	H	H	L	36
Fault	x	x	H	H	x	L	H	L	32
Standby	x	x	H	H	x	H	H	L	36
Output Ohms, Current, I, or V < 30 V	x	x	H	H	x	H	L	H	35
Output V > 30 V	x	x	H	H	x	L	L	H	31
Output V < 30 V, Monitor HVCOM current via SMUX	x	x	H	L	x	H	L	H	25
Output V > 30 V, Monitor HVCOM current via SMUX	x	x	H	L	x	L	L	H	21
Output Ohms, I, or V >30 V, Monitor Internal Temperature via SMUX	x	x	L	H	x	H	L	H	15
Output V > 30 V, Monitor Internal Temperature via SMUX	x	x	L	H	x	L	L	H	11
Key: x = don't care, H = High (Off), L = Low (On)									

LED Control and Output Cables

Sheet 5 of the schematic shows the LED control (panel LED's connector). The LEDs are mounted on their own daughter card with control wires cabled from the A3 Motherboard PCA. A description of each LED is provided in Table 2-5.

Table 2-5. Functional Description of LED Signals

Signal	Functional Description
STANDBY*	Turns on the STANDBY LED when asserted Low (YELLOW)
OPERATE*	Turns on the OPERATE LED when asserted Low (GREEN)
WARNING*	Turns on the WARNING LED when asserted Low (RED)
CKHVCUR*	Turns on an analog switch to place the rectified and filtered shunt voltage generated by the HVCOM current onto the SMUX line when asserted Low
CKIT*	Turns on a switch to connect the output of the temperature to SMUX.

Sheet 1 of the A3 Motherboard PCA schematic shows the connection and wiring for the output cable from the A3 Motherboard PCA to the front panel binding posts. Note that there are two guards - IGUARD and GUARD (voltage guard). These guards may be tied together through K8 when voltage is selected. The other signal leads are OUT_HI, SNS_HI, OUT_LO, and SNS_LO. The output high and low signals (OUT_HI and OUT_LO) are used for the main output for volts, current, and ohms. The output sense signals (SNS_HI and SNS_LO) are used to sense and internally adjust the output signals. The sense terminals are not used for standard (uncompensated) two wire ohms or ac and dc current.

Signal Buses

The system analog and digital buses are brought to the circuit cards through the A3 Motherboard PCA connectors J105-108 and J205-208. J105-J108 provides the in-guard (IG) digital bus signal lines while J205-208 route the in-guard analog signal lines. Guard is tied to chassis through a set of diodes and MOVs (CR57, CR58, and RV3 and CR69, CR68, and RV1) and prevents the guard from floating more than 20 V from chassis. The guard is tied to SCOM through CR55, CR56, RV2, and R86. Note that relay K5 on Sheet 1 can connect the guard trace directly to SCOM.

Low Volt Buffer

The low voltage buffer circuit is shown on Sheet 4 of the A3 Motherboard PCA schematic (along the bottom-middle of the Sheet). The V3_3 input signal to U2 comes from the A6 Digital Synthesis PCA (A6). U2, combined with Q1,2,7 and 8, act to buffer the V3_3 signal and isolate the output voltage from the A6 card. Q3 and Q4 limit the output current that may be drawn.

In-guard Power Supplies

The power supplies for the analog circuits, also referred to as in-guard supplies, are shown on Sheets 2, 3, and 4 of the A3 Motherboard PCA. On Sheet 2 of the A3 Motherboard PCA schematic, the raw transformer secondaries enter at P2. 5AC1, 5AC2, 15AC1 and 15AC2 go to Sheet 3 of the A3 Motherboard PCA schematic along with the GUARD signal. RT7-10 protects the transformer from large current draws that might occur if a diode bridge on Sheet 3 of the A3 Motherboard PCA schematic or other components short.

The 45 ac, 180 ac, and 360 ac provide the raw voltages that will be used by the A8 High Voltage and A5 Ohms PCAs. If secondary voltages become too large, TRIAC Q19 will turn on the limit voltage, open the mains fuse, and prevent damage. CR62 is the full wave rectifier for the +/-45UNR supply. The +/-45UNR are regulated to become the +/-45V supplies. MP7 and MP8 are assemblies that contain the heat sinks and the main pairs of drive transistors for the 45 V regulated supplies. U18 controls the regulation. Q12 with resistor R48 and R54 and Q13 with resistors R49 and R57 limit the output currents to ~120 mA. CR28 with VR10 and VR11 and CR 26 with VR12 and VR 13 protect against high voltages damaging the regulation circuits. Note that the HVCOM line caries the ground return currents for the high voltage supplies back to the center tap of the transformer.

On Sheet 3 of the A3 Motherboard PCA schematic, CR67 and CR51 rectify the 15 V ac and 5 V ac (left side of the Sheet), respectively. The resulting +15UNR goes through U21, a dual regulator., and becomes the guarded +15 V supply. -15UNR goes into U22 and becomes the -15 V supply. VR14 and VR15 limit short term over-voltages to 22 V or so. The 5 ac signals are regulated to be the power for the relays (+5RLH) and the logic (+5 V). The +/-15 V supplies are referenced to SCOM, while the +/-5 V supplies are referenced to DCOM. Note that SCOM and DCOM grounds are kept close to each other electrically due to the Schottky diodes, CR18 and CR19. CR29 and CR31 limit the amount that the +/-15 V and +/-5 V power supplies can float from each other. Each regulator in the design is protected against short-term over voltages occurring at the regulator output with diodes CR41, CR48, CR35, CR36, and CR34. The 6 turn beads reduce conducted noise.

Outguard Power Supplies

The connector P1 and the out-guard secondaries labeled 12GAC and 5GAC are shown on Sheet 2 of the A3 Motherboard PCA schematic. These unregulated supplies including +5VG_UNR, become the regulated supplies for the outguard controller card (A9) and include +5VG and +/-12VG. These supply power the A9 Out-Guard CPU PCA through the connector J1 (found on Sheet five). RT1, and RT3-RT5 protect the transformer from large current draws that might occur if there is a short down stream. Each regulator in the design (U20, U25, and U19) is protected against short-term over voltages occurring at the regulator output with diodes CR42, CR43, and CR59. The 6 turn beads reduce conducted noise. The regulated +/-12 V supplies also provide power to the 24 V fan located at the front of the instrument. A second fan connector was added for a future version of the instrument. GCOM is the reference and is tied through resistors to earth, and tied to DCOM (the in-guard digital ground) through a 24 V bi-directional Zener, VR17.

Miscellaneous Circuits

On Sheet five of the A3 Motherboard PCA schematic, J1 connects the digital signals from the A9 Controller card to the A3 Motherboard PCA. The serial data signals form the communication path to the A6 Digital Synthesis PCA (which also controls the in-guard digital bus). J6 is used for trouble shooting the circuitry in manufacturing and service testing. Also on that Sheet is an area marked NOT INSTALLED. These circuits may be used in a future version of the product.

Sheet 3 of the A3 Motherboard PCA schematic shows U27, a switch used to connect signals to the SMUX bus line for monitoring the A6 Digital Synthesis PCA. CKHVCUR* is driven by U7 pin 12 on Sheet 5 of the A3 Motherboard PCA schematic for connecting the output of the circuit checking the HVCOM current to SMUX. CKIT* can turn on a switch in U27 to connect the output of the temperature sensor h30 to SMUX.

Troubleshooting Test Points

When a problem occurs with the instrument operation, one likely place to look is the A3 Motherboard PCA and its power supplies. There are a number of convenient test points to monitor the supply voltages. The test points are listed in Table 2-6.

The test points can be divided into several groups: general, function unique, out-guard, and fault. General test points include V3BUF, +/-5UNR, +/-5V, +/-15UNR, and +/-15V. The V3BUF monitors the buffered signal used for ac and dc output voltages between 220 mV and 2.2 V +/-5UNR, +/-5V, +/-15UNR, and +/-15V monitor the main supplies used in all of the in-guard board circuitry.

Power supplies unique to the A7 Current PCA are monitored by MMONGO, MMCOM, IREF, ICOM, +/-15I_UNR, and 15I. Power supplies unique to the A8 High Voltage PCA are +/-45UNR, +/-45V, +/-180UNR, and +/-360UNR. The A8 High Voltage PCA uses the +/-45V, +/-180UNR and +/-360UNR to produce the high voltage outputs. The A5 Ohms PCA uses the general and +/-45Vsupplies.

Out-guard test points monitor provide access to +5VG_UNR, +5VG, GGND, +/-12VG_UNR, and +/-12VG power signals. These power supplies are only used for the controller card (A9) and for manufacturing test fixtures.

Besides monitoring the power supplies, several test points are used to monitor fault conditions. Note that the FAULT* signal is a wired "O". The main fault signal is TP3. If any fault occurs, TP3 becomes active. TP2 monitors the 15V BALANCE FAULT* signal and provides status on the +15 V and -15 V supplies. If either supply varies from the other by too much (indicating excessive load or failure), the fault becomes active. TP4 monitors the HVCOM signal trace. If the HVCOM signal moves more than 0.5 V from SCOM, the fault becomes active. TP5 monitors OVER22V. This signal indicates if SCOM differs from chassis ground by more than about 23 V. TP49 monitors 45 V BALANCE FAULT. This fault is similar to the 15 V BALANCE FAULT and monitors that +45 V and -45 V supplies stay within a fixed range of each other.

Table 2-6. A3 Motherboard PCA Test Points List

Number	Description	Number	Description	Number	Description
TP 1	V3BUF	TP21	+45 V	TP41	+MMONGO
TP 2	15V BALANCE FAULT*	TP22	-45 V	TP42	+15UNR
TP 3	FAULT*	TP23	+15 V	TP43	-15UNR
TP 4	HVCOM FAULT*	TP24	SCOM	TP44	-12VG
TP 5	CHASSIS 22V FAULT*	TP25	SCOM	TP45	-15I_UNR
TP 6	+5VG_UNR	TP26	-15 V	TP46	+12VG_UNR
TP 7	DCOM	TP27	HVCOM	TP47	-12VG_UNR
TP 8	DCOM	TP28	HVCOM	TP48	-45UNR
TP 9	-5 V	TP29	GGND	TP49	45V BALANCE FAULT*
TP10	+5RLH	TP30	+360UNR		
TP11	+5 V	TP31	+180UNR		
TP12	-MMONGO	TP32	-180UNR		
TP13	MMCOM	TP33	-360UNR		

Table 2-6. A3 Motherboard PCA Test Points List (cont.)

Number	Description	Number	Description	Number	Description
TP14	MMCOM	TP34	GGND		
TP15	+IREF	TP35	-5UNR		
TP16	-IREF	TP36	+15I_UNR		
TP17	-15I	TP37	+5VG		
TP18	ICOM	TP38	+12VG		
TP19	ICOM	TP39	+5UNR		
TP20	+15I	TP40	+45UNR		

List of Fuses

There are several fuses used on the A3 Motherboard PCA when resistive thermal switches cannot be used. The fuses are used primarily in the high-voltage power supply circuits. F1 and F2 are used to protect the raw +/-45 V supplies. F4 and F5 protect the +/-180 V supplies, and F3 and F6 protect the +/-360 V supplies.

A5 Ohms PCA

The following discussion covers the theory of operations for the A5 Ohms PCA circuitry. The A5 Ohms PCA sources 1x and 1.9x fixed value resistances, provides compensation, and generates an active guard. The A5 Ohms PCA can source ohms in one of several ways: two-wire, two-wire with compensation, and four-wire ohms. For discussion purposes, the A5 Ohms PCA can be divided into several areas: precision thin film resistor networks, relay switch matrix and control circuits, other control circuits, guard circuit, two-wire compensation circuits, monitoring circuits, and diagnostic circuits. See Figure 2-1 for a block diagram of the A5 Ohms PCA. The last part of this section discusses diagnostic capability built into the A5 Ohms PCA. See the A5 Ohms PCA schematics for circuit details.

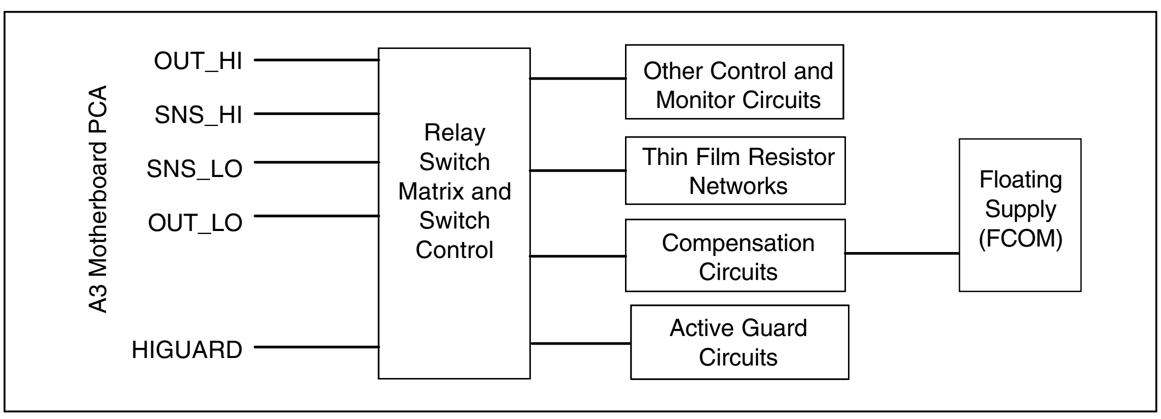

Figure 2-2. Block Diagram of the A5 Ohms PCA

Precision Resistor Networks

Fluke proprietary hermetically sealed thin film resistors (Z1-5) are used in the A5 Ohms PCA. While the values are not exact, the thin film resistors are made to have excellent time and thermal stability with low temperature coefficients. The resistors are made for 4-wire operation but may be used as 2-wire devices with degraded specifications. In four-wire mode, the resistors are connected to OUT_HI, SNS_HI, OUT_LO, and SNS_LO. The resistors have the following nominal ohm values: 0 (short), Z1 (1, 1.9), Z2 (10, 19, 100, 190, 1.0 k, 1.9 k), Z3 (10 k, 100 k, 1 M, 10 M), Z4 (19 k, 190 k, 1.9 M, 19 M). As an example, at 19 M, the maximum peak current is 1.6 µA. The limit is required because an active circuit used to guard the resistance value from leakage has a maximum range of about +/-33 V. Exceeding that voltage may cause the ZGUARD buffer to cause errors in resistance measurement. Note that the resistors have maximum peak currents that should not be exceeded, and excessive current for extended periods of time may damage the resistors and create a long term offset. Only one resistor is switched onto the out high and out low signal traces at a time. The output and sense resistor traces are directed to the output terminals through a series of relays.

Relay Switch Matrix and Control

The relay switch matrix and resistors are shown on Sheet 1 of the A5 Ohms PCA schematic, and the switch control circuits are shown on Sheet 5 of the A5 Ohms PCA schematic. A block diagram of the high/low and high-sense/low-sense relay routing is shown in Figures 2-2 and 2-3. The relay matrix provides switching between the various resistor values and the A3 Motherboard PCA, and also switches in guard circuits, 2-wire mode compensation circuits, and other compensation circuits. These relays are latching type and can be set or reset.

A3 Motherboard PCA connections are shown on Sheet 1 (8A-8D). K29 and K30 isolate the ohms output and sense lines from the A3 Motherboard PCA. The HIGUARD signal is switched through K25 and can be used to drive the shields of HI cables when the Calibrator output is active. See the Guard Circuits section for more details.

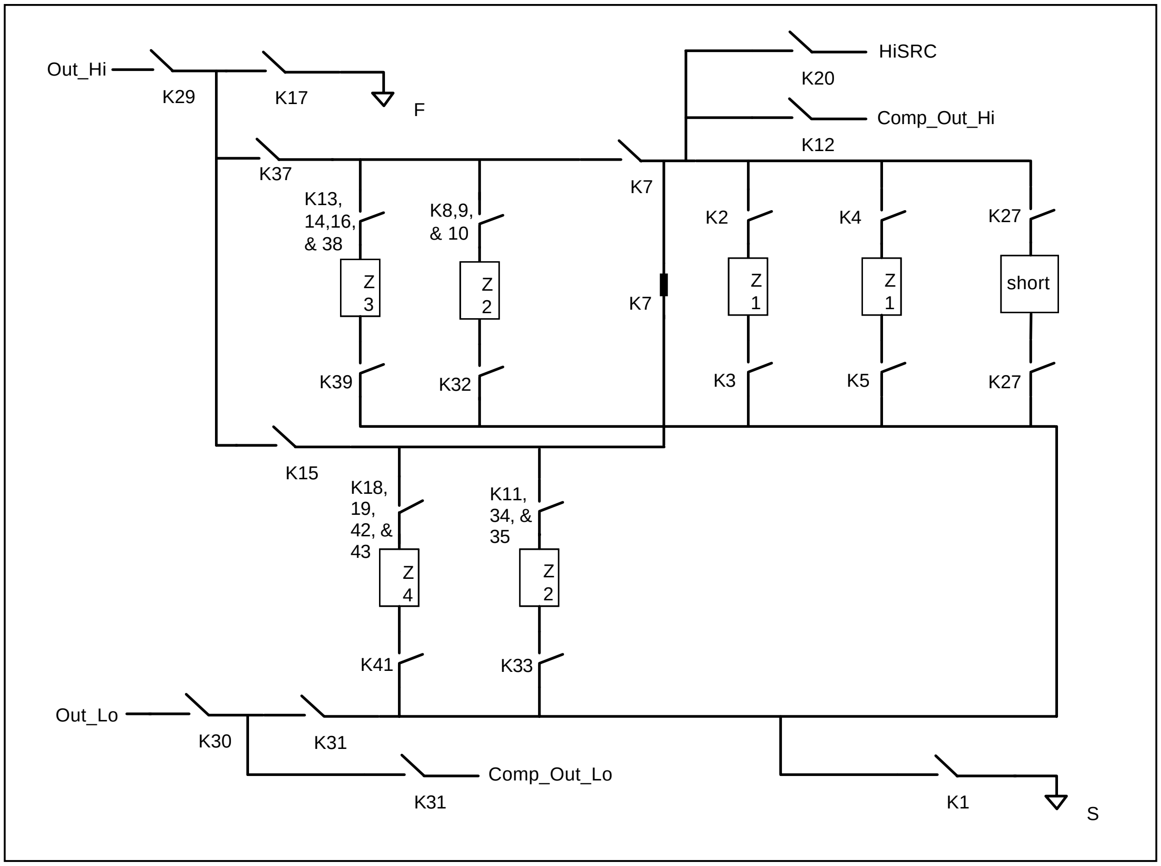

Figure 2-3. A5 Ohms PCA High/Low Output

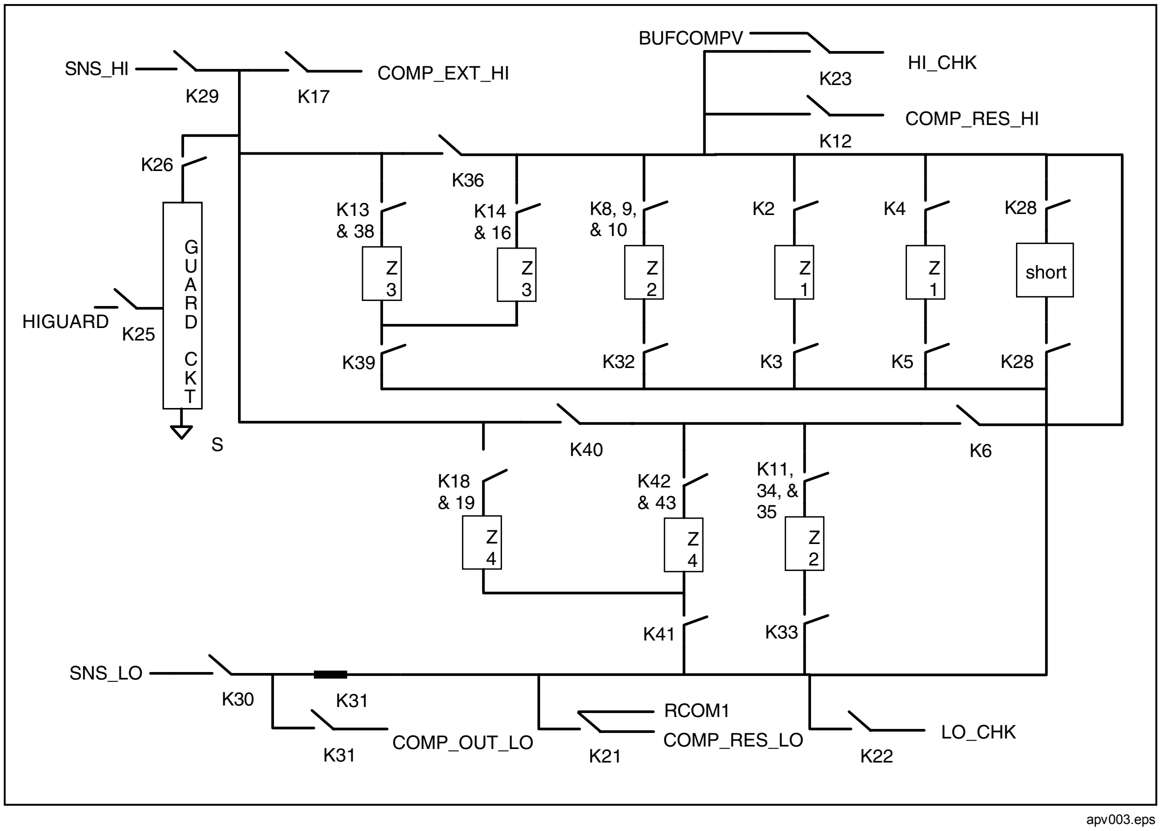

Figure 2-4. A5 Ohms PCA High/Low Sense

Table 2-7 provides a functional description of the relay function for either the set or reset condition on the A5 Ohms PCA. Table 2-8 provides information on the hardware control map for the relays and shows the relay setting for each state. Table 2-9 shows the final relay states by instrument state.

Table 2-7. Functional Description of A5 Ohms PCA Relays

Relay	Functional Description
K1	Reset: Connect OHMS_OUT_LO to SGND Set: Disconnect OHMS_OUT_LO from SGND
K2	Reset: Connect 1.9 Ω Z1 resistance to OHMS_OUT_HI and OHMS_SNS_HI Set: Disconnect 1.9 Ω Z1 resistance from HI
K3	Reset: Connect 1.9 Ω Z1 resistance to OHMS_OUT_LO and OHMS_SNS_LO Set: Disconnect 1.9 Ω Z1 resistance from LO
K4	Reset: Connect 1 Ω Z1 resistance to OHMS_OUT_HI and OHMS_SNS_HI Set: Disconnect 1 Ω Z1 resistance from HI
K5	Reset: Connect 1 Ω Z1 resistance to OHMS_OUT_LO and OHMS_SNS_LO Set: Disconnect 1 Ω Z1 resistance from LO
K6	Reset: Connect 19 Ω through 190 kΩ HI sense bus to OHMS_SNS_HI Set: Disconnect 19 Ω through 190 kΩ HI sense bus from OHMS_SNS_HI
K7	Reset: Connect 10 Ω through 100 kΩ HI source bus to OHMS_OUT_HI Set: Connect 19 Ω through 190 kΩ HI source bus to OHMS_OUT_HI
K8	Reset: Connect 1 kΩ Z2 resistance to OHMS_SNS_HI and 10 Ω through 100 kΩ HI source bus Set: Disconnect 1 kΩ Z2 resistance from HI
K9	Reset: Connect 100 Ω Z2 resistance to OHMS_SNS_HI and 10 Ω through 100 kΩ HI source bus Set: Disconnect 100 Ω Z2 resistance from HI
K10	Reset: Connect 10 Ω Z2 resistance to OHMS_SNS_HI and 10 Ω through 100 kΩ HI source bus Set: Disconnect 10 Ω Z2 resistance from HI
K11	Reset: Connect 1.9 kΩ Z2 resistance to 19 Ω through 190 kΩ HI sense and source buses Set: Disconnect 1.9 kΩ Z2 resistance from HI
K12	Reset: Connect OHMS_OUT_HI to COMP_OUT_HI and OHMS_SNS_HI to COMP_RES_HI Set: Disconnect OHMS_OUT_HI from COMP_OUT_HI and OHMS_SNS_HI from COMP_RES_HI
K13	Reset: Connect 10 MΩ Z3 resistance to HI_OHMS_HI and HI_SNS_HI Set: Disconnect 10 MΩ Z3 resistance from HI
K14	Reset: Connect 100 kΩ Z3 resistance to OHMS_SNS_HI and 10 Ω through 100 kΩ HI source bus Set: Disconnect 100 kΩ Z3 resistance from HI

Table 2-7. Functional Description of A5 Ohms PCA Relays (cont.)

Relay	Functional Description
K15	Reset: Connect 19 Ω through 190 kΩ HI source bus to HI_OHMS_HI Set: Disconnect 19 Ω through 190 kΩ HI source bus from HI_OHMS_HI
K16	Reset: Connect 10 kΩ Z3 resistance to OHMS_SNS_HI and 10 Ω through 100 kΩ HI source bus Set: Disconnect 10 kΩ Z3 resistance from HI
K17	Reset: Connect HI_SNS_HI to COMP_EXT_HI and HI_OHMS_HI to 2-wire comp FGND Set: Disconnect HI_OHMS_HI from FGND and connect COMP_EXT_HI to IZGRD and not to HI_SNS_HI
K18	Reset: Connect 1.9 MΩ Z4 resistance to HI_OHMS_HI and HI_SNS_HI Set: Disconnect 1.9 MΩ Z4 resistance from HI
K19	Reset: Connect 19 MΩ Z4 resistance to HI_OHMS_HI and HI_SNS_HI Set: Disconnect 19 MΩ Z4 resistance from HI
K20	Reset: Connect HI_SRC to OHMS_OUT_HI Set: Disconnect HI_SRC from HI
K21	Reset: Connect OHMS_SNS_LO to COMP_RES_LO Set: Connect COMP_RES_LO to RCOM1 and not to OHMS_SNS_LO
K22	Reset: Connect OHMS_SNS_LO to LO_CHK Set: Disconnect OHMS_SNS_LO from LO_CHK
K23	Reset: Connect OHMS_SNS_HI to HI_CHK Set: Connect BUFHCOMPV to HI_CHK
K24	Reset: Short COMP_EXT_LO to COMP_OUT_LO Set: Remove Short between COMP_EXT_LO and COMP_OUT_LO
K25	Reset: Connect A3 Motherboard PCA HIGUARD to ZGUARD drive Set: Disconnect A3 Motherboard PCA HIGUARD from ZGUARD
K26	Reset: Connect HI_SNS_HI to input of ZGUARD amplifier Set: Disconnect HI_SNS_HI from ZGUARD amplifier input
K27	Reset: Connect 0 Ω resistor (Short) to OHMS_OUT_HI and OHMS_OUT_LO Set: Disconnect 0 Ω from HI and LO source
K28	Reset: Connect 0 Ω resistor (Short) to OHMS_SNS_HI and OHMS_SNS_LO Set: Disconnect 0 Ω from HI and LO sense
K29	Reset: Connect A3 Motherboard PCA OUT_HI to HI_OHMS_HI and motherboard SNS_HI to HI_SNS_HI Set: Disconnect A3 Motherboard PCA OUT_HI and SNS_HI from HI_OHMS_HI and HI_SNS_HI

Table 2-7. Functional Description of A5 Ohms PCA Relays (cont.)

Relay	Functional Description
K30	Reset: Connect A3 Motherboard PCA OUT_LO to LO_OHMS_LO and motherboard SNS_LO to LO_SNS_LO Set: Disconnect A3 Motherboard PCA OUT_LO and SNS_LO from LO_OHMS_LO and LO_SNS_LO
K31	Reset: Connect LO_SNS_LO to OHMS_SNS_LO and LO_OHMS_LO to OHMS_OUT_LO Set: Connect LO_SNS_LO to COMP_EXT_LO and LO_OHMS_LO to COMP_OUT_LO
K32	Reset: Connect 10 Ω, 100 Ω, and 1 kΩ Z2 resistors to OHMS_SNS_LO and OHMS_OUT_LO Set: Disconnect 10 Ω, 100 Ω, and 1 kΩ Z2 resistors from LO
K33	Reset: Connect 19 Ω, 190 Ω, and 1.9 kΩ Z2 resistors to OHMS_SNS_LO and OHMS_OUT_LO Set: Disconnect 19 Ω, 190 Ω, and 1.9 kΩ Z2 resistors from LO
K34	Reset: Connect 19 Ω Z2 resistance to 19 Ω through 190 kΩ HI sense and source buses Set: Disconnect 19 Ω Z2 resistance from HI
K35	Reset: Connect 190 Ω Z2 resistance to 19 Ω through 190 kΩ HI sense and source buses Set: Disconnect 190 Ω Z2 resistance from HI
K36	Reset: Connect OHMS_SNS_HI to HI_SNS_HI Set: Disconnect OHMS_SNS_HI from HI_SNS_HI
K37	Reset: Connect 10 Ω through 100 kΩ HI source bus to HI_OHMS_HI Set: Disconnect 10 Ω through 100 kΩ HI source bus from HI_OHMS_HI
K38	Reset: Connect 1 MΩ Z3 resistance to HI_OHMS_HI and HI_SNS_HI Set: Disconnect 1 MΩ Z3 resistance from HI
K39	Reset: Connect 10 kΩ, 100 kΩ, 1 MΩ, and 10 MΩ Z3 resistors to OHMS_SNS_LO and OHMS_OUT_LO Set: Disconnect 10 kΩ, 100 kΩ, 1 MΩ, and 10 MΩ Z3 resistors from LO
K40	Reset: Connect 19 Ω through 190 kΩ HI sense bus to HI_SNS_HI Set: Disconnect 19 Ω through 190 kΩ HI sense bus from HI_SNS_HI
K41	Reset: Connect 19 kΩ, 190 kΩ, 1.9 MΩ, and 19 MΩ Z4 resistors to OHMS_SNS_LO and OHMS_OUT_LO Set: Disconnect 19 kΩ, 190 kΩ, 1.9 MΩ, and 19 MΩ Z4 resistors from LO
K42	Reset: Connect 19 kΩ Z4 resistance to 19 Ω through 190 kΩ HI sense and source buses Set: Disconnect 19 kΩ Z4 resistance from HI
K43	Reset: Connect 190 kΩ Z4 resistance to 19 Ω through 190 kΩ HI sense and source buses Set: Disconnect 190 kΩ Z4 resistance from HI

Table 2-8. A5 Ohms PCA Power-up Fault Relay States

Relay	State on Power-up or After Fault
K25	Set: Disconnects A3 Motherboard PCA HIGUARD from ZGUARD
K29	Set: Disconnects A3 Motherboard PCA OUT_HI and SNS_HI from HI_OHMS_HI and HI_SNS_HI
K30	Set: Disconnects A3 Motherboard PCA OUT_LO and SNS_LO from LO_OHMS_LO and LO_SNS_LO
K1 to K24	Undefined state (do not care)
K26 to K28	Undefined state (do not care)
K31 to K43	Undefined state (do not care)

Table 2-9. Final Relay States by Instrument State

Relay (Virtual) Register:	ORLY																																
Relay:	-	K8,K11	K13,K19	K14,K43	K15,K40	K36,K37	K6	K7	K16,K42	K18,K38	K10,K34	K9,K35	K4,K5	K2,K3	K26	K27,K28	K41	K39	K33	K32	K24	K22	K23	K20	K12	K31	K21	K17	K30	K1	K25	K29	
Inst. State \ Bit Weight:	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	**Hex**
Power Up	x	s	s	s	s	s	s	r	s	s	s	s	s	s	s	s	s	s	s	s	r	s	s	s	s	r	s	s	s	s	s	s	7eff f7bf
Dormant	x	s	s	s	s	s	s	r	s	s	s	s	s	s	s	s	s	s	s	s	r	s	s	s	s	r	s	s	s	s	s	s	7eff f7bf
Short, 4 Wire	x	s	s	s	s	r	s	r	s	s	s	s	s	s	r	r	s	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	7afc f7b0
Short, 4 Wire, STBY	x	s	s	s	s	r	s	r	s	s	s	s	s	s	r	r	s	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	7afc f7bb
1 Ω, 4 Wire	x	s	s	s	s	r	s	r	s	s	s	s	r	s	r	s	s	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	7af5 f7b0
1 Ω, 4 Wire, STBY	x	s	s	s	s	r	s	r	s	s	s	s	r	s	r	s	s	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	7af5 f7bb
1.9 Ω, 4 Wire	x	s	s	s	s	r	s	r	s	s	s	s	s	r	r	s	s	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	7af9 f7b0
1.9 Ω, 4 Wire, STBY	x	s	s	s	s	r	s	r	s	s	s	s	s	r	r	s	s	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	7af9 f7bb
10 Ω, 4 Wire	x	s	s	s	s	r	s	r	s	s	r	s	s	s	r	s	s	s	s	r	r	s	s	s	s	r	s	s	r	r	r	r	7add e7b0
10 Ω, 4 Wire, STBY	x	s	s	s	s	r	s	r	s	s	r	s	s	s	r	s	s	s	s	r	r	s	s	s	s	r	s	s	s	r	s	s	7add e7bb
19 Ω, 4 Wire	x	s	s	s	r	s	s	r	s	s	r	s	s	s	r	s	s	s	r	s	r	s	s	s	s	r	s	s	r	r	r	r	76dd d7b0
19 Ω, 4 Wire, STBY	x	s	s	s	r	s	s	r	s	s	r	s	s	s	r	s	s	s	r	s	r	s	s	s	s	r	s	s	s	r	s	s	76dd d7bb
100 Ω, 4 Wire	x	s	s	s	s	r	s	r	s	s	s	r	s	s	r	s	s	s	s	r	r	s	s	s	s	r	s	s	r	r	r	r	7aed e7b0
100 Ω, 4 Wire, STBY	x	s	s	s	s	r	s	r	s	s	s	r	s	s	r	s	s	s	s	r	r	s	s	s	s	r	s	s	s	r	s	s	7aed e7bb
190 Ω, 4 Wire	x	s	s	s	r	s	s	r	s	s	s	r	s	s	r	s	s	s	r	s	r	s	s	s	s	r	s	s	r	r	r	r	76ed d7b0
190 Ω, 4 Wire, STBY	x	s	s	s	r	s	s	r	s	s	s	r	s	s	r	s	s	s	r	s	r	s	s	s	s	r	s	s	s	r	s	s	76ed d7bb
1 kΩ, 4 Wire	x	r	s	s	s	r	s	r	s	s	s	s	s	s	r	s	s	s	s	r	r	s	s	s	s	r	s	s	r	r	r	r	3afd e7b0
1 kΩ, 4 Wire, STBY	x	r	s	s	s	r	s	r	s	s	s	s	s	s	r	s	s	s	s	r	r	s	s	s	s	r	s	s	s	r	s	s	3afd e7bb

Table 2-9. Final Relay States by Instrument State (cont.)

Relay (Virtual) Register:	ORLY																																
Relay:	-	K8,K11	K13,K19	K14,K43	K15,K40	K36,K37	K6	K7	K16,K42	K18,K38	K10,K34	K9,K35	K4,K5	K2,K3	K26	K27,K28	K41	K39	K33	K32	K24	K22	K23	K20	K12	K31	K21	K17	K30	K1	K25	K29	
Inst. State \ Bit Weight:	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	**Hex**
1.9 kΩ, 4 Wire	x	r	s	s	r	s	s	r	s	s	s	s	s	s	r	s	s	s	r	s	r	s	s	s	s	r	s	s	r	r	r	r	36fd d7b0
1.9 kΩ, 4 Wire, STBY	x	r	s	s	r	s	s	r	s	s	s	s	s	s	r	s	s	s	r	s	r	s	s	s	s	r	s	s	s	r	s	s	36fd d7bb
10 kΩ, 4 Wire	x	s	s	s	s	r	s	r	r	s	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	r	r	r	r	7a7d b7b0
10 kΩ, 4 Wire, STBY	x	s	s	s	s	r	s	r	r	s	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	s	r	s	s	7a7d b7bb
19 kΩ, 4 Wire	x	s	s	s	r	s	s	r	r	s	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	767d 77b0
19 kΩ, 4 Wire, STBY	x	s	s	s	r	s	s	r	r	s	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	767d 77bb
100 kΩ, 4 Wire	x	s	s	r	s	r	s	r	s	s	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	r	r	r	r	6afd b7b0
100 kΩ, 4 Wire, STBY	x	s	s	r	s	r	s	r	s	s	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	s	r	s	s	6afd b7bb
190 kΩ, 4 Wire	x	s	s	r	r	s	s	r	s	s	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	66fd 77b0
190 kΩ, 4 Wire, STBY	x	s	s	r	r	s	s	r	s	s	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	66fd 77bb
1 MΩ, 4 Wire	x	s	s	s	s	s	s	r	s	r	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	r	r	r	r	7ebd b7b0
1 MΩ, 4 Wire, STBY	x	s	s	s	s	s	s	r	s	r	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	s	r	s	s	7ebd b7bb
1.9 MΩ, 4 Wire	x	s	s	s	s	s	s	r	s	r	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	7ebd 77b0
1.9 MΩ, 4 Wire, STBY	x	s	s	s	s	s	s	r	s	r	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	7ebd 77bb
10 MΩ, 4 Wire	x	s	r	s	s	s	s	r	s	s	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	r	r	r	r	5efd b7b0
10 MΩ, 4 Wire, STBY	x	s	r	s	s	s	s	r	s	s	s	s	s	s	r	s	s	r	s	s	r	s	s	s	s	r	s	s	s	r	s	s	5efd b7bb
19 MΩ, 4 Wire	x	s	r	s	s	s	s	r	s	s	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	r	r	r	r	5efd 77b0
19 MΩ, 4 Wire, STBY	x	s	r	s	s	s	s	r	s	s	s	s	s	s	r	s	r	s	s	s	r	s	s	s	s	r	s	s	s	r	s	s	5efd 77bb

Table 2-9. Final Relay States by Instrument State (cont.)

Relay (Virtual) Register:	ORLY																																
Relay:	-	K8,K11	K13,K19	K14,K43	K15,K40	K36,K37	K6	K7	K16,K42	K18,K38	K10,K34	K9,K35	K4,K5	K2,K3	K26	K27,K28	K41	K39	K33	K32	K24	K22	K23	K20	K12	K31	K21	K17	K30	K1	K25	K29	
Inst. State \ Bit Weight:	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	**Hex**
Short, 2W Comp, STBY	x	s	s	s	s	s	s	r	s	s	s	s	s	s	r	r	s	s	s	s	s	s	s	s	r	s	r	r	s	r	s	s	7efc ff4b
1 Ω, 2W Comp	x	s	s	s	s	s	s	r	s	s	s	s	r	s	r	s	s	s	s	s	s	s	s	s	r	s	r	r	r	r	r	r	7ef5 ff40
1 Ω, 2W Comp, STBY	x	s	s	s	s	s	s	r	s	s	s	s	r	s	r	s	s	s	s	s	s	s	s	s	r	s	r	r	s	r	s	s	7ef5 ff4b
1.9 Ω, 2W Comp	x	s	s	s	s	s	s	r	s	s	s	s	s	r	r	s	s	s	s	s	s	s	s	s	r	s	r	r	r	r	r	r	7ef9 ff40
1.9 Ω, 2W Comp, STBY	x	s	s	s	s	s	s	r	s	s	s	s	s	r	r	s	s	s	s	s	s	s	s	s	r	s	r	r	s	r	s	s	7ef9 ff4b
10 Ω, 2W Comp	x	s	s	s	s	s	s	r	s	s	r	s	s	s	r	s	s	s	s	r	s	s	s	s	r	s	r	r	r	r	r	r	7edd ef40
10 Ω, 2W Comp, STBY	x	s	s	s	s	s	s	r	s	s	r	s	s	s	r	s	s	s	s	r	s	s	s	s	r	s	r	r	s	r	s	s	7edd ef4b
19 Ω, 2W Comp	x	s	s	s	s	s	r	s	s	s	r	s	s	s	r	s	s	s	r	s	s	s	s	s	r	s	r	r	r	r	r	r	7ddd df40
19 Ω, 2W Comp, STBY	x	s	s	s	s	s	r	s	s	s	r	s	s	s	r	s	s	s	r	s	s	s	s	s	r	s	r	r	s	r	s	s	7ddd df4b
100 Ω, 2W Comp	x	s	s	s	s	s	s	r	s	s	s	r	s	s	r	s	s	s	s	r	s	s	s	s	r	s	r	r	r	r	r	r	7eed ef40
100 Ω, 2W Comp, STBY	x	s	s	s	s	s	s	r	s	s	s	r	s	s	r	s	s	s	s	r	s	s	s	s	r	s	r	r	s	r	s	s	7eed ef4b
190 Ω, 2W Comp	x	s	s	s	s	s	r	s	s	s	s	r	s	s	r	s	s	s	r	s	s	s	s	s	r	s	r	r	r	r	r	r	7ded df40
190 Ω, 2W Comp, STBY	x	s	s	s	s	s	r	s	s	s	s	r	s	s	r	s	s	s	r	s	s	s	s	s	r	s	r	r	s	r	s	s	7ded df4b
1 kΩ, 2W Comp	x	r	s	s	s	s	s	r	s	s	s	s	s	s	r	s	s	s	s	r	s	s	s	s	r	s	r	r	r	r	r	r	3efd ef40
1 kΩ, 2W Comp, STBY	x	r	s	s	s	s	s	r	s	s	s	s	s	s	r	s	s	s	s	r	s	s	s	s	r	s	r	r	s	r	s	s	3efd ef4b
1.9 kΩ, 2W Comp	x	r	s	s	s	s	r	s	s	s	s	s	s	s	r	s	s	s	r	s	s	s	s	s	r	s	r	r	r	r	r	r	3dfd df40
1.9 kΩ, 2W Comp, STBY	x	r	s	s	s	s	r	s	s	s	s	s	s	s	r	s	s	s	r	s	s	s	s	s	r	s	r	r	s	r	s	s	3dfd df4b
10 kΩ, 2W Comp	x	s	s	s	s	s	s	r	r	s	s	s	s	s	r	s	s	r	s	s	s	s	s	s	r	s	r	r	r	r	r	r	7e7d bf40
10 kΩ, 2W Comp, STBY	x	s	s	s	s	s	s	r	r	s	s	s	s	s	r	s	s	r	s	s	s	s	s	s	r	s	r	r	s	r	s	s	7e7d bf4b

Table 2-9. Final Relay States by Instrument State (cont.)

Relay (Virtual) Register:	ORLY																																
Relay:	-	K8,K11	K13,K19	K14,K43	K15,K40	K36,K37	K6	K7	K16,K42	K18,K38	K10,K34	K9,K35	K4,K5	K2,K3	K26	K27,K28	K41	K39	K33	K32	K24	K22	K23	K20	K12	K31	K21	K17	K30	K1	K25	K29	
Inst. State \ Bit Weight:	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	**Hex**
19 kΩ, 2W Comp	x	s	s	s	s	s	r	s	r	s	s	s	s	s	r	s	r	s	s	s	s	s	s	s	r	s	r	r	r	r	r	r	7d7d 7f40
19 kΩ, 2W Comp, STBY	x	s	s	s	s	s	r	s	r	s	s	s	s	s	r	s	r	s	s	s	s	s	s	s	r	s	r	r	s	r	s	s	7d7d 7f4b
100 kΩ, 2W Comp	x	s	s	r	s	s	s	r	s	s	s	s	s	s	r	s	s	r	s	s	s	s	s	s	r	s	r	r	r	r	r	r	6efd bf40
100 kΩ, 2W Comp, STBY	x	s	s	r	s	s	s	r	s	s	s	s	s	s	r	s	s	r	s	s	s	s	s	s	r	s	r	r	s	r	s	s	6efd bf4b
190 kΩ, 2W Comp	x	s	s	r	s	s	r	s	s	s	s	s	s	s	r	s	r	s	s	s	s	s	s	s	r	s	r	r	r	r	r	r	6dfd 7f40
190 kΩ, 2W Comp, STBY	x	s	s	r	s	s	r	s	s	s	s	s	s	s	r	s	r	s	s	s	s	s	s	s	r	s	r	r	s	r	s	s	6dfd 7f4b
DIAG, 19 Ω, 4 Wire	x	s	s	s	r	s	r	s	s	s	r	s	s	s	r	s	s	s	r	s	r	r	r	r	s	r	s	s	s	r	s	s	75dd d0bb
DIAG, 190 Ω, 4 Wire	x	s	s	s	r	s	r	s	s	s	s	r	s	s	r	s	s	s	r	s	r	r	r	r	s	r	s	s	s	r	s	s	75ed d0bb
DIAG, 1.9 kΩ, 4 Wire	x	r	s	s	r	s	r	s	s	s	s	s	s	s	r	s	s	s	r	s	r	r	r	r	s	r	s	s	s	r	s	s	35fd d0bb
DIAG, 19 kΩ, 4 Wire	x	s	s	s	r	s	r	s	r	s	s	s	s	s	r	s	r	s	s	s	r	r	r	r	s	r	s	s	s	r	s	s	757d 70bb
DIAG, 190 kΩ, 4 Wire	x	s	s	r	r	s	r	s	s	s	s	s	s	s	r	s	r	s	s	s	r	r	r	r	s	r	s	s	s	r	s	s	65fd 70bb
DIAG, 1 MΩ, 4 Wire	x	s	s	s	s	r	s	r	s	r	s	s	s	s	r	s	s	r	s	s	r	r	r	r	s	r	s	s	s	r	s	s	7abd b0bb
DIAG, 1.9 MΩ, 4 Wire	x	s	s	s	r	s	r	s	s	r	s	s	s	s	r	s	r	s	s	s	r	r	r	r	s	r	s	s	s	r	s	s	75bd 70bb
DIAG, 10 MΩ, 4 Wire	x	s	r	s	s	r	s	r	s	s	s	s	s	s	r	s	s	r	s	s	r	r	r	r	s	r	s	s	s	r	s	s	5afd b0bb
DIAG, 19 MΩ, 4 Wire	x	s	r	s	r	s	r	s	s	s	s	s	s	s	r	s	r	s	s	s	r	r	r	r	s	r	s	s	s	r	s	s	55fd 70bb
DIAG, Any Ω, 2/4 W, Measure Ivref, LO, HI, or Vcompl (use mod mask 00000700h)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	r	r	x	x	x	x	x	x	x	x	0000 0000
DIAG, Any Ω, 2/4 W, Connect Guard Amp and measure Vcompl (use mod mask 00020000h)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0000 0000

Table 2-9. Final Relay States by Instrument State (cont.)

Relay (Virtual) Register:	ORLY																																
Relay:	-	K8,K11	K13,K19	K14,K43	K15,K40	K36,K37	K6	K7	K16,K42	K18,K38	K10,K34	K9,K35	K4,K5	K2,K3	K26	K27,K28	K41	K39	K33	K32	K24	K22	K23	K20	K12	K31	K21	K17	K30	K1	K25	K29	
Inst. State \ Bit Weight:	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	**Hex**
LO Comp, V (dc, ac)	x	s	s	s	s	s	s	r	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	r	s	s	s	7eff fff7

Key: x = don't care, r = reset, s = set

Notes

- When sourcing a resistance, K25, K29, and K30 are reset after all other relays have been put into position.
- When entering STBY, K25, K29, and K30 are set first.
- Four Wire and two Wire (No Comp) use the same ORLY values. 4 Wire uses Remote Sense and 2 Wire (No Comp) uses Internal Sense, as selected by a Motherboard relay.
- Two wire comp works only to 190 K.

Other Control Circuits

Other controls on the A5 Ohms PCA are used for selecting a number of different parameters. Table 2-10 lists the name of the other control signals and provides a functional description. The control signals are driven by U39 and U35 as shown on Sheet 4 of the A5 Ohms PCA schematic.

Table 2-10. Functional Description of Signals

Signal	Functional Description
ENCOMPFAULT*	Connects the divided and buffered SNS_HI compliance voltage to the circuit that will pull down the INS-HI line if the voltage exceeds +/-33.5 V when asserted Low.
CKEXTRA*	Not used.
CKCOMPV*	Connects the divided and buffered SNS_HI voltage to the SMUX line when asserted Low.
CKLO*	Connects the LO_CHK output from relay K22 to the SMUX line when asserted Low.
CKHI*	Connects the HI_CHK output from relay K23 to the SMUX line when asserted Low.
CKIVREF*	Connects the IVREF voltage to the SMUX line when asserted Low.
INRCOM*	Connects the RCOM1 line to the IVREF ground reference buffer when asserted Low.
INIVREF*	Connects the I_ACDC and the IFBCK lines to the IVREF control amplifier when asserted Low.
ZIVREF*	Selects 0 V to the IVREF control amplifier when asserted low to select zero output current. ZIVREF* should only be asserted when INIVREF* is de-asserted.
ISELHNA*	Selects the Hundreds of nano-Amp current source output when asserted Low.
ISELUA*	Selects the Micro-Amp current source output when asserted Low.
ISELTUA*	Selects the Tens of Micro-Amp current source output when asserted Low.
ISELHUA*	Selects the Hundreds of Micro-Amp current source output when asserted Low.
ISELMA*	Selects the Milli-Amp current source output when asserted Low. This is the normal default ISEL line. Only one of the ISEL lines is normally asserted at one time.

Guard Circuits

The U40 guard amplifier circuit drives IZGRD, ZGUARD, and also HIGUARD (see A3 Motherboard PCA pins A29 and C29) whenever the instrument is put in Operate for ohms. IZGRD also drives the shield to T1 shown on Sheet 2 of the A5 Ohms PCA schematics. Since HIGUARD is connected to the I-GUARD terminal, the guard amp drives that terminal plus whatever is connected to it as well. In Standby, HIGUARD is not driven. For volts, HIGUARD is shorted to GUARD, so that output terminal I-GUARD is connected to and driven by V-GUARD. The circuitry around U40, including, Q6, R58-61, VR3, C93, VR4, and K46 provide capacitive load compensation and regulate the 45 V supply from the A3 Motherboard PCA to about +/-6 V referenced to SNS.HI.

Compensation Circuits

In addition to four-wire ohms and two-wire ohms, the user can also select to have two-wire compensated ohms where amplifiers and floating supplies are used to negate most of the effects of path loss associated with a two terminal resistance measurement instrument. Sheet 2 contains the compensation circuits for the HI and LO paths. HI compensation (COMP_OUT_HI) is controlled by U19 with inputs from either the internal resistance (COMP_RES_HI) and the external HI (COMP_EXT_HI). U20 provides the drive capability. Similarly, U17 and U41 control the low compensation output (COMP_OUT_LO). Relay K24 shorts the low compensation current inputs when not in use. The maximum output compensation current exceeds 100 mA. The low compensation circuit is referenced to SCOM while the high compensation circuit is referenced to FCOM. The 2 Wire Comp sense, either internal or remote, is selected by a A3 Motherboard PCA relay.

The floating power supply used to power the HI compensation circuit is also shown on Sheet 2 of the A5 Ohms PCA schematic. The floating +3.75/-5 V power supply is generated by transformer T1, full wave rectifier bridge CR4, and a number of 1000 uF capacitors, as regulated by Q1, Q2, U24 and associated components. VR1 along with the R23/ R20 resistor divider set the positive regulator output. VR1 along with R30, R18, R16, and R19 set the negative regulator output.

Monitor

The embedded software continually monitors specific hardware aspects when in operate. In ohms, monitoring protects the instrument from damage and particularly the high-performance Fluke resistor networks from damage. This is accomplished by checking the compliance voltage against the appropriate limit on a regular basis. Short-term overloads below the hardware trip threshold will be allowed, while longer-period over-compliance voltages will cause the instrument to go to Standby.

Whenever sourcing a resistance:

- ENCOMPFAULT* line will be asserted so that excessive compliance voltages (above +-33 V) will quickly cause the hardware to trip out the instrument.
- The compliance voltage is measured regularly using the SMUX line when in Operate. The absolute value of the measurement is internally compared with the SMUX limit given in Table 2-12 for the appropriate resistance output. If too many consecutive measurements exceed the limit, meaning the compliance voltage has been too high for over 2.5 seconds, then the software will generate an over-compliance error and put the instrument into Standby.

Table 2-11. Compliance Voltage Thresholds

Output Resistance	Max Vcompliance V dc	Max BUFHCOMPV V dc	SMUX Limit V dc
0 Ω	0	0	0.010
1.0 Ω	0.14	0.047	0.05
1.9 Ω	0.28	0.093	0.10
10 Ω	0.14	0.047	0.05
19 Ω	0.28	0.093	0.10
100 Ω	1.41	0.47	0.5
190 Ω	2.83	0.94	1.00
1.0 kΩ	2.83	0.94	1.00
1.9 kΩ	4.24	1.413	1.50
10 kΩ	14.14	4.714	5.00
19 kΩ	7.07	2.357	5.00
100 kΩ	14.14	4.714	5.00
190 kΩ	14.14	4.714	10.0
1.0 MΩ	28.28	9.427	10.0
1.9 MΩ	28.28	9.427	10.0
10 MΩ	28.28	9.427	10.0
19 MΩ	28.28	9.427	10.0

Diagnostics

Diagnostics which may be executed as a remote command, check that the relays are working, and that each of the resistances is close to its calibrated value. If problems are found, an error message is printed. The error messages can be found in Appendix A of the *57LFC/AN Operators Manual*. Table 2-12 lists a few of the relay settings after a power up.

Ohms diagnostics work as follows for each resistance in turn:

- Sets the relays (see Table 2-8, ORLY) to the DIAG state for the resistance desired.
- Set the OTEST register for the test current desired based on Table 2-14.
- Set the I_ACDC DDS output voltage to be that for the proper test current shown in the Table 2-14.
- Set the OCHK register (see Table 2-13) to the DIAG state for measuring Ivref, and measure the SMUX line.
- Next, set the OCHK register to the DIAG state for measuring LO, and measure the SMUX line. This reading should be less than the limit given in the Table 2-14. If not, there is likely a relay or resistor problem. Save this reading for subtracting from the following HI measurement.
- Next, set the OCHK register to the DIAG state for measuring HI, and measure the SMUX line. Subtract the LO reading, divide by the Ichk current, and compare the resistance with the calibration value. The difference should a couple percent. If the difference is too large, there’s likely a relay, resistance, or diagnostic circuit problem.

Table 2-12. OTEST Register States by Instrument State

Control Register:	OTEST								
Signal:	**ISEL-MA***	**ISEL-HUA***	**ISEL-TUA***	**ISEL-UA***	**ISEL-HNA***	**ZIVREF***	**IN-IVREF***	**IN-RCOM***	
Instrument State \ Bit Weight:	8	4	2	1	8	4	2	1	**Hex**
Dormant	L	h	h	h	h	L	h	h	7b
Any non-Ω function	L	h	h	h	h	L	h	h	7b
Any Ω, 2/4 W, Oper or STBY or Measure Vcompl	L	h	h	h	h	L	h	h	7b
DIAG, 1.5 to 3.3 mA Ichk	L	h	h	h	h	h	L	L	7c
DIAG, 150 to-330 µA Ichk	h	L	h	h	h	h	L	L	bc
DIAG, 15 to 33 µA Ichk	h	h	L	h	h	h	L	L	dc
DIAG, 1.5 to 3.3 µA Ichk	h	h	h	L	h	h	L	L	ec
DIAG, 150 to 330 nA Ichk	h	h	h	h	L	h	L	L	f4
Key: x = don't care, h = high (off, de-asserted), L = low (on, asserted)									

Table 2-13. OCHK Register States by Instrument State

Control Register:	OCHK								
Signal:	-	-	CK-IVREF*	CKHI*	CKLO*	CK-COMP-V*	CK-EXTRA*	EN-COMP-FAULT*	
Instrument State \ Bit Weight:	**8**	**4**	**2**	**1**	**8**	**4**	**2**	**1**	**Hex**
Dormant	x	x	h	h	h	h	h	h	3f
Any non-Ω function	x	x	h	h	h	h	h	h	3f
Any Ω, 2/4 W	x	x	h	h	h	h	h	L	3e
Any Ω, 2/4 W, STBY	x	x	h	h	h	h	h	h	3f
Any Ω, 2/4 W, Measure Vcompl	x	x	h	h	h	L	h	L	3a
DIAG, Any Ω, Measure Ivref	x	x	L	h	h	h	h	h	1f

Table 2-13. OCHK Register States by Instrument State (cont.)

Control Register:	**OCHK**								
Signal:	**-**	**-**	**CK-IVREF***	**CKHI***	**CKLO***	**CK-COMP-V***	**CK-EXTRA***	**EN-COMP-FAULT***	
Instrument State \ Bit Weight:	**8**	**4**	**2**	**1**	**8**	**4**	**2**	**1**	**Hex**
DIAG, Any Ω, Measure LO	x	x	h	h	L	h	h	h	37
DIAG, Any Ω, Measure HI	x	x	h	L	h	h	h	h	2f
DIAG, Any Ω, Measure Vcompl	x	x	h	h	h	L	h	h	3b

Key: x = don't care, h = high (off, de-asserted), L = low (on, asserted)

Notes:

- Only one of the CKx lines can be asserted low at a time to switch a signal onto the SMUX line for measurement

Table 2-14. Diagnostic Values by Instrument State

Instrument State	Ichk Test Current	IDAC (X2) Vdc	OTES T Reg Hex	Ivref SMUX Vdc	LO Limit SMUX Vdc	Nominal HI SMUX Vdc
Dormant	0 mA	-	7b	-	-	-
Any non-Ω function	0 mA	-	7b	-	-	-
Any Ω, 2/4 W, Oper or STBY or Monitor Comp or Msr Vcompl	0 mA	-	7b	-	-	-
DIAG, 0 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	<.0017
DIAG, 1 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	0.003
DIAG, 1.9 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	0.0057
DIAG, 10 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	0.030
DIAG, 19 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	0.057
DIAG, 100 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	0.300
DIAG, 190 Ω, Check Ivref, LO, or HI	3 mA	6.0	7c	3.000	0.001	0.570
DIAG, 1 kΩ, Check Ivref, LO, or HI	2 mA	4.0	7c	2.000	0.001	2.00
DIAG, 1.9 kΩ, Check Ivref, LO, or HI	2 mA	240	7c	2.000	0.001	3.80
DIAG, 10 kΩ, Check Ivref, LO, or HI	0.2 mA	4.0	bc	2.000	0.0001	2.00
DIAG, 19 kΩ, Check Ivref, LO, or HI	0.2 mA	4.0	bc	2.000	0.0001	3.80
DIAG, 100 kΩ, Check Ivref, LO, or HI	20 µA	4.0	dc	2.000	0.0001	2.00
DIAG, 190 kΩ, Check Ivref, LO, or HI	20 µA	4.0	dc	2.000	0.0001	3.80
DIAG, 1 MΩ, Check Ivref, LO, or HI	3 µA	6.0	ec	3.000	0.0001	3.00
DIAG, 1.9 MΩ, Check Ivref, LO, or HI	3 µA	6.0	ec	3.000	0.0001	5.70
DIAG, 10 MΩ, Check Ivref, LO, or HI	300 nA	6.0	f4	3.000	0.0001	3.00
DIAG, 19 MΩ, Check Ivref, LO, or HI	300 nA	6.0	f4	3.000	0.0001	5.70

Key: - = doesn't apply

Notes:

1. +-30 mV, +-300 mV, +-12 V full-scale can be measured on the SMUX line.
2. 0 to +/-3.3 V is the range of voltages that can be output on I_ACDC.

A6 Digital Synthesis PCA

The A6 Digital Synthesis PCA contains the following functional blocks:

- Precision, dual tracking, +/-7 V references
- Two precision, 28 bit, pulse width modulated, digital to analog converters (DAC's)
- A 500 kHz, dual channel, variable phase, arbitrary waveform generator
- A 3.3 V, AC/DC output amplifier
- A 33 mV/330 mV, 50 Ω output attenuator
- A 0.33 V – 1000 V sense divider and buffer amplifier
- Two ac/dc averaging converters
- Two amplitude control loops, for dual channel operation
- An 18 bit analog to digital (A/D) converter with input mux and variable gain amplifier
- A thermocouple based temperature sourcing and measuring circuit
- Digital control circuitry consisting of octal latches, relay drivers, and a high speed serial link to the main CPU.

These functional blocks, when used with the A8 High Voltage PCA, and/or A7 Current PCA, provide single or dual channel ac/dc V/A/W, offset table and nonsinusoidal waveforms, duty cycle, temperature measuring and sourcing, internal calibration and diagnostics, and digital control over all the analog assemblies. A brief description of each block is described below.

Precision, Dual Tracking, +/-7 V References

Refer to Sheet 2 of the A6 Digital Synthesis PCA schematic.

The reference circuit is based on the ref amp set used in the 8842A. Reference amplifier, Q1, and op amp, U38, along with Z3 and Z4 generate a trimmed -7 V reference. This reference is inverted by a flying capacitor inverter circuit consisting of U76, C60 and C74, and buffered by U27. Each reference is also buffered by a discrete output stage; Q4 & Q5.

Precision, 28bit, PWM, Dual DAC's

Refer to Sheet 2 of the A6 Digital Synthesis PCA schematic.

Since the two precision DAC's are identical, only the voltage channel DAC will be described. This DAC design uses pulse width modulation (PWM) to convert a digital value to a precise analog voltage. The duty cycle is generated by programmable counter logic contained in an FPGA, U5. The counters are 14 bit binary, operating off of the 10Mhz clock, generating a variable duty factor pulse train at a frequency of 610.3515Hz. The duty cycle has a resolution of 1 part in 16384 (14bits).

This variable duty cycle is complemented and deskewed by a D flip flop and outputted from the FPGA as DAC1PREF and DAC1NREF, driving the gate pins of a quad analog switch, U45. U45 alternately connects the input of the DAC filter, Z10, to the +/-7 V references. The output of this filter which consists of Z10, R75,R76, U28, and C76-78, will have a voltage equal to the average value of the voltage at its input.

VDC = (D-.5)*14

and
D = N/16384 where N is the value that the timer is programmed to.

U52 and Z10 are used to cancel the resistance of U45, while U58 and Z2 buffer the output and divide it by two.

To obtain an additional 14bits of resolution, another PWM channel is generated and output at U18-12. This signal is inverted by U19A, divided by R70, R72, and R73, and summed into the filter at C76.

DC Voltage Operation

Refer to Sheet 3 of the A6 Digital Synthesis PCA schematic.

In the 3.3 V dc range the VDAC output from Z2 is applied to the non-inverting input of the control loop integrator, U60. The output of U60 is inverted by U87B and is buffered by the 3.3 V output amp, U42, and switched to VMID by K8. VMID is switched to the instrument output by the A3 Motherboard PCA relay A3-K3. This output is sensed by NSNS_HI and switched to VDIV by A3-K2. VDIV is applied to the sense divider, Z5, by K3. The composite sense amplifier, U57 and U21, invert the sense signal which is then applied to the inverting input of U60. The net result is an instrument output dc voltage that is equal to -VDAC.

The 33 V dc range operates in a similar way, except the inverting amp, U87B, is bypassed by switch U48D and the output of U42 is amplified and inverted by the A8 High. The output of the A8 High Voltage PCA is applied to VMID and the 33 V sense input is selected by K2.

The 330 m V dc range does not use the sense divider/amplifier, but instead receives its feedback through analog switch U15A. U87B is bypassed in this range so there is no inversion in this mode of operation. The output of U42 is then divided by 10 by Z8, with the output of Z8 connected to VMID by K7.

The 330 V dc and 1000 V dc ranges are generated by rectifying a high voltage ac signal. First the output of U25, a DDS generated 2kHz square wave, is switched to the input of U42 by switch U48C. This square wave is amplified, stepped up, rectified and filtered by the A8 High Voltage PCA to approximately the desired dc voltage. This dc voltage is then connected to VDIV for connection to the instrument output and for sensing. In the case of the 330 V range, VDIV is connected to the sense divider/amplifier by K1. In the 1000 V range, U98 is used to invert the signal on VDIV. This divided voltage is applied to U60, which generates an error signal. This error signal is fed back to U49 (Sheet 1 of the A6 Digital Synthesis PCA schematic) for inversion and amplification before being applied to the multiplying reference pin of the DDS waveform generation DAC, U13. The voltage at this pin controls the amplitude of the ac square wave, thus adjusting the dc voltage to exactly the desired value.

DDS Waveform Generation

Refer to Sheets 1 and 8 of the A6 Digital Synthesis PCA schematic.

Direct digital synthesis was first used at Fluke in the modulation oscillator of the 6080A synthesized signal generator. It uses a high speed waveform reconstruction DAC, digital phase accumulator, and a waveform lookup table to generate repetitive ac signals of arbitrary waveform. A modified and improved circuit, based on the same technique is contained in the FPGA, U5. The DDS circuit uses a 40 phase accumulator and uses SRAM, U1 to store the wave tables. Each memory location in the SRAM wave table corresponds to a phase. The value of each location in the wave table is the instantaneous amplitude value of the waveform for that particular phase. As the phase accumulator sequences through address locations the amplitude data is routed to the 16 bit DDS DAC's (U13, U44) where, point by point, the waveform is generated.

The FPGA splits the addresses into two channels where the address of the secondary channel can be offset from the first, thereby causing a phase difference between the two. It also provides logic for writing the waveform data to the table.

The differential output current of the primary DDS DAC (U13) is converted to a voltage of about 9.7 V p-p by R41,R47 and U4. It is then filtered to remove glitches and clock feed thru and adjusted in amplitude by the scaling DAC, U53 & U25. This voltage can be further adjusted by adjusting the current flowing into U13's IREFIN pin. This is done by amplifying the control loop error voltage by an amount inversely proportional the scaling DAC's attenuation and applying it through R11 to the U13 pin 24.

The secondary DDS channel works in a similar way.

AC Voltage Operation

Refer to Sheet 3 of the A6 Digital Synthesis PCA schematic.

The output of the primary DDS channel is routed to the 3.3 V output amplifier, U42, through switch U48. This amplified/divided, outputted and sensed the same as for V dc except instead of the sense amplifier output being applied to the loop integrator, it is first converted to a dc voltage by an average responding ac/dc converter, U40, U20, Q2, Q3, CR5, U39. This dc voltage is filtered and buffered by U84 and U3, and switched into the loop integrator by U15. As in dc the loop integrator reference pin has the VDAC signal on it. The difference between the VDAC and the output of the averaging converter is integrated and applied to the DDS DAC IREFIN pin. This adjusts the output voltage of the DDS DAC, U13, until the difference is zero.

DC Current Operation

Refer to Sheets 2 and 4 of the A6 Digital Synthesis PCA schematic.

In all the dc current ranges the IDAC output from Z1 is applied to the noninverting input of the control loop integrator, U9. The output of U9 is switched to I_AC/DC by U33A. This signal is converted to a high impedance current source by the transconductance amplifier on the A7 Current PCA. This current is routed to the AUX HI output and flows through the UUT, returning into AUX LO terminal. It then passes through a shunt on the A7 Current PCA, converting it back into a voltage, I_FBK. I_FBK is switched to the inverting input of U9 by U31, which integrates the difference between its two inputs, forcing them to be equal.

AC Current Operation

In all the ac current ranges, the second DDS channel from U34 is switched to I_ACDC by U33C. This signal is converted to a current, outputted, and fed back on I_FBK the same way as for dc currents. In AC, I_FBK is switched to the input of U14B where it is rectified and filtered by U14A, CR1, U84A and U3 before it is switched into the negative input of the error integrator, U9. U9 integrates the difference between this feedback signal and the IDAC output, generating an error signal. This error signal is amplified by the loop compensation DAC, U47, and U90 and then routed to the reference pin of the DDS waveform DAC, U44, adjusting the output until the difference between the inputs of U9 is zero.

Thermocouple Temperature Measurement

Thermocouples consist of a pair of wires that are each made of different metals or alloys. On one end of this pair, the wires are electrically connected to each other. The other end is terminated to copper contacts fastened to an isothermal block. The voltage produced at the iso-thermal block is a function of the thermocouple type and the temperature difference between the iso-thermal block and the end of the wire pair. Thus, to measure the temperature of a thermocouple, its voltage, and the temperature of the iso-thermal block must be measured.

Iso-thermal Block Reference Junction Temperature Measurement

Refer to Sheet 5 of the A6 Digital Synthesis PCA schematic.

The iso-thermal block contains two copper buttons to connect to the thermocouple plug, a precision 10 kΩ bead themistor glued between the buttons, and a 6-layer PWB. It is constructed to maintain as low a temperature difference between the buttons and the transistor as possible. The thermistor is biased with a programmable current sink via TC_ISO_SRC. This current sink consists of U97, U6, R108, R126, and R127 and provides about 10 µA, developing about 1 V across the thermistor. The voltage of the themistor is measured by connecting TC_ISO to the A/D input with U82A.

Thermocouple Voltage Measurement:

The thermocouple voltage is multiplied by 10 on the A10 Isothermal PCA. It is then switched into the A/D by U82. The A7A10 Isothermal PCA is assembled and tested as part of the A7 Current PCA.

Thermocouple Temperature Simulation

All that is required to simulate a thermocouple is source a voltage that would be generated by a thermocouple at that temperature. The reference junction is measured to determine the temperature of the isothermal block. Then this temperature and the requested temperature are used to determine the correct output voltage. This voltage is generated by the 3.3 DC range, buffered by U13 and divided by 10 on the A10 Isothermal PCA before being outputted on the thermocouple connector.

Analog to Digital Converter

Refer to Sheet 4 on the A6 Digital Synthesis PCA schematic.

All internal calibration and diagnostic measurements are buffered by a gain programmable instrumentation amplifier, U10. The gain of this amplifier is selected by closing U82D (X10), closing U82C (/40), or by leaving both open (X1). The output of U10 is applied to the A/D, U30 where it is converted into a digital value to be read by the micro-controller.

Fault Detection

Refer to Sheet 7 of the A6 Digital Synthesis PCA schematic.

In order to minimize damage caused by misuse, abuse, component malfunction, or software errors, a fault detection circuit was incorporated into the Calibrator. It consists of a set/reset fault latch, a power MOSFET for driving reset coils, and various fault detecting comparators. On the A6 Digital Synthesis PCA, the only kind of faults detected are destructive voltages present at the instrument output during voltage mode operation. This type of fault is detected with a window comparator, U50, that monitors the output of the sense buffer, U21. When the output of U21 exceeds +/-10 V the output of U50 goes low, setting the fault latch, U16. The output of the fault latch sets the signal CLR_DRVR hi, disabling all the latching relay drivers, and turns on Q6, which resets all the latching relays connected to REL_RST*. The fault latch also signals the FPGA of a fault condition via the IG_FAULT signal, allowing the software to respond appropriately. In the case of the DDS assembly, a fault condition disconnects all DDS relays that are connected to the output.

The FAULT*, REL_RST*, and CLR_DRVR signals are also routed to the A3 Motherboard PCA, allowing any other assembly to detect and respond to any abnormal conditions as needed.

Digital Control

Refer to Sheet 8 of A6 Digital Synthesis PCA schematic.

The inguard analog circuitry is controlled through an FPGA, U5. U5 contains a 1 megabit/s serial link, a serial to parallel shift register, and a state machine to provide a microprocessor style data, address and control signals. U5 also incorporates six PWM circuits for DAC's and a two channel DDS circuit with phase adjust and phase error measurement. There are also some general purpose registers for control of the analog circuitry.

A7 Current PCA

Figure 2-4 shows the operation of DC current functions. The DC input signal to the A7 Current PCA comes from the A6 Digital Synthesis PCA on the I_ACDC line. The signal is generated by a high resolution digital-to-analog-converter (IDAC), buffered by amplifier U58, divided by Z1, and applied to the positive input of amplifier U9.

The output of U9 is the I_ACDC signal. The negative input of U9 is connected to the IFBK line, which is the feedback from the shunt amplifier on the A7 Current PCA. In operation the IFBK signal must be equal to the IDAC_OUT signal. If it is not equal, the output of U9 changes the I_ACDC signal to adjust the A7 Current PCA output to make them equal.

The I_ACDC signal is switched by U25 to provide the I_ACDC_SW input to U18. The output of U18 is buffered and applied to one of the three transconductance output amplifiers. The low current amplifier provides the 220 µA and 2.2 mA ranges. The mid current amplifier provides the 22 mA and 220 mA ranges. The high current amplifier provides the 2.2 A range.

The output current is driven through the load connected to the OUT_HI and OUT_LO terminals and returned through the shunt resistors. The differential shunt amp amplifies the voltage developed across the shunt resistors and generates the IFBK feedback signal to the A6 Digital Synthesis PCA as noted above and also to U18 amplifier. When IFBK and I_ACDC_SW signals at the input to U18 are equal the system is in balance providing the correct output current.

Figure 2-5 shows the operation of ac current functions. Operation of the ac current function is similar to dc operation except the signal provided on the I_ACDC line is an ac signal generated by the DDS and scaling DACs on the A6 Digital Synthesis PCA. The ac feedback on the IFBK line is buffered by U14 and converted to DC by the averaging ac converter before it is applied to U9 on the A6 Digital Synthesis PCA.

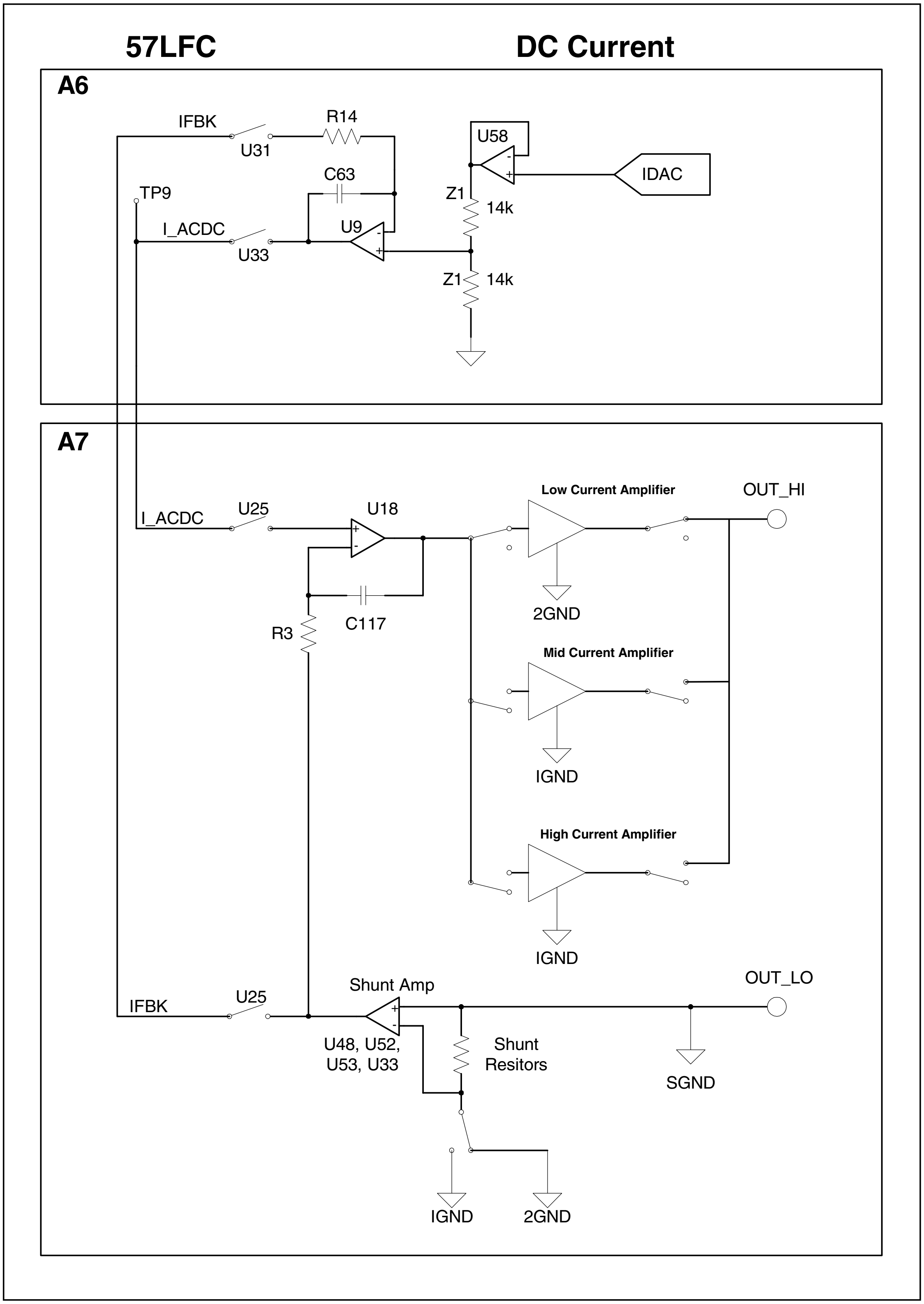

Figure 2-5. DC Current Functions

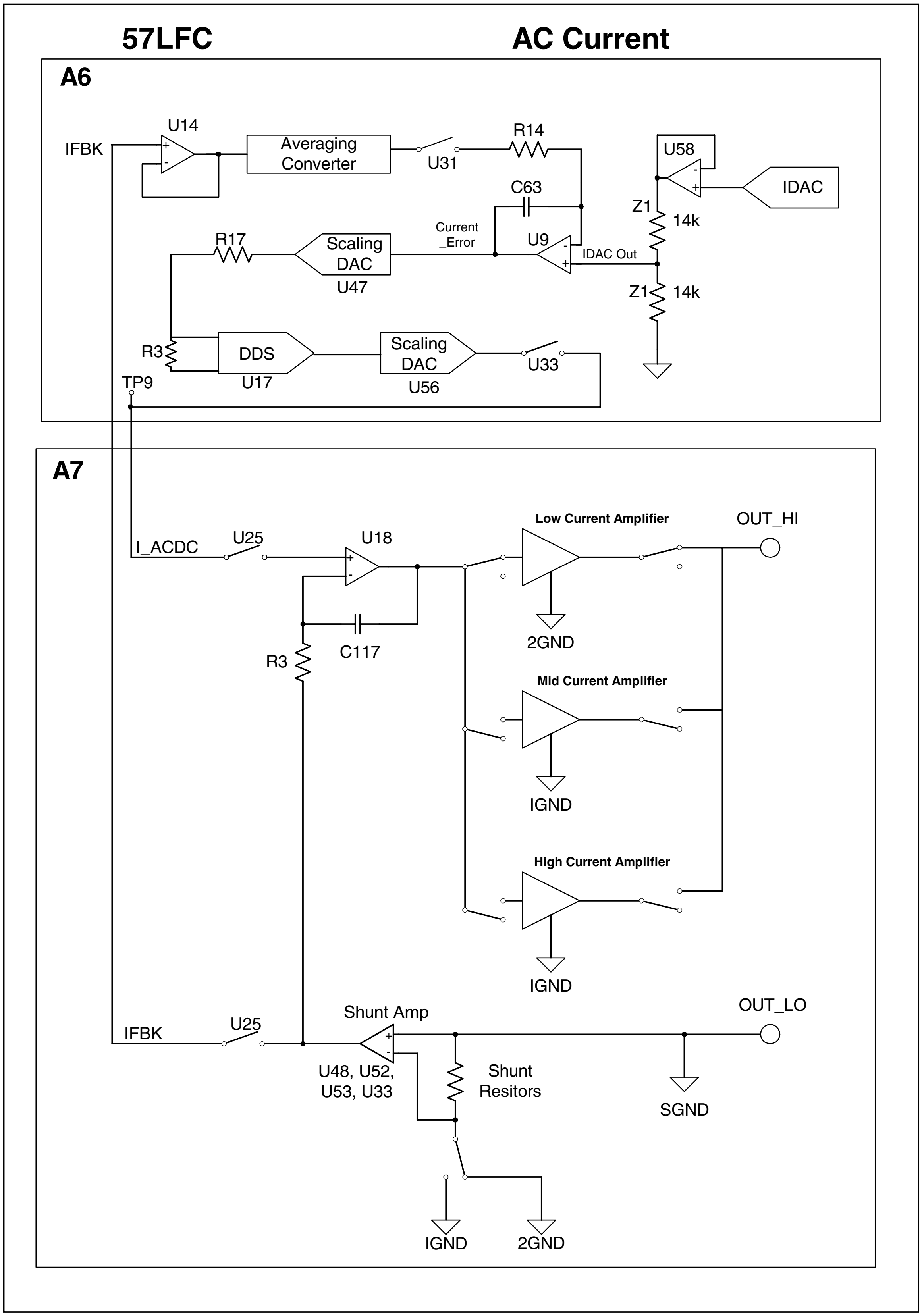

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Figure 2-6. AC Current Functions

Detailed Hardware Description of DC/AC Current

Current returning from the output load is sensed by current shunt R1 for the 2.2 A range, by the 4 Ω shunt in R-net Z2 for the 220 mA range, by the 40 Ω shunt in R-net Z2; for the 22 mA range, by the 400 Ω shunt in R-net Z2 for the 2.2 mA range, and by the four 1k resistors in series (4 k total) R19, R20, R52, R155 for 220 µA range.

Solid state switches U23, U10, and U28 select the shunt required by each range.

The SHUNT_SEL lines from the digital control circuits activate the switches for the range required. Both the Hi and Low sides of the shunt are selected in pairs.

The shunt voltage is amplified by a differential amplifier composed of amplifiers U33, U48, U53, U52 and associated components. R-net Z4 sets the gain of the differential amp to 2.5. Amplifier U29 cancels any current in the RCOM1 line. U33 provides an additional gain of 4 to the 2.2 A range shunt voltage so that a smaller value shunt could be used for less power dissipation.

The output of the differential shunt amp is fed back to the A6 Digital Synthesis PCA on the IFBCK line and the CAL_OS line via solid state switches U25 and U27, and to the distortion loop error amp U18 via resistor R3.

The feedback from the differential shunt amplifier via R3 is compared to the input signal from the A6 Digital Synthesis PCA I_ACDC_SW, by amplifier U18. Any difference is amplified by U18, and the difference is used to drive one of the three output amplifiers, depending on range, to the correct output level and to correct for any distortion produced by the output amplifiers within the limits of the loop gain around the whole loop.

Switch U26 connects various feedback components to U18. The STBY* control line from the digital control circuit turns on a switch to short U18 output to the negative input during instrument standby to keep U18 biased to 0 output. The COMP3 control line switches C135 around U18 to reduce the loop bandwidth in DC mode and the LCOMP ON in the AC mode. The other control lines switch resistors in and out to tailor the response of the loop as needed for each range.

The output U18 feeds an isolation amplifier composed of U44, U13 and associated components. This isolation amplifier provides high impedance isolation from circuits referenced to “S” common to circuits referenced to both “I” common and “2” common. The “I” common and “2” common are separated from the “S” common by the shunt resistor that is in use for each range. The output of the isolation amplifier is fed to the low current, mid current, or high current output amplifiers via relays K10 and K1. Relays K10 and K1 also configure the “I” and “2” commons as required by the output amplifier in use.

Low Current Output Amplifier

The output amplifier for the 220 µA and 2.2 mA ranges is composed of U32, U35, Q16, Q19, Q 20, and associated components. This amplifier uses the “2” common for its ground reference and has its own floating power supply referenced to the “2” common. The power supply is composed of transformer T1, CR26, C102, C103, U50, U51 and associated components. Amplifier U49 drives a shield in transformer T1 to reduce the capacitance between “S” common and the “2” common. Capacitance between the two commons appears across the current sensing shunt and degrades the frequency response and therefore the accuracy of the instrument.

Transistor Q20, ½ of amplifier U35, CR11, R44, R148, R47, and R198 form a pull down current source of 2 mA in the 220 µA range and 6.5 mA in the 2.2 mA range. Amplifier U32, Q16, and R37 convert the input voltage at U32 pin 3 into a current that flows into R43 and forms a voltage at U35 pin 5. The other input at U35 pin 6 is derived from the resistors at the emitter of Q19 (R165, R147, and R48). Relay K12 switches R48 into the circuit for the 2.2 mA range and out for the 220 µA range. The other half of K12 switches R47 and R198 into the circuit for the 2.2 mA range and out for the 220 µA range. When the voltage at U35 pin 6 is equal to the voltage at pin 5 the amplifier is biased for operation at 6.5 mA on the 2.2 mA range and 2 mA on the 220 µA range.

Transistors Q41, Q42, and resistor R7 limit the current that could be forced back into the circuit if a voltage is applied to the output terminals of the instrument when the low current amplifier is in use. The current will be limited to between 10 mA and 50 mA with transient voltages up to 350 V.

Solid-state relay U34 is used to disable the amplifier when it is not being used. A high on the LO_CURRENT_DISABLE line from the digital control circuit will turn on the relay, shut off the bias current in the amplifier and put it in a dormant state.

The transconductance of this current amplifier is 2 mA/ V on the 2.2 mA range and 214 µA/ V on the 220 µA range.

Mid-Current Output Amplifier

The output amplifier for the 22 mA and 220 mA ranges is composed of U7, U58, U31, Q3, Q5, Q14, Q15, MP13, MP14 and associated components. This amplifier uses the “I” common for its ground reference.

This is a class-A push-pull output stage amplifier with 242 mA bias on the 220 mA range and 27 mA bias on the 22 mA range.

MP13 and Q14 supply the positive output current. MP14 and Q15 supply the negative output current. Relay K2 switches in the resistors to set the bias current. With the 1 ohm resistors switched in to the emitters of MP13 and MP14, the bias will be set at 242 mA. With the 10 ohm resistors switched in, the bias will be 27 mA.

Input pin 6 of U31 connects to the emitter resistors of MP13 and input pin 5 of U31 connects to R23 through R85. U31 will adjust the base voltage of Q14 and MP13 to make the voltage at its inputs equal. Therefore, the voltage across R23 will set the bias for positive output transistors. In similar manner, the other half of U31 will set the voltage at the emitter of MP14 equal to the voltage across R32. The voltage across R32 will set the bias for the negative output transistors.

With no output current, the current from the positive output transistors will flow into the negative output transistors. To obtain a positive output, the current out of MP13 and Q14 is increased and the current through MP14 and Q15 is decreased by the same amount. The total output current is therefore equal to two times the amount of the increase from the positive output transistors. The current increment that was flowing in the negative output transistors is now diverted to the output to supply ½ of the output, and the other ½ of the output comes from the increase in the positive output transistors. Negative output currents are obtained in a similar manner. When the negative output transistors current is increased, the positive output is decreased by the same amount.

The maximum output from the amplifier for class A operation will therefore be equal to 2 times the bias current. When either the positive transistors or the negative transistors current is reduced to zero, the opposite side transistors will be supplying 2 times the bias current to the output.

The differential drive for the output transistors is obtained from U7, U58, Q5, Q3 and associated components. The positive output transistor drive voltage across R23 is obtained from current supplied by Q5. Q5 is configured as a common base amplifier. Current from R25 in the emitter of Q5 is passed out of the collector and into R23. Q5 is biased by ½ of amplifier U58. R6 and R12 form a divider across the +15I supply to provide +2 V at the positive input of U58. The negative input of U58 is connected to the emitter of Q5. U58 will therefore drive the base of Q5 to keep the emitter of Q5 at +2 V.

The input to the mid current output amplifier is amplified by U7. The output of U7 is connected to R25//R28 and R27//R84. With zero input voltage the output of U7 will be zero. The current through R25//R28 will be 2 mA (2 V/1 K). The 2 mA through R25//R28 will be passed through Q5 to R23 to provide a voltage of 242 mV (2 mAx121 Ω).

The voltage at emitter of MP13 tracks the voltage on R23 as explained above. With the 1 Ω resistor R53 switched in, the bias current will be 242 mA (242 mV/1 Ω). With the 10 Ω resistor, R50 switched in the bias current will be 27 mA (24 2 mV/9.1 Ω) (10 Ω in parallel with 100 Ω = 9.1 Ω).

The negative output transistor drive operates in a similar manner. Drive voltage across R32 is obtained from the collector of Q3. Q3 is a common base stage biased to –2 volts by the other ½ of U58 and divider R14 and R15, which is across the –15I supply. The input current to Q3 emitter is from R27, which in turn is connected to the output of U7. The current through R27 will be 2 mA also, and will pass through Q3 to R32 to provide the 242 mV for the negative output transistor drive and sets the bias in the same way as explained above for the positive output transistor.

Solid-state relay U30 is used to disable the amplifier when it is not being used. A high on the MID_CURRENT_DISABLE line from the digital control circuit will turn on the relay, shut off the bias current in the amplifier and put it in a dormant state.

The transconductance of this current amplifier is 242 mA/ V on the 220 mA range and 27 mA/ V on the 22 mA range.

High Current Output Amplifier

The output amplifier for the 2.2 A range is composed of U17, U59, U37, Q9, Q4, Q10, Q1, Q2, Q8 and associated components. This amplifier uses the "I" common for its ground reference.

This is a class-A push-pull output stage amplifier with 1.8 A bias in the ac mode and a class-AB push-pull output stage amplifier with 0.5 A bias in the dc mode.

The circuit topology is similar to the mid current output amplifier. The output drive transistors, bias current determination, and differential drive are established in the same way as the mid current output amplifier. Refer to the mid current output amplifier above for details of the operation.

Bias current for dc operation is set at 0.5 A. Relay K22 switches resistor R79 in parallel with R74 on the positive side, and R78 in parallel with R77 on the negative side. This parallel combination sets up the 0.5 A bias in the output stage. With R79 and R78 switched out of the circuit, the higher resistance and therefore higher voltage across them boost the bias in the output stage to 1.8 A for ac operation.

With 0.5 A bias in the output stage in the dc mode, either the positive output transistor or the negative output transistor will shut off, depending on the polarity of the output current, at about 1 A of output current. At this point, the amplifier operates class-B with only one or the other of the output transistors in use at a time.

Solid-state relay U38 is used to disable the amplifier when it is not being used. A high on the 2.2A_DISABLE line from the digital control circuit will turn on the relay, shut off the bias current in the amplifier and put it in a dormant state.

The transconductance of this current amplifier is 1.83 A/ V for ac and .55 A/ V for dc ≤1 A and .45 A/ V for dc >1 A.

The temperatures of MP2 and MP3 are monitored with some TMP36 temperature sensors mounted to small circuit boards that are soldered to the tabs of the transistors. The temperature sensors put out 10 mV/degree C and have a 500 mV offset. A voltage divider and capacitor on the sensor circuit board reduce the +15 V supply down to around +5 V to power the sensor. The output of the sensor goes through a RC low-pass filter and is sent through U10 to the SMUX line where it can be periodically monitored when in the 2.2 A range. An out-of-range condition would indicate some kind of circuit failure or a blocked or failed fan.

High Current Amplifier Power Supplies (Mongo Supplies)

The power supply for the 2.2 A high current amplifier was designed to have a magnitude 5 V higher than the output peak compliance voltage. The supply will therefore be +/-5 V with 0 V compliance and +/-11 V with 6 V peak (4 V rms) compliance.

The circuitry used to detect the peak compliance voltage is composed of U16, U21, U20, U19, and U47 and associated components. U16 is a unity gain buffer that monitors the output voltage from the current PCB on the OUT_HI line through K19 and R114. The output of U16 is switched by U47 to the input of U21. U21 is configured as a full-wave rectifier which gives a positive rectified output for either polarity of the input signal. This rectified output is filtered by R169, C58, and then applied to switch U47 where it is switched to the PMUX line. PMUX is monitored by the A6 Digital Synthesis PCA, which generates the "compliance voltage exceeded" message and places the instrument back to standby.

The output of full-wave rectifier U21 is also applied to a track-and-hold circuit composed of U20, C59, R170, and R193. The positive input signal from U21 is inverted and charges C59 to a negative value of the same magnitude as the input. As the input voltage begins to decrease U20 will turn off and leave C59 with a voltage equal to the negative of the peak input voltage. C59 charges quickly through U20 and discharges slowly through R193 and R170 after U20 shuts off. (U20 has an open collector output stage).

The voltage across C59 is applied to the positive input of one op-amp in U19. The negative input is connected to Zener diode VR2 (5.1 V) that is connected between the op-amp output and the negative input. VR2 is biased on by R108 and by R63, when solid-state relay U45 is on. With this circuit configuration the output of the op-amp will always be 5.1 V lower than the voltage on the positive input. With 0 V compliance, the voltage across C59 will be 0 and therefore the output of U19 will be -5.1 V. With 6 V compliance the voltage across C59 will be -6 V and therefore the output of U19 will be -11.1 V. The output of this op-amp is the –IREF that is supplied to the high current power supply on the A3 Motherboard PCA. The other half of U19 is configured as a unity gain inverter, and inverts the –IREF to generate the +IREF signal for the high current power supply.

At power ON, solid state relay U45 will be off and the bias current to VR2 and C57, which is in parallel with VR2, must come from R108 (200k). The output signals +IREF and –IREF will therefore rise slowly and in turn, the high current power supply will come up slowly. After a delay, relay U45 will turn on and normal bias current will be provided by R63.

The high current power supply is located on the A3 Motherboard PCA, and is composed of U23, U24, Q14, Q17, Q9, C87, C53 and associated components. The AC input voltage from the main power transformer is full-wave rectified by CR64 and CR60 for the positive supply and by CR65 and CR61 for the negative supply.

When transistor Q14 is on, the positive rectified voltage will charge C87, which provides the +MMONGO output. Q14 is controlled by U23. The inputs to U23 are the +IREF on the + input and the full-wave + rectified AC on the negative input. If the +IREF signal is larger than the AC input signal, the open collector output of U23 will be off and the gate of Q14 will be biased on by the +15I_UNR supply through R70 and R74. Once Q14 is on, it will remain on until C87 is charged up to a voltage equal the +IREF signal and then Q14 will be turned off by U23. The voltage at the negative input of U23 turns on the output and shorts the input voltage to Q14. If Q14 is off, diode CR47 (which is connected between the negative input of U23 and the supply output) will begin to conduct when the AC input is one diode drop greater than the supply output. If the supply output decreases more than one diode drop from the +IREF, U23 will turn off and turn Q14 on and allow C87 to charge for more of the AC input cycle, rather then waiting for the next cycle of the AC input.

When transistor Q9 is on, the negative rectified voltage will charge C53, which provides the -MMONGO output. U24 and Q17 control Q9. The inputs to U24 are the

-IREF on the + input and the full-wave - rectified ac on the negative input. If the -IREF signal is more negative than the AC input signal, the output of U24 will be negative, which will turn on Q17. With Q17 on the +15I supply voltage will turn on Q9. Once Q9 is on, it will remain on until C53 is charged up to a voltage equal the -IREF signal and then Q9 will be turned off by U24/Q17. The voltage at the negative input of U24 turns the output off, which turns off Q17 and Q9. If Q9 is off, diode CR37, which is connected between the negative input of U24 and the negative supply output, will begin to conduct when the AC input is one diode drop less than the negative supply output. If the negative supply output increased more than one diode drop from the -IREF, U24/Q17 will turn on which will turn Q9 on and allow C53 to charge for more of the AC input cycle, rather then waiting for the next cycle of the AC input.

A8 High Voltage PCA

The function of the A8 High Voltage PCA is to amplify the 2.2 V (nominal max.) signal from the A6 Digital Synthesis PCA to the output levels required for the 22 V and 220 V ranges. The A11 Isothermal PCA is assembled and tested as part of the A8 High Voltage PCA.

This is accomplished by employing separate amplifiers for each range. These amplifiers have gains of 10 and 100 for the 22 V and 220 V ranges respectively.

The exact gain of each amplifier is not critical as overall amplitude control is maintained by an outer amplitude control loop external to the A8 High Voltage PCA. However, this outer loop does not correct for distortion, noise or offset, all of which must be suitably controlled within the amplifiers. Both amplifiers are directly (dc) coupled to the output terminals and protection against short circuit is provided by appropriate output stage current limit circuits.

The A8 High Voltage PCA also contains a dual polarity high voltage regulator circuit which serves to isolate the 220 V amplifier from raw dc supply voltage variations resulting from mains fluctuations, transformer regulation and ripple. The magnitude of the positive and negative outputs may be independently set under firmware control to levels of 188 V or 375 V as dictated by the required amplifier output, thus allowing amplifier output device dissipation to be reduced. The regulator also contains a current limit and over-current shutdown feature to further protect the 220 V amplifier in the event of an output short circuit. See Figure 2-7 a diagram of the A8 High Voltage PCA 22 V and 220V amplifier.

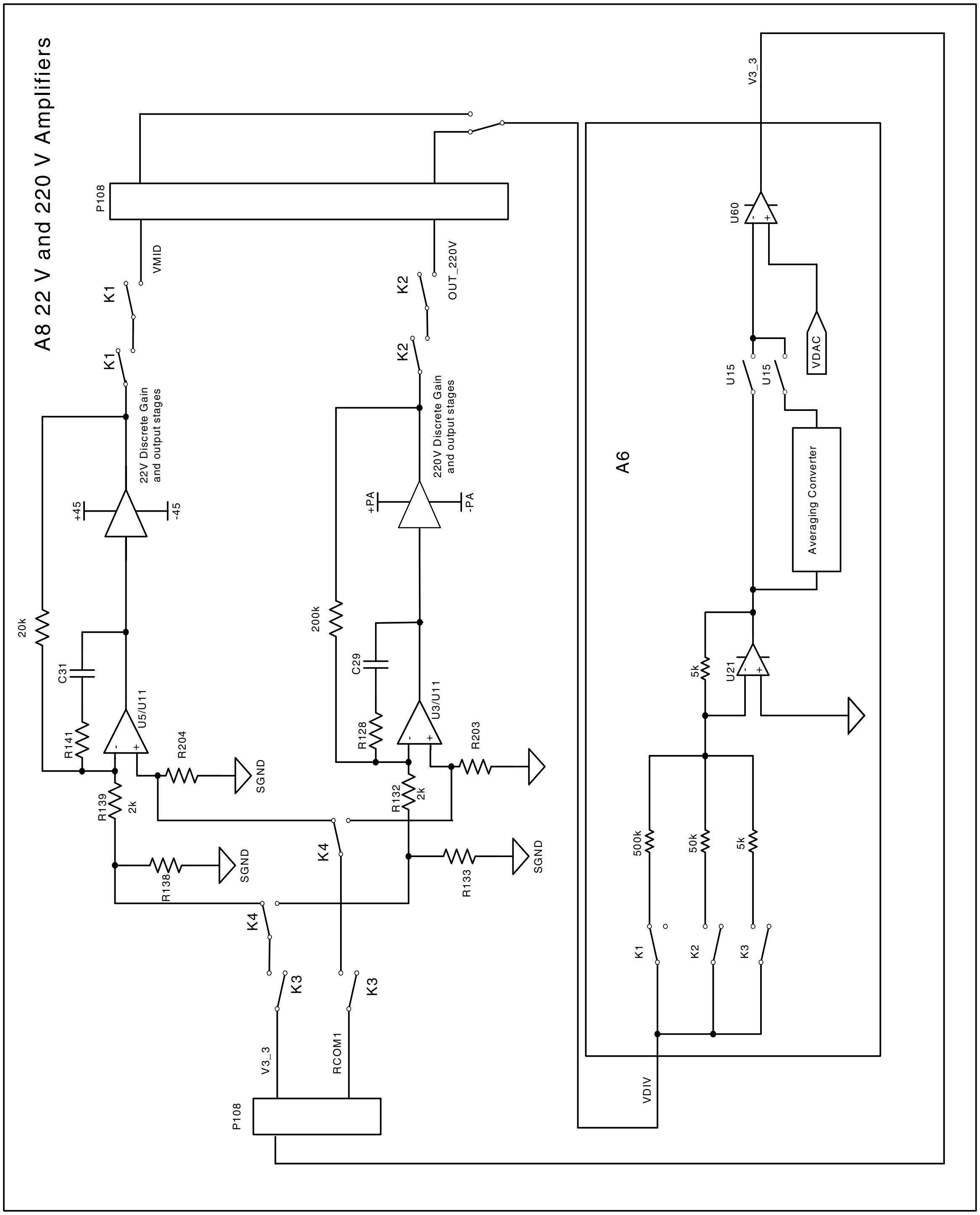

Figure 2-7. A8 High Voltage PCA 22 V and 220 V Amplifier

Detailed Hardware Description of the 22 V Amplifier

The 22 V amplifier has a gain of 10 and provides output voltages of between 2.2 V and 22 V dc or ac rms at frequencies up to 100 kHz. The amplifier is designed to accommodate a maximum burden of 50 mA dc or ac rms and a maximum capacitive load of 500 pF. To achieve the maximum required voltage swing under ac conditions the output stage is operated from ±45 V supply rails, whilst the input stages are operated from ±15 V rails. All power supplies are derived externally.

In the 22 V range relays K3 and K4 route the input signal (V3_3) and it's associated ground (RCOM1) from connector P108 to the inverting and non-inverting inputs respectively of an operational amplifier input stage comprising U5 and U11. The combination of wide bandwidth amplifier U5 and chopper-stabilised amplifier U11 allows wide bandwidth and good dc performance to be achieved simultaneously.

Transistors Q59 and Q60, diodesVR23 and VR24 and resistors R233 and R234 form a feedback voltage clamp around the op-amp to ensure the output and inverting input always remain within their linear operating range. This is necessary to prevent conditional large signal instability of the 22V amplifier resulting from the finite overload recovery time of the op-amp. Dual diodes CR31 and CR32 and associated components clamp the op-amp inverting input at approximately ±1.5V under overload conditions.

The output of U5 is fed via R144, to voltage-to-current converter stage Q56. The transconductance of this stage is set by R210 and emitter bias current is provided by current source Q55. Diode CR47 is included to prevent reverse base-emitter breakdown of Q56 which would otherwise occur under overload conditions.

The output from the collector of Q56 is applied to the input of common emitter amplifier Q36: this stage is referenced to the -45V supply rail and provides the full output voltage swing of the amplifier. Collector bias current for Q26 is supplied by current source Q35, thus maximising the low frequency gain of the stage.

The output from Q35 is buffered by emitter followers Q11 (biased by current source Q8/Q10) and Q12 (biased by current source Q9/Q34) before being fed to complimentary output emitter followers Q4 and Q5 respectively. The output stage bias current is defined by the quiescent voltage imposed across the series/parallel combination of resistors R3 to R10: this voltage is the sum of the base emitter voltages of Q11 and Q12 and the voltage across dual diodes CR16 and CR17 less the base emitter voltages of Q4 and Q5 and the voltage across CR3 and CR6. Resistors R3 to R10 are chosen to set this current at approximately 40mA so that the output stage operates in class A under all specified load conditions to eliminate crossover distortion.

Transistor Q3 provides limiting for positive output currents by absorbing further increases in base current to Q4 once sufficient voltage is developed across the R3/R4 parallel combination to turn Q3 on: Q6 provides limiting for negative currents in a similar manner by restricting the base current to Q5. Under current limit conditions, dual diodes CR16 and CR17 prevent reverse base-emitter breakdown of Q11and Q12 respectively whilst diodes CR4 and CR5 prevent current flow from Q11 and Q12 to the output via the forward biased collector-base junctions of Q3 and Q6 respectively.

The overall gain of the amplifier within the specified operating bandwidth is defined by feedback network R139, R145 and R146 and is given by the expression (R145 + R146)/R139. Stability is ensured by dominant pole compensation provided by local feedback around Q35 via capacitor C33. Additional open loop frequency response shaping is provided by local feedback around U5/U11 via R141 and C31.

Fuse F1 and diodes CR14 and CR15 are included to help protect the amplifier in the event of an external high voltage source being connected to the output terminals. During such an occurrence the amplifier output is clamped to the ±45V supply rails by CR14 and/or CR15, providing short-term protection. The resulting large current flow eventually causes F1 to rupture, thus providing protection in the longer term. To minimize undesirable effects due to variability in fuse characteristics with operating point, temperature and time F1 is connected within the overall feedback loop of the amplifier.

The amplifier output is routed to connector P108 via resistor R143 and relay K1. R143 is included to help prevent output stage instability in the presence of capacitive loads.

Detailed Description of the 220 V Amplifier

The 220 V amplifier has a gain of 100 and provides output voltages of between 22 V and 220 V dc or ac rms at frequencies up to 100 kHz. The amplifier is designed to accommodate a maximum burden of 20 mA dc or ac rms or a maximum capacitive load of 675 pF for ambient temperatures up to 40 °C. Above this temperature, the allowable load capacitance is reduced.

To achieve the maximum required voltage swing under ac conditions the output stage is operated from ±375 V supply rails (±PA). These rails are regulated to provide isolation from raw dc supply voltage variations caused by mains fluctuations, transformer regulation and ripple. To minimize output stage power dissipation (particularly under dc output conditions), the positive and negative PA rails can be independently switched to a value of 188 V under firmware control when compatible with the required amplifier output voltage. See Table 2-15 for the supply values as a function of range.

Table 2-15. Supply Values as a Function of Ranges

Calibrator Output	+PA	-PA
±22 V to ±110 V dc	+188 V	-188 V
110 V to 220 V dc	+375 V	-188 V
-110 V to -220 V dc	+188 V	-375 V
22 V to 101 V ac	+188 V	-188 V
101 V to 220 V ac	+375 V	-375 V

The amplifier input stages are operated from ±15 V rails. Regulator circuits for the high voltage rails are located on-the A8 High Voltage PCA while the ±15 V rails are derived externally.

In the 220 V range relays K3 and K4 route the input signal (V3_3) and it's associated ground (RCOM1) from connector P108 to the inverting and non-inverting inputs respectively of an operational amplifier input stage comprising U3 and U4. The combination of wide bandwidth amplifier U3 and chopper-stabilized amplifier U4 allows wide bandwidth and good DC performance to be achieved simultaneously. Transistors Q31 and Q32, diodesVR22 and VR42 and resistors R129 and R130 form a feedback voltage clamp around the op-amp to ensure the output and inverting input always remain within their linear operating range. This is necessary to prevent conditional large signal instability of the 220 V amplifier resulting from the finite overload recovery time of the op-amp. Dual diode CR30 clamps the op-amp inverting input at approximately ±0.7 V under overload conditions.

The output of U3 is fed via R131 to voltage to current converter stage Q53. The transconductance of this stage is set by R199 and emitter bias current is provided by current source Q54. Diode CR29 is included to prevent reverse base-emitter breakdown of Q53 which would otherwise occur under overload conditions.

The output from the collector of Q53 is fed via common-gate connected high voltage P-channel mosfet Q52 to the collector/base of Q51. Q52 is necessary to isolate the collector of Q53, which is a low voltage small signal device, from the high voltage associated with the -PA supply rail.

Q51 forms the input of a current mirror whose output flows into the collector of Q50. The output/input current ratio of this mirror is defined essentially by the ratio of the values of R198 and R118 and is approximately 4.7. The collector of Q50 is isolated from high-voltage signal excursions by common-gate configured N-channel mosfet stage Q33, and at low frequencies the mirror output current almost entirely flows via the drain of this device. The gate of Q33 is referenced to the -PA supply rail via VR18, and the drain of this device provides the full output voltage swing of the amplifier. Drain bias current for Q33 is supplied by a current source comprising Q47, Q48, CR46 and R194, thus maximising the low frequency current-to-voltage gain of the stage: this current is set at approximately 8 mA. Common base stage Q30 is included to recover mirror output current which would otherwise be lost via the drain-gate capacitance of Q33 at high frequencies. This is necessary to prevent loss of gain and to alleviate distortion caused by variations of drain-gate capacitance with voltage.

The signal at the drain of Q33 is then fed to complimentary Darlington emitter follower output transistors Q45/Q27 and Q46/Q44. The output stage bias current is set by the quiescent voltage imposed across the series/parallel combination of resistors R186 to R189: this voltage is the collector-emitter voltage of 'Vbe multiplier' transistor Q49 less the base emitter voltages of Q27, Q44, Q45 and Q46. Resistors R186 to R189 in conjunction with resistors R195, R196 and variable resistor R197 are chosen to allow this current to be set at 18 mA.

High-voltage N-channel mosfet devices Q1 and Q25 isolate Q27 and Q45 from the high potentials necessary to obtain the specified Amplifier output voltage swing. The collector-emitter voltage of Q27 and Q45 is set at approximately 12 V by Zener diode VR15 (which is referenced to the amplifier output) and the gate-source voltage of Q1. Bias current for VR15 is supplied by series/parallel resistor combination R95, R96, R98 to R101, R103 and R104 which also serves to set the gate voltage of Q25 at approximately half way between the +PA supply and amplifier output voltages: the voltage presented across Q1 and Q25 is thus shared equally between the two devices. C18 is included to counteract the effect of input capacitance of Q25, thus ensuring effective voltage sharing up to the maximum operating frequency. High-voltage P-channel mosfet devices Q2 and Q29 isolate Q44 and Q46 in a similar manner. Because the voltage difference between the Amplifier output and the ±PA power supply rails is supported almost entirely by Q1, Q2, Q25 and Q29, the bulk of the amplifier output stage power dissipation is liberated in these in devices.

Transistor Q26 provides limiting for positive output currents by absorbing further increases in gate-source voltage of Q4 once sufficient voltage is developed across the R105 to turn Q3 on. Q6 provides limiting for negative currents in a similar manner by restricting the gate-source voltage of Q2.

The overall gain of the amplifier within the specified operating bandwidth is defined by feedback network R125, R127 and R132 and is given by the expression (R125 + R127)/R132. Stability is ensured by dominant pole compensation provided by local feedback from the emitter of Q46 to the base of Q50 via capacitor C48. Additional open loop frequency response shaping is provided by local feedback around U3/U4 via R281 and C29.

Fuse F2 is included to provide limited protection in the event of an external high voltage source being connected to the output terminals. This device is connected within the overall feedback loop of the Amplifier to minimise distortion, particularly at low frequencies, resulting from the non-linear characteristic of the device.

The amplifier output is routed to connector P108 via fuse F2, resistors R183 and R185, chokes L2 and L2 and relay K1. R183, R185, L2 and L2 are included to help prevent output stage instability in the presence of capacitive loads.

Op-Amp U15, transistors Q13 and Q61 and resistors R49, R94 and R97 comprise a precision current mirror whose output from the collectors of Q13 and Q61 is proportional to the current flowing from the +PA supply into the output stage. The input/output ratio of the mirror is defined by the ratio of R49 to the parallel combination of R94 and R97 and is set at a nominal value of 110:1. Low-pass R-C network R235 and C65 restricts the bandwidth of the signal fed to U15 and Darlington connected transistors Q14 and Q62 increase the output voltage capability of the mirror to accommodate the +PA supply. The mirror output is sensed by resistor R58, and C67 is included to provide low-pass filtering so that at high frequencies the resultant voltage represents the average output stage current.

Dual FET-input operational amplifier U2, diode CR65, capacitor C92 and resistors R264 and R277 comprise a peak detector circuit that senses the voltage developed across R58 and temporarily holds its peak value. This ensures that at low frequencies the peak value of current, which is more representative of output device dissipation than the average, is sensed. The peak detector output is multiplexed onto the SMUX line via U10 for subsequent A-to-D conversion.

The current from the -PA supply into the output stage is monitored in a similar manner to that from the +PA supply.

Detailed Hardware Description of the High Voltage Regulator

The high voltage regulator circuits provides linear voltage regulation of the raw high voltage dc supplies from the A3 Motherboard PCA to produce the ±PA supply rails required by the 220 V amplifier output stage. The positive and negative outputs may be set to zero or independently set to levels of 188 V or 375 V under firmware control. The regulator has output current limit to protect both the 220 V amplifier and itself in the event of fault and applied short-circuit conditions.

Raw unregulated dc supplies +360UNR, +180UNR, -180UNR and -360UNR (having nominal values of +545 V, +270 V, -270 V and -545 V respectively) are presented at connector P108.

For a required +PA output voltage of +375 V, control lines +HI/LO_V and +ON/OFF are set low (-14 V) so that transistors Q18, Q20 and Q17 are turned off and pin 2 of analogue switch U20 (SWA) is connected to HVCOM. The output of current source transistor Q21 (approx. 0.8mA) thus flows in resistors R241, R242, R252 and R253 and transistor Q66. Op-amp U21 controls the gate drive to Q66 to maintain the voltage at the junction of R241 and R242 equal to that at the output of 5 V reference U22, and the voltage at the drain of Q66 is therefore set at 379 V due to the potential divider action of R241, R242, R252 and R253. This voltage is applied to the gate of +PA output transistor Q22, resulting in a nominal regulator output voltage of 375 V at the source terminal of the device. Resistors R38, R41 to R43, R76, R78, R81 and R84 form a potential divider chain which sets the gate (and consequently source) voltage of Q7 at approximately half way between the voltages at the +360UNR input and the Regulator output (VR3, VR5, VR6 and VR7 do not conduct as the sum of their breakdown voltages exceeds that appearing at this node in normal operation and Q18 is turned off). The +PA Regulator input/output voltage difference, and consequently output device power dissipation, is thus shared equally between Q7 and Q22, allowing higher input voltages and output currents than if a single output device were used. In this mode, diodes CR11 and CR12 are reverse biased to prevent current flows from the +180UNR raw supply. Zener diodes VR9 and

VR10 are included to restrict the regulator output voltage if Q66 or any of it's associated components fails.

For a required +PA output voltage of +188 V, control line +HI/LO_V is set high (+14 V) and +ON/OFF is set low (-14 V). Transistor Q18 is thus turned on, shorting Zener diodes VR5, VR6 and VR7 and causing diode VR3 to conduct via resistors R38 and R41 to R43. The gate, and consequently source, of Q7 are thus held at approximately 150 V. As this is lower in voltage than the +180UNR input supply, diode CR13 is reverse biased and all regulator input current flows from the +180UNR supply via CR12 into the drain terminal of Q22: the drain potential of Q22 is thus essentially equal to that of the +180UNR supply. In this condition, pin 2 of analogue switch U20 (SWA) is left unconnected to HVCOM and R240 is thus included in series with R241 so that the voltage at the drain of Q66 is now controlled at 192 V. This voltage is applied to the gate of +PA output transistor Q22, resulting in a nominal regulator output voltage of 188 V.

For a required +PA output voltage of zero, control line +ON/OFF is set high. This turns on Q17, shorting out shorting the drain terminal of Q66 to ground and resulting in a nominal voltage of zero at this point. It should be noted that the +PA and -PA outputs cannot be set to zero independently as their control lines are derived from the same logic control signal.

Current flowing from the +PA output is sensed by R88, the voltage across which is applied to the base and emitter terminals of Q23. The collector current of Q23 is sensed by the parallel combination of VR33 and R171, and the voltage developed is applied to an R-C low-pass filter comprising R168 and C15. The filter output is applied to the non-inverting input (pin 5) of one half of dual comparator U9, the inverting input (pin 6) of which is normally held at approximately 3.5 V by current source CR21 and resistor R77. Under normal operation, Q23 does not conduct and. Pin 5 of U9 therefore remains at approximately 0 V. The comparator output (pin 7) therefore pulls low (approximately -14 V), reverse biasing CR36 and allowing the gate voltage of Q17 to be set in accordance with the +ON/OFF line.

When the +PA supply output current exceeds a pre-determined overload limit of approximately 90 mA, Q23 rapidly starts to conduct and the filter output begins to rise. If the overload condition persists for longer than approximately 75 ms, the filter output voltage becomes sufficient to cause the comparator output to start to change state. The positive-going comparator output voltage causes Q19 to start to conduct. This results in positive feedback via the inverting input, thus accelerating the change in state. This process terminates when the open-collector output of the comparator is completely inactive. In this state the gate voltage of Q17 is pulled up to approximately 7.5 V by R159 and Q19 is saturated. Q17 is thus turned on, shorting out the drain of Q66 and resulting in the +PA output being reduced to zero.

Reducing +PA to zero causes the output current to fall, and consequently Q23 stops conducting. The filter output voltage applied to the non-inverting (pin 5) comparator input therefore starts to fall. When it reaches the level on the inverting input (the collector saturation voltage of Q19) the comparator reverts to its original state. Q17 is again allowed to be turned off by the low (-14 V) +ON/OFF line and the voltage at the drain of Q66 begins to increase slowly towards its normal reference value as capacitor C13 charges.

When the regulator output voltage reaches a value sufficient to again cause the over-current condition the process repeats, and this cyclical operation continues until the cause of the over-current is removed.

Resistor R90 and transistor Q24 comprise a secondary over-current detector, set at approximately 0.5 A, whose function is to protect the Regulator against a short-circuit applied to the +PA output. Collector current flowing in Q24 causes the voltage across

Zener diode VR39 to increase rapidly towards a limit of 10 V. This voltage is applied to the non-inverting (pin 5) input of U9 without filtering so that in the event of an overload, no intentional delay occurs before the comparator changes state and the supply shuts-down.

To provide a safer environment for fault finding of the 220 V amplifier, the high voltage regulator outputs (±PA) my be reduced to approximately ±45 V by re-routing the drain terminals of output transistors Q22 and Q34 to the ±45 V regulated supplies on the A3 Motherboard PCA. This is implemented by setting switch S1 to its alternative position i.e., with the switch actuator set furthest from the connector edge of the A8 High Voltage PCA.

The operating principles used to derive the Regulator -PA output are identical to those for the +PA output. The -PA output voltage is set to -188 V or -375 V by low (-14 V) and high (+14 V) states respectively of control line -HI/LO_V, and is set to zero when the -ON/OFF assumes it's low (-14 V) state. Note that the +ON/OFF and -ON/OFF lines are derived from the same control signal and therefore the +PA and -PA outputs cannot be set to zero independently.

Heat Sink Temperature Measurement

The temperature of the heatsinks for 220 V amplifier output devices Q25, Q29, and high voltage regulator output devices Q22 and Q42 are monitored by heatsink mounted integrated circuit temperature sensors U25, U26, U27 and U28. The sensor output voltages are multiplexed onto the SMUX line by U19 via U10 for subsequent A-to-D conversion.

Digital Interface and Control

The digital interface to the A8 High Voltage PCA comprises an 8-bit data bus (IG_DATA<7..0>), three address lines (ID_ADDR0, ID_ADDR1 and ID_ADDR2), a board select line (IG_CSO) and a write line (IG_WR*).

When the board select line is low, U7 routes the IG_WR* signal (which is normally held high) to the clock inputs of 4-bit relay drivers U12 and U13 or one of two 8-bit latches, U14 and U17, as determined by the state of the three address lines. 8-bit data is clocked into the latching inputs of U12 and U13 (which are connected to act as a single 8-bit device), U14 or U17 in response to the IG_WR* line being taken momentarily low, data being latched on the low to high transition.

The open-collector outputs of U12 and U13 are grouped in pairs, each pair driving the set and reset coils of one of the four on-board latching relays. The four reset coils are also connected together via diodes CR49 to CR53 so that all relays can be simultaneously reset by pulling the RLY_RST* line low.

The outputs of U14 are used to control U10 and U20 directly. Outputs Q5 to Q7 are also translated by quad comparator U8 to produce the ±14 V signals +ON/OFF, -ON/OFF, +HI/LO_V and -HI/LO_V. This process introduces an inversion in deriving +ON/OFF and +HI/LO_V.

Outputs Q0 to Q2 of U17 control the output routing for the heatsink temperature monitor IC's via U19.

A9 Out-Guard CPU PCA

The CPU manages all of the internal remote functions including: IEEE-488 and RS-232 remote communication, calibration enable, watchdog timer, serial communication with the FPGA on the A6 Digital Synthesis PCA. See Sheet 1 of the A9 Out-Guard CPU PCA schematic.

The main processor (U10) is a Motorola 68306 that runs on code stored in flash memory (See Sheet 2 of the A9 Out-Guard CPU PCA schematic). The processor directs all internal operations in the Calibrator. It receives commands from the IEEE-488 interface. The RS-232 interface is used in the factory for special testing.

There are two serial ports. One serial port is used for communication with a host PC. The other port, AUX, can be used as a programmable serial output port. When the Calibrator is used with Fluke's hand held scope meters, the port may be used to control the scope meter.

The CPU communicates with the A6 Digital Synthesis PCA through serial communication lines through J1, a 20-pin cable to the A3 Motherboard PCA. All communication with the A6 Digital Synthesis PCA is through differential transceivers and transformers. The differential drivers reduce noise coupling between the guarded and non-guarded CPU circuits. The transformers isolate the guarded and unguarded circuits. The transformers are found on the A6 Digital Synthesis PCA. See Sheet 7 of the A6 Digital Synthesis PCA schematic.

There are several miscellaneous items to note on the A9 Out-Guard CPU PCA. First, there is a watchdog timer circuit, U1. If the CPU loses communication with either the front panel or the A6 Digital Synthesis PCA, the watchdog timer is not signaled which allows a hard reset to the instrument. Secondly, there is the calibration enable switch. When a 57LFC is calibrated, it is recommended that the switch be set to inactivate calibrating the instrument until the normal calibration interval has expired. Finally, a JTAG port is available to allow programming the flash memory through the CPU when changes are made to the software. This can only be used by the factory.

Real Time Clock Memory

There is over 640 K bytes of static RAM on the CPU board. The RAM has a bank of 128 k x 16 and a bank of 512 k x 16. The is also 512 k x 16 flash memory in U5 and U6. At power-up, the flash is moved into RAM. Program execution is then out of RAM. The real time clock provides the calendar functions for the instrument. If the real-time lock battery wears out, when power off, the instrument will lose its ability to keep track of the calibration cycle. See Sheet 2 of the A9 Out-Guard CPU PCA schematic.

IEEE-488 Interface

The TMS9914 IEEE-488 IC is used for all remote IEEE-488 communication. There are two buffers that provide the correct driver capability for the IEEE-488 bus. In general, the product complies will all parts of the IEEE-488 standard. Note that U12 and U19 are not installed. See Sheet 3 of the A9 Out-Guard CPU PCA schematic.

Chapter 3
Calibration and Verification

Title **Page**

Calibration

Calibration of the 57LFC is accomplished using two internal calibration procedures.

The first of these is an offset or "zero" calibration and requires no external standards. The second procedure is used to establish range gains and other constants using external standards. The first internal procedure will be referred to as "zero" calibration and the second will be referred to as "main" calibration for the remainder of this discussion. See Table 3-1 for a list of the equipment required by the main calibration procedure.

The calibration procedures consist of a number of calibration steps. While the user has no direct access to the procedures or the individual steps that comprise them, an understanding of their structure makes it easy to write an external computer program to utilize them. For this reason, the internal procedure architecture is described in the following section.

Procedure Architecture

There are three parts to a calibration procedure. Every procedure has an entry point, one or more steps, and an end point. In this section we will describe each of these and its implications for the programmer writing a calibration application.

Note

In this section, "controller" refers to the computer controlling the Calibrator. The term "@LFC" refers to the IEEE488 address of the Calibrator. The examples shown are in pseudo code.

`PROC <name>` (Defines the procedure entry point)

The procedure name is used to define the start of a calibration procedure. There are three (3) PROC definitions for the Calibrator: ZERO, MAIN, and DIAG. The name associated with the PROC declaration is used in conjunction with the CAL_START command to initiate a calibration procedure. The procedure names are defined below. Note that case is ignored.

ZERO

ZERO (The offset or zero's calibration procedure as described above.)

```
print @LFC "cal_start zero"
```

MAIN

MAIN (The main calibration procedure as described above.)

```
print @LFC "cal_start main"
```

DIAG

DIAG (The diagnostics procedure as described in that section).

```
print @LFC "cal_start diag"
```

Calibration Steps

There are four types of calibration steps: RUN, INS, REF and NOT.

Whenever a calibration procedure is running the controller may query the Calibrator to determine which of the four types of steps is currently being executed by the internal calibration engine. To query the Calibrator for the calibration step type, use the CAL_STATE? Command. As described below, the controller is expected to take different actions depending on the internal step type. See the example below:

```
print @LFC "CAL_STATE?"
input @LFC A$
print A$
(shows RUN)
```

RUN

A run step requires no external intervention (input or output) it simply runs an internal function to perform some calibration operation. Zero calibration is composed of an entry point, followed a number of RUN steps and an END.

Instruction Step (INS)

This step causes the procedure to pause at the current step and an instruction is made available via the CAL_INFO? command. To resume the procedure, a CAL_NEXT command must be issued. This step is used to inform the user that some operator intervention is required, such as an external connection to a measurement standard.

Note

The CAL_INFO? command is not mandatory.

Reference Step (REF)

A reference step, like an INS step, causes the procedure to pause and an instruction is made available via the CAL_INFO? command. Additionally, the controller is expected to supply a floating point number. This number is typically a reference reading from an external DMM. As an example, the internal calibration procedure may setup the Calibrator to source 1.9 V. Then a REF step would prompt the user to go to operate. The controller would need to send the operate command and command an external DMM to take a reading. The reading from the DMM would be sent to the Calibrator using a CAL_NEXT command. The Calibrator would use that value to calculate a new calibration constant and then would continue to the next step. See the example below:

```
print @LFC "CAL_INFO?"
input @LFC A$
print A$
(shows "Go to operate and measure the expected value.")
print @LFC "OPER"// Go to operate
INPUT @DMM reading// get measurement from DMM
print @LFC "CAL_NEXT" + reading// send DMM reading to LFC
```

NOT

NOT simply means that the calibration procedure in no longer running. If the controller determines that the NOT step was returned due to a normal termination of the calibration procedure, a CAL_STORE command MUST be issued to store the newly derived calibration constants into non volatile memory.

Once the calibration constants are saved, it is a good idea to reset the instrument using a *RST command

For a complete list of remote commands for calibration see Chapter 3 of the *57LFC/AN Operators Manual*.

During calibration, it is a good idea to check the Calibrator fault queue after each calibration command. This will alert the user to any problems during the calibration. To check the fault queue, send the command "ERR?" as shown below.

```
print @LFC "ERR?"
input @LFC A$
print A$
```

Verification Tests

The verification tests are used as the basis of:

- Final product testing performed in manufacturing
- Automated test system design
- Product acceptance by the end user

This section describes the minimum testing necessary to verify with reasonable certainty that the Calibrator is totally functional and will meet its published specifications over the specified environmental conditions and for the specified calibration interval. Any personnel using the verification tests must be familiar with the operation of the Calibrator and the have ability to set up and operate the recommended test equipment. While the verification tests were developed for manual testing, if the test steps listed are followed and test uncertainty ratios are kept above 3:1, automation of the verification test will meet the requirements of verifying the product specifications.

⚠⚠Warning

This instrument is capable of outputting lethal voltages. Observe all safety precautions. To avoid shock, the operator should not electrically contact the Output V or Sense binding posts during operation. Lethal voltages of up to 230 V ac or dc may be present.

Whenever the nature of the operation permits, keep one hand away from the equipment to reduce the hazard of current flowing through vital organs of the body.

The verification tests are sufficient to insure that the shipped units will meet and/or exceed published specifications over the specified environmental conditions and specified calibration interval. All tests limits are based on specifications measured within 23 °C +/- 3 °C (room temperature) and humidity less than 80%. Any test that fails will be rerun immediately. If the failure repeats, it will be noted as a failure and testing will continue with the next step if possible. Failures will be repaired and then the unit will be retested.

Test Equipment

The equipment listed in Table 3-1 is for reference only. You can substitute any of the equipment provided adequate measurement accuracy with a test uncertainty ratio of 4:1 if possible. Only equipment that is calibrated and traceable according to the manufacturer specifications may be used for performance verification testing.

Table 3-1. Recommended Equipment for Calibration and Verification

Recommended Equipment	Recommended Model	Purpose
Calibration and Verification Procedure	Chapter 3 of the *57LFC/AN Service Manual*	Define procedure test points and specifications
Test Lead Kit	Fluke 8508A-LEAD or equivalent	Cable interconnect assembly
8-1/2 digit DMM	Fluke 8508A DMM or equivalent	Measure DC Volts, DC Current, AC Volts, AC Current, and Resistance
Precision Calibrator	Fluke 5720A or equivalent	Characterize 8508 for ac voltage and ac current measurements
Harmonic Distortion Analyzer	Boonton 1130 or equivalent	Measure LF harmonic distortion of ac voltage and current
Harmonic Distortion Analyzer	Agilent ESA 4411A Spectrum Analyzer or equivalent	Measure harmonic distortion of ac voltage for f > 30 kHz
Test Controller	Computer with an IEEE-488 interface card or equivalent	Connect to and communicate with the Calibrator
Frequency Measurement	Fluke 8508A or counter with 10 Hz to 100 kHz frequency range and 25 ppm frequency uncertainty or equivalent	
Shunt Resistors (5% 1/8 watt unless noted)	0.1 (1 W), 10, 100, and 1 k	Harmonic testing for AC current
Load Resistors (10%)	1.8 (10 W), 40 (0.1 W), 440 (2 W), and 1k (5 W), and 22 k (5 W)	Compliance testing
Resistor Divider (10% 1/4 W)	2 M/20 k	Harmonic Testing

Calibrator Configuration and Pre-check

The Calibrator must be switched on and powered for at least 30 minutes prior to verification testing and the air filter inspected for adequate airflow. Refer to filter inspection and cleaning procedure provided in Chapter 4 for detailed cleaning instructions.

Verification can only be performed using a controller as the Calibrator has no front panel controls. Furthermore the Calibrator has no internal hardware adjustments.

When powered correctly the Calibrator front interface panel STANDBY LED indicator will illuminate (yellow). When in operate, the OPERATE LED will illuminate (green). If the output voltage goes above 30 V, the warning LED will illuminate (red). If the unit encounters an output fault, both the yellow and red LEDs will light. For example, if in current mode and the load is removed, a fault condition will be indicated since the output compliance voltage will go to a maximum value.

Self-test routines are executed at power up that test the internal controller device and memory. Any failure at power up will be displayed with both the yellow and red LEDs lighting. A failure message can be requested over the IEEE-488 bus as part of the instrument status (see Chapter 3 in the *57LFC/AN Operators Manual* for additional information).

Confirm Cal Enable (J1) is in the disabled condition before starting the rest of the verification procedures. If the unit passes all tests. Cover the Cal Enable switch with a calibration label.

DC Voltage Test

The dc voltage amplitude accuracy test verifies the accuracy of dc voltage at the Calibrator front panel output terminals. Use the specifications in Chapter 1 to determine maximum load for testing. Connect the equipment as shown in Figure 3-1 and verify the Calibrator is within the limits shown in Table 3-2.

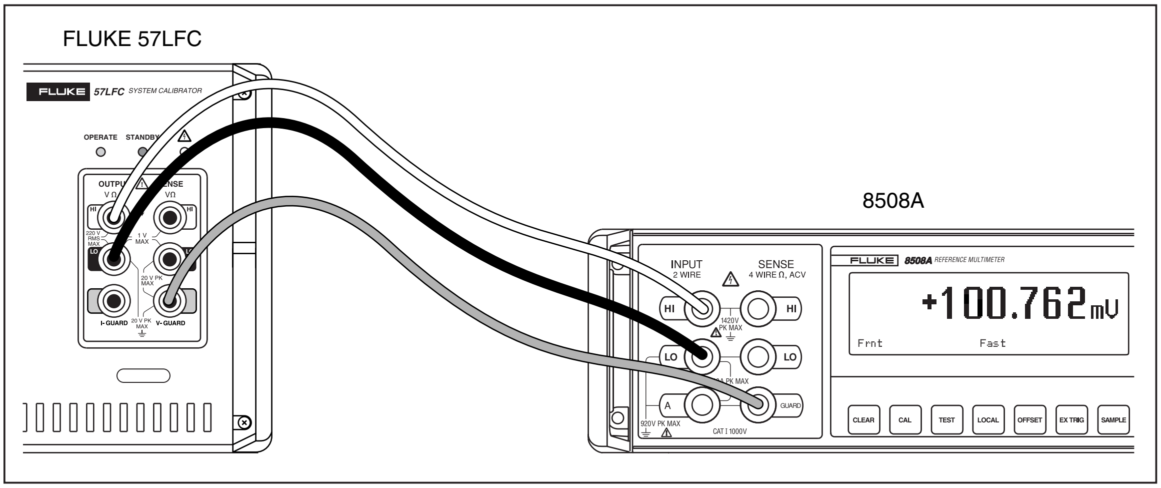

Figure 3-1. 8508A Connections to the 57LFC for DC Volts Measurement

Table 3-2. DC Volts Measurement Limits

Range	Amplitude	Reading	Upper Limit (V)	Lower Limit (V)
200.0E-3	0		2.40E-6	-2.40E-6
200.0E-3	219.0E-3		219.0075E-3	218.9925E-3
200.0E-3	-219.0E-3		-218.9925E-3	-219.0075E-3
2	0		2.40E-6	-2.40E-6
2	2.19		2.19003696	2.18996304
2	-2.19		-2.18996304	-2.19003696
20	0		24.00E-6	-24.00E-6
20	10		10.00017920	9.99982080
20	-10		-9.99982080	-10.00017920
20	21.9		21.9003696	21.8996304
20	-21.9		-21.8996304	-21.9003696
200	0		240.00E-6	-240.00E-6
200	219		219.0057984	218.9942016
200	-219		-218.9942016	-219.0057984

AC Voltage Tests

AC Voltage Accuracy Test

The ac voltage amplitude accuracy test verifies the accuracy of ac voltage at the Calibrator front panel terminals. First, use the 5720A to characterize all the points in Table 3-3. Next, connect the equipment as shown in Figure 3-2 and verify the Calibrator is within the limits shown in Table 3-3.

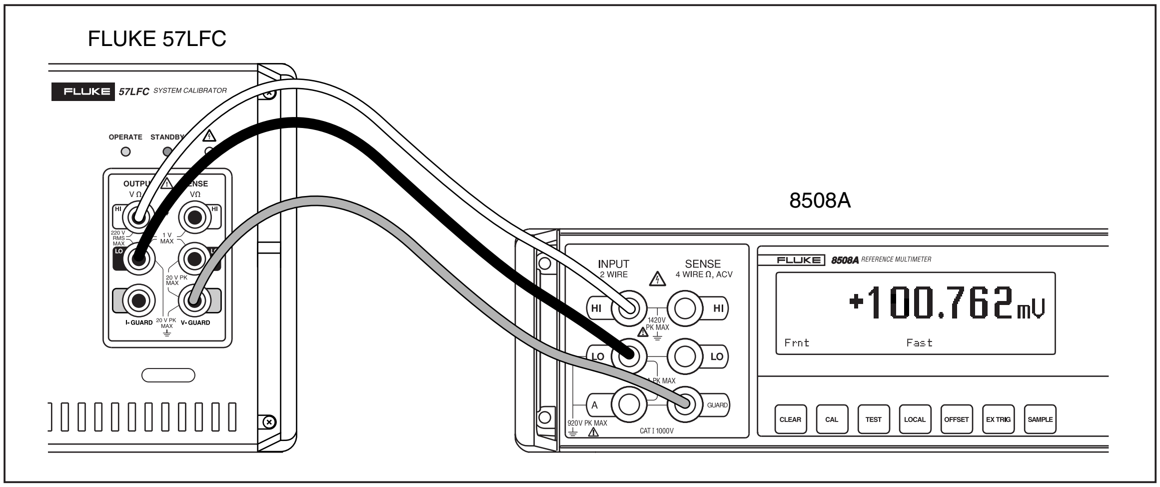

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Figure 3-2. 8508A Connections to the 57LFC for AC Volts Measurement

Table 3-3. AC Volts Measurement Limits

Range	Amplitude	Frequency	Reading	Upper Limit (V)	Lower Limit (V)
20.0E-3	21.9E-3	10		21.93382E-3	21.86618E-3
20.0E-3	21.9E-3	45		21.92401E-3	21.87599E-3
20.0E-3	21.9E-3	20.0E+3		21.92401E-3	21.87599E-3
20.0E-3	21.9E-3	50.0E+3		21.94784E-3	21.85216E-3
20.0E-3	21.9E-3	100.0E+3		22.00208E-3	21.79792E-3
200.0E-3	219.0E-3	10		219.2422E-3	218.7578E-3
200.0E-3	219.0E-3	45		219.1021E-3	218.8979E-3
200.0E-3	219.0E-3	20.0E+3		219.1021E-3	218.8979E-3
200.0E-3	219.0E-3	50.0E+3		219.3824E-3	218.6176E-3
200.0E-3	219.0E-3	100.0E+3		219.6886E-3	218.3114E-3
2	2.19	10		2.19156160	2.18843840
2	2.19	45		2.19076480	2.18923520
2	2.19	20.0E+3		2.19076480	2.18923520
2	2.19	50.0E+3		2.19160640	2.18839360
2	2.19	100.0E+3		2.19478400	2.18521600
20	21.9	10		21.9146560	21.8853440
20	21.9	45		21.9076480	21.8923520
20	21.9	20.0E+3		21.9076480	21.8923520
20	21.9	50.0E+3		21.9146560	21.8853440
20	21.9	100.0E+3		21.9363200	21.8636800
200	219	10		219.146560	218.853440
200	219	45		219.076480	218.923520
200	219	20.0E+3		219.076480	218.923520
200	219	53.88E+3		219.363200	218.636800
200	118	100.0E+3		118.409600	117.590400

Frequency Accuracy Test

The specification for frequency is 100 ppm (0.01%). Connect the 8508A to the Calibrator output terminals as shown in Figure 3-3. Then set the Calibrator to 2 V at the output frequencies specified in Table 3-4. Verify that the meter reads within the limits specified on the test record.

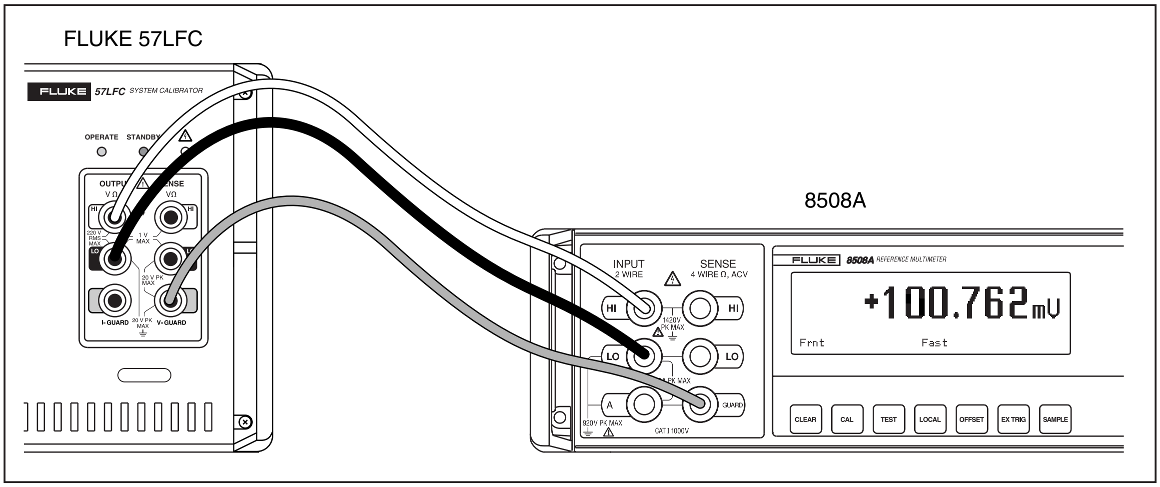

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Figure 3-3. 8508A Connections to the 57LFC for AC Frequency Measurement

Table 3-4. AC Frequency Values

Frequency Value	Measured Value	Lower Limit	Upper Limit
11 Hz		10.999296 Hz	11.000704 Hz
1000 Hz		999.936 Hz	1000.064 Hz
10000 Hz		99993.6 Hz	100006.4 Hz

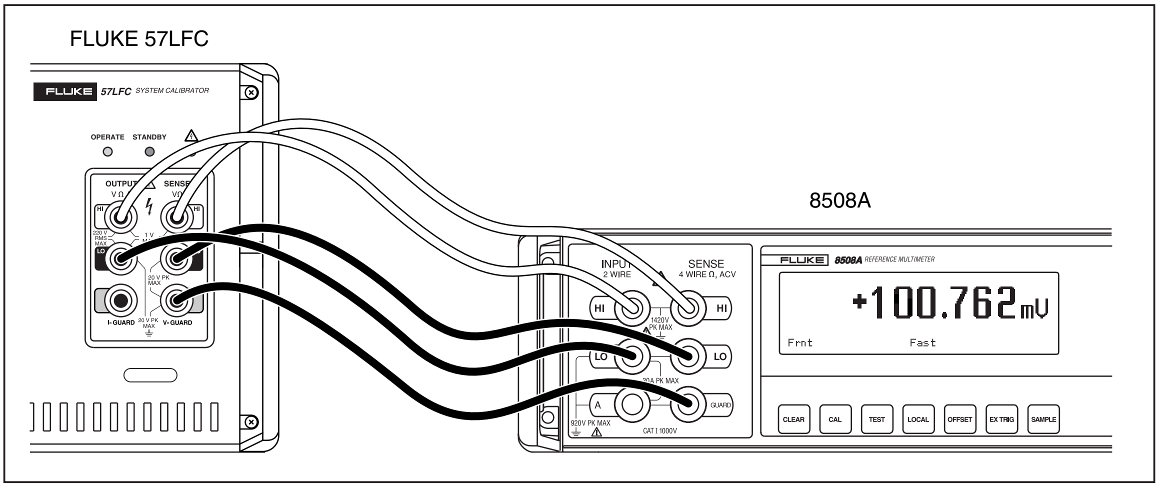

Figure 3-4. 8508A Connections to the 57LFC for 4-Wire Ohms

Table 3-5. 4-Wire Ohm Values

Nominal	Calibrated Value	Measured Value	Difference	Specification
0 Ω				640E-6 Ω
1 Ω				640E-6 Ω
1.9 Ω				1.280E-3 Ω
10 Ω				2.560E-3 Ω
19 Ω				5.120E-3 Ω
100 Ω				6.40E-3 Ω
190 Ω				12.80E-3 Ω
1.0E+ Ω3				64.0E-3 Ω
1.9E+3 Ω				128.0E-3 Ω
10.0E+3 Ω				640.0E-3 Ω
19.0E+3 Ω				1.280 Ω
100.0E+3 Ω				6.40 Ω
190.0E+3 Ω				12.80 Ω
1.0E+6 Ω				64.0 Ω
1.9E+6 Ω				128.0 Ω
10.0E+6 Ω				640.0 Ω
19.0E+6 Ω				1280.0 Ω

*Note: Calibrated ohm values are measured and stored during calibration. These values can be accessed remotely or from the factory test report supplied with the instrument. This measurement assumes four-wire connection. The measured value is made with a Fluke 8508A or equivalent.

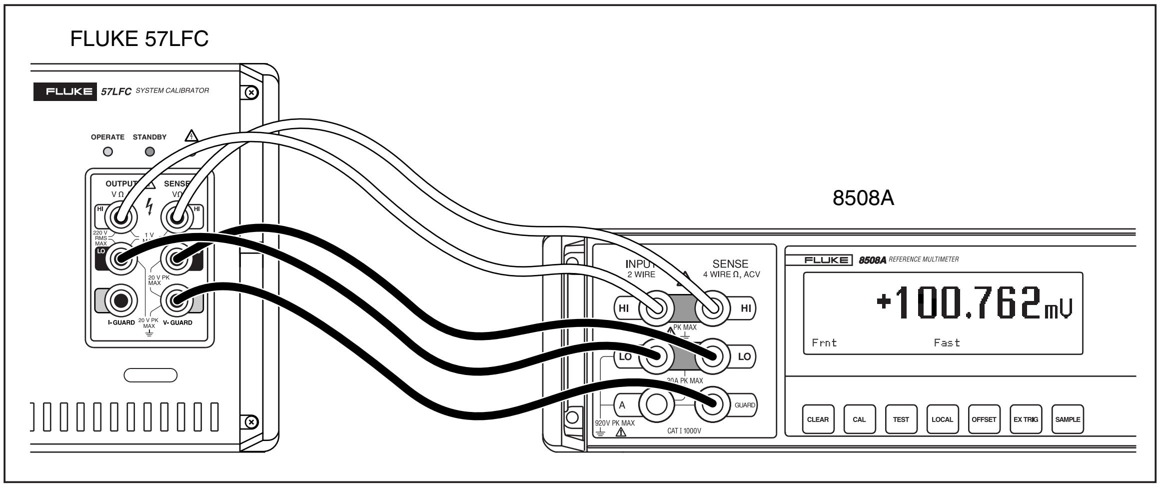

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Figure 3-5. 8508A Connections to the 57LFC for 2-Wire Compensated Ohms

Table 3-6. 2-Wire Ohm Values

Nominal	Calibrated Value	Measured Value	Difference	Specification
0 Ω				0.0013 Ω
1 Ω				0.0013 Ω
1.9 Ω				0.0019 Ω
10 Ω				0.0032 Ω
19 Ω				0.0058 Ω
100 Ω				0.0070 Ω
190 Ω				0.0134 Ω
1.00E+03 Ω				0.0704 Ω
1.90E+03 Ω				0.1344 Ω
1.00E+04 Ω				0.7040 Ω
1.90E+04 Ω				1.4080 Ω
1.00E+05 Ω				7.0400 Ω
1.90E+05 Ω				14.0800 Ω

DC Current Test

The dc current amplitude accuracy test verifies the accuracy of dc current at the Calibrator output terminals. First, use the 5720A to characterize all the points in Table 3-7. Next, connect the 8508A to the appropriate terminals on the Calibrator (as shown in Figure 3-6) and verify the Calibrator is within the limits shown in Table 3-7. Maximum compliance voltage is 4 V in 2.2 A range and 10 V on other ranges.

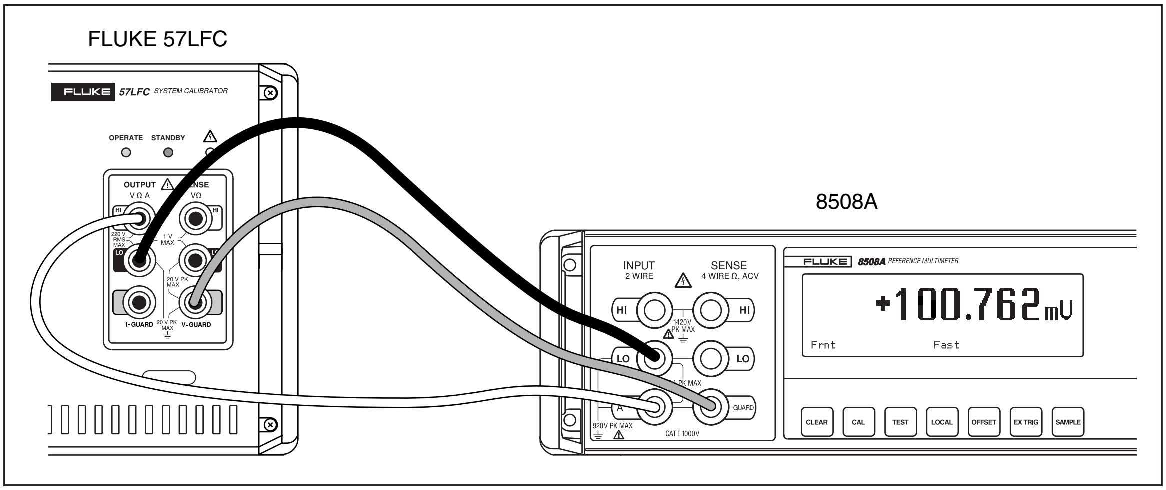

Figure 3-6. 8508A Connections to the 57LFC for DC Current Measurement

Table 3-7. DC Current Readings

Range	Amplitude	Reading	Upper Limit	Lower Limit
200.0E-6	000.0E+0		16.00E-9	-16.00E-9
200.0E-6	219.0E-6		219.082880E-6	218.917120E-6
200.0E-6	-219.0E-6		-218.917120E-6	-219.082880E-6
2.0E-3	0.00E+00		40.0E-9	-40.00E-9
2.0E-3	2.19E-3		2.1907328E-3	2.1892672E-3
2.0E-3	-2.19E-3		-2.1892672E-3	-2.1907328E-3
20.0E-3	0.00E+00		200.00E-9	-200.00E-9
20.0E-3	21.90E-3		21.907168E-3	21.892832E-3
20.0E-3	-21.90E-3		-21.892832E-3	-21.907168E-3
200.0E-3	000.0E+0		2.00E-6	-2.00E-6
200.0E-3	219.0E-3		219.0717E-3	218.9283E-3
200.0E-3	-219.0E-3		-218.9283E-3	-219.0717E-3
2.0	0.00		32.00E-6	-32.00E-6
2.0	2.19		2.1910067	2.1889933
2.0	-2.19		-2.1889933	-2.1910067

AC Current Test

The ac current amplitude accuracy test verifies the accuracy of AC Current at the Calibrator output terminals. First use the 5720A to characterize all the points in Table 3-8. Next, connect the equipment as shown in Figure 3-7 and verify the Calibrator is within the limits shown in Table 3-8. Maximum compliance voltage is 4 V in 2.2 A range and 7 V on other ranges

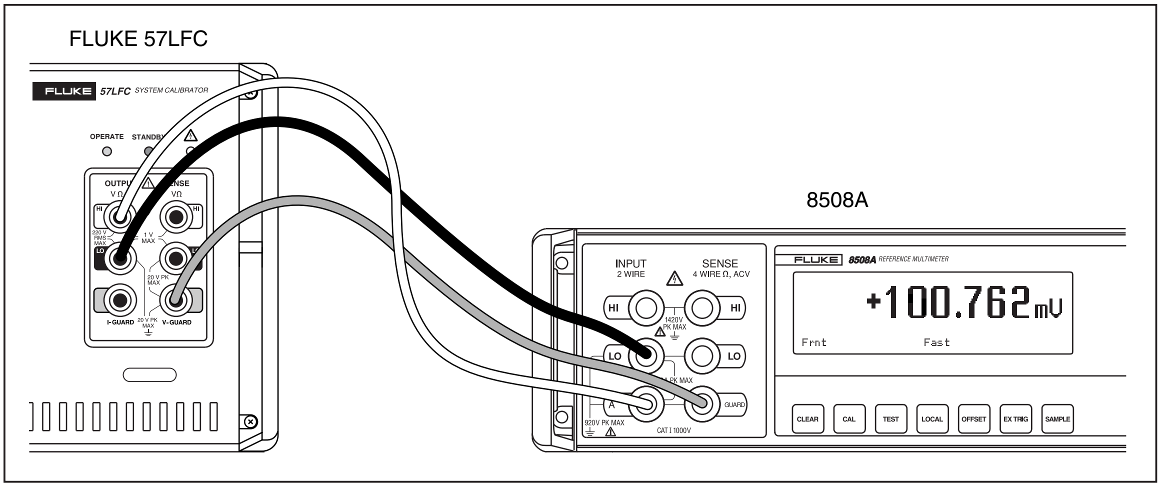

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Figure 3-7. 8508A Connections to the 57LFC for AC Current Measurement

Table 3-8. AC Current Limits

Range	Amplitude	Frequency	Reading	Upper Limit	Lower Limit
200.0E-6	219.0E-6	10		219.54848E-6	218.45152E-6
200.0E-6	219.0E-6	20		219.33824E-6	218.66176E-6
200.0E-6	219.0E-6	45		219.30320E-6	218.69680E-6
200.0E-6	219.0E-6	1.0E+3		219.30320E-6	218.69680E-6
200.0E-6	219.0E-6	5.0E+3		219.75264E-6	218.24736E-6
200.0E-6	219.0E-6	10.0E+3		221.35840E-6	216.64160E-6
2.0E-3	2.19E-3	10		2.1929952E-3	2.1870048E-3
2.0E-3	2.19E-3	20		2.1922944E-3	2.1877056E-3
2.0E-3	2.19E-3	45		2.1915936E-3	2.1884064E-3
2.0E-3	2.19E-3	1.0E+3		2.1915936E-3	2.1884064E-3
2.0E-3	2.19E-3	5.0E+3		2.1929952E-3	2.1870048E-3
2.0E-3	2.19E-3	10.0E+3		2.2015328E-3	2.1784672E-3
20.0E-3	21.90E-3	10		21.929952E-3	21.870048E-3
20.0E-3	21.90E-3	20		21.915936E-3	21.884064E-3
20.0E-3	21.90E-3	45		21.915936E-3	21.884064E-3
20.0E-3	21.90E-3	1.00E+3		21.915936E-3	21.884064E-3
20.0E-3	21.90E-3	5.00E+3		21.929952E-3	21.870048E-3
20.0E-3	21.90E-3	10.00E+3		21.959264E-3	21.840736E-3
20.0E-3	21.90E-3	20.00E+3		22.015328E-3	21.784672E-3
200.0E-3	219.0E-3	10		219.27149E-3	218.72851E-3
200.0E-3	219.0E-3	20		219.15936E-3	218.84064E-3
200.0E-3	219.0E-3	45		219.15936E-3	218.84064E-3
200.0E-3	219.0E-3	1.0E+3		219.15936E-3	218.84064E-3
200.0E-3	219.0E-3	5.0E+3		219.45248E-3	218.54752E-3
200.0E-3	219.0E-3	10.0E+3		219.62464E-3	218.37536E-3
200.0E-3	219.0E-3	20.0E+3		220.24928E-3	217.75072E-3
2.0	2.19	10		2.192714880	2.187285120
2.0	2.19	20		2.192714880	2.187285120
2.0	2.19	45		2.19159360	2.18840640
2.0	2.19	1.00E+03		2.19159360	2.18840640
2.0	2.19	5.00E+03		2.2059360	2.1740640
2.0	2.19	10.0E+3		2.2632800	2.1167200

Current Output Compliance Test

Connect the Calibrator to the 8508A as shown in Figure 3-8. Apply the load to the 8508A terminals. For safety reasons, please observe the power limits of the resistors used in the test. See Table 3-9 for power limits.

- Apply the maximum dc current output (1.8 Ω load for 4 V compliance voltage) when set to 2.19 A dc.
- Verify that the current remains at the correct limit by measuring the current as described in the resistance accuracy test earlier in this Chapter.

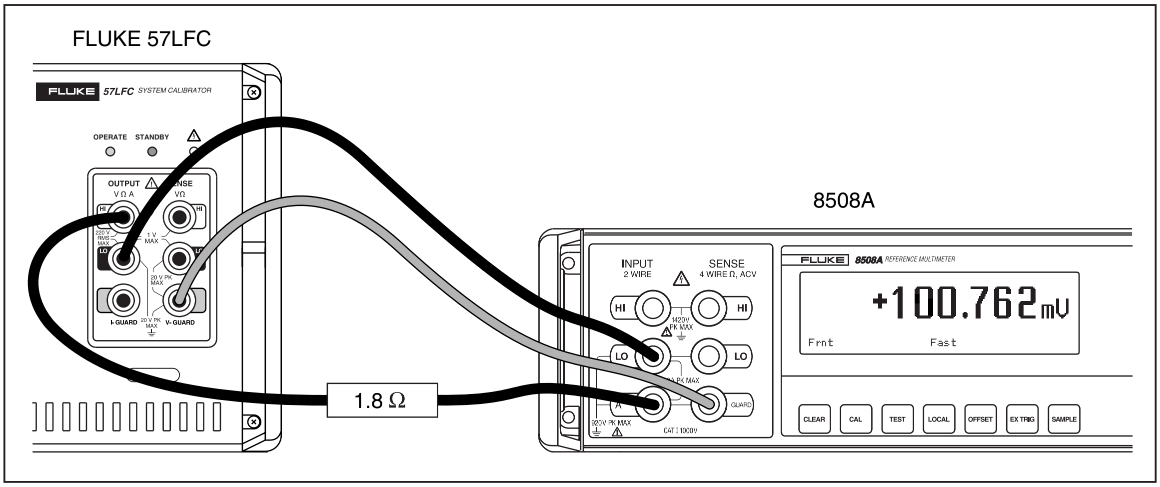

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Figure 3-8. 8508A Connections to the 57LFC for Load Current Compliance Test

Table 3-9. Current Output Compliance Limits

Amplitude	Frequency	Shunt	Reading	Upper Limit	Lower Limit
2.19 A	0	1.8 Ω		2.1910067	2.1889933

Voltage Output Compliance Test

⚠⚠Warning

This instrument is capable of outputting lethal voltages. Observe all safety precautions while performing this test.

Connect the Calibrator to the 8508A as shown in Figure 3-9. Apply the load to the 8508A terminals. For safety reasons, please observe the power limits of the resistors used in the test. Table 3-10 contains the test limits.

- Apply the maximum load (440 Ω for 50 mA) to the dc voltage output when set to 21.9 V dc (using 8508A to measure).
- Verify that the voltage is at the correct limit.
- Apply the maximum load (440 Ω) to the ac voltage output when set to 100 kHz and 21.9 V rms (using 8508A to measure).
- Verify that the voltage is at the correct limit.
- Apply the maximum load (11 kΩ for 20 mA) to the dc voltage output when set to 219 V dc (using 8508A to measure).
- Verify that the voltage is at the correct limit.

- Apply the maximum load (11 kΩ) to the ac voltage output when set to 1 kHz and 219 V rms (using 8508A to measure).
- Verify that the voltage is at the correct limit.

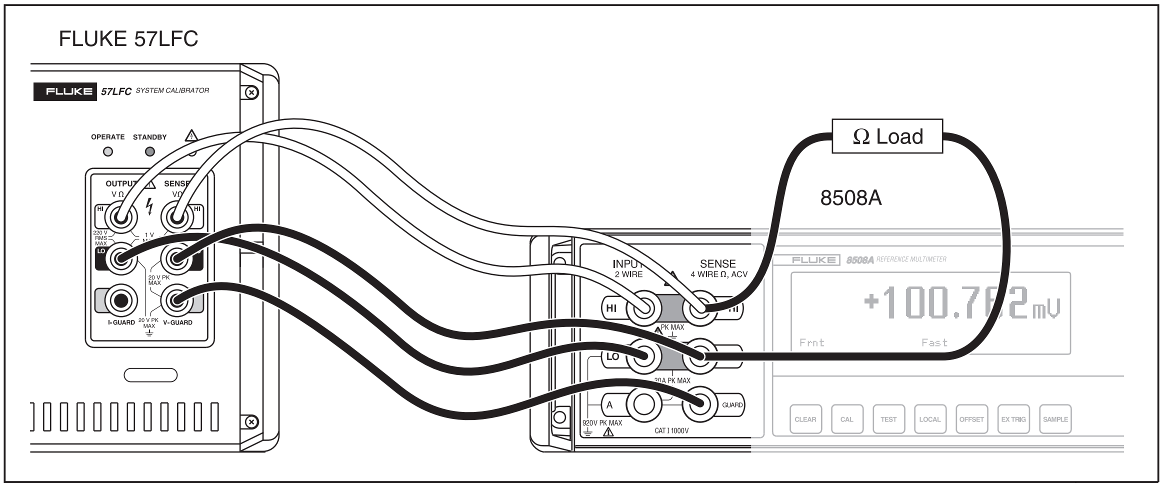

Figure 3-9. 8508A Connections to the 57LFC for Voltage Compliance Testing

Table 3-10. Voltage Output Compliance Limits

Range	Amplitude	Frequency	Reading	Upper Limit	Lower Limit
20 V	21.9	0		21.9003696 V	21.8996304 V
20 V	21.9	100.0E+3		21.9363200 V	21.8636800 V
200 V	219	0		219.005798 V	218.994201 V
200 V	219	1kHz		219.1195 V	218.8805 V

Harmonic Test Levels for AC Volts

The harmonic ac voltage test verifies that the output ac signal has a limited amount of noise in the signal. For these tests, the use of the distortion analyzer or spectrum analyzer is required. Follow the vendor's specifications for setting up those instruments. The connection used will depend on which test instrument is used. Figure 10 shows the set up used for a Booton 1130A and Agilent 4411A instrument. The Booton is used below 30 kHz and the Agilent is used above 30 kHz. A set of test limits is provided in Table 3-11.

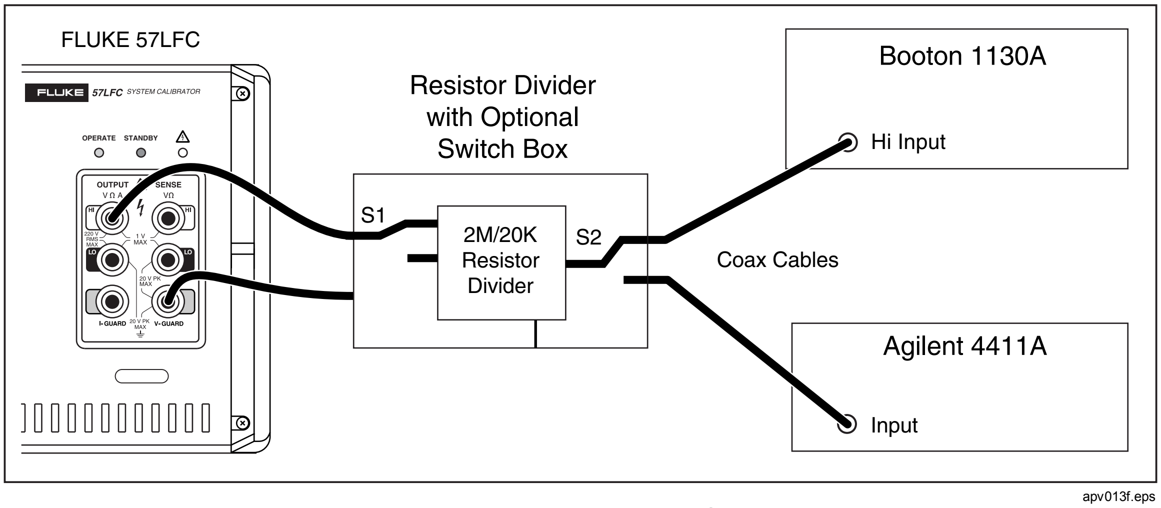

Figure 3-10. Harmonic Test Setup

Table 3-11. Harmonic Test Values for AC Volts

Amplitude	Frequency	Load	Reading	Maximum Distortion
20.0E-3	10.0E+0			0.600%
20.0E-3	45.0E+0			0.485%
20.0E-3	20.0E+3			0.485%
20.0E-3	50.0E+3			0.600%
20.0E-3	100.0E+3			0.700%
200.0E-3	10.0E+0			0.195%
200.0E-3	45.0E+0			0.080%
200.0E-3	20.0E+3			0.080%
200.0E-3	50.0E+3			0.195%
200.0E-3	100.0E+3			0.245%
2.0	10.0E+0			0.160%
2.0	45.0E+0			0.045%
2.0	20.0E+3			0.045%
2.0	50.0E+3			0.160%
2.0	100.0E+3			0.210%
20.0	10.0E+0			0.160%
20.0	45.0E+0			0.045%
20.0	20.0E+3			0.045%
20.0	50.0E+3			0.210%
20.0	100.0E+3			0.510%
200.0	10.0E+0			0.155%
200.0	45.0E+0			0.055%
200.0	20.0E+3			0.055%
219.0	50.0E+3			0.805%
118.0	100.0E+3			1.008%
2	10	40 Ω		0.160%
2	100.0E+3	40 Ω		0.210%
14.2	10	400 Ω		0.164%
14.2	100.0E+3	400 Ω		0.514%
219	50.0E+3	22000 Ω		0.805%

Harmonic AC Current Test

The harmonic ac current test verifies that the output ac signal has a limited amount of noise in the signal. A distortion analyzer is required for this test. Follow the vendor's specifications for setting up those instruments. It is necessary to use a shunt resistor across the Calibrator output. A set of test limits is provided in Table 3-12. See Figure 3-10 for a sample test setup.

Table 3-12. Harmonic Test Values for AC Current

Amplitude	Frequency	Shunt	Reading	Maximum Distortion
219.0E-6	1.0E+3	1000 Ω		0.2783%
219.0E-6	10.0E+3	1000 Ω		1.2283%
2.19E-3	1.0E+3	100 Ω		0.1185%
2.19E-3	10.0E+3	100 Ω		1.0685%
21.9E-3	1.0E+3	10 Ω		0.0928%
21.9E-3	10.0E+3	10 Ω		0.7228%
21.9E-3	20.0E+3	10 Ω		1.0228%
219.0E-3	1.0E+3	1 Ω		0.0928%
219.0E-3	10.0E+3	1 Ω		0.7228%
219.0E-3	20.0E+3	1 Ω		1.0228%
2.0	1.0E+3	0.1 Ω		0.0950%
2.0	10.0E+3	0.1 Ω		2.0250%

External Trigger

No external trigger mechanism is available on the Calibrator.

Verification Test Check List

Verification Test Procedure			
Date			
Temperature (23 °C +/- 3 °C)			
Serial Number for the Calibrator Under Test			
AC Mains		120 V/60 Hz	
Operator			
Verification Test Procedure Check List		**Equipment**	**Test Results (Pass/Fail)**
Calibrator Configuration and Pre-check			
	Unit powered for 30 minutes	None	
	Switch set to disable calibration	None	
	Yellow LED lights on Standby	None	
	Green LED lights on Operate	None	
	Red LED lights at 30 V ac	None	
	Red and Yellow LEDs light when load removed during current output	0.1 Ω shunt resistor or equivalent	
	Output relays disconnect terminals from instrument during self test.	None	
DC Voltage		Fluke 8508A or equivalent	
AC Voltage			
	Frequency Accuracy	Fluke 8508A or equivalent	
	ACV Accuracy	Fluke 8508A or equivalent	
DC Current		Fluke 8508A or equivalent	
AC Current		Fluke 8508A (characterized by a Fluke 5720) or equivalent	
Resistance		Fluke 8508A or equivalent	
	2-wire		
	4-wire		
Harmonic Test Levels for AC Volts		Booton and Agilent Analyzer with resistor divider	
Harmonic Test Levels for AC Current		Booton and Agilent Analyzer with resistor divider	
External Trigger			
	No external trigger mechanism is available on the Calibrator	NA	
Voltage Output Compliance Test		Fluke 8508A or equivalent with 440 W (22 V) or 11 kW load resistor (220 V)	
Current Output Compliance Test		Fluke 8508A or equivalent with 1.8 Ω combined shunt resistance	

Chapter 4
Maintenance

Title	Page

Introduction

This chapter explains how to perform the maintenance tasks required to keep your calibrator in optimal operating condition. The tasks covered in this chapter include the following.

- Replacing the fuse
- Cleaning the air filter and external surfaces
- Replacing the PCA modules

Replacing the Fuse

⚠⚠Caution

To prevent instrument damage, verify that the correct fuse is installed for the line voltage setting.

The line power fuse is accessible on the front panel. The fuse rating label to the right of the fuse holder shows the correct replacement fuse rating for each operating voltage. To check or replace the fuse:

1. Disconnect line power.
2. Insert a small screwdriver in the fuse holder release slot and push upward until the fuse compartment pops free. See Figure 4-1.
3. Slide the fuse and fuse holder out of the fuse compartment.
4. Inspect or replace the fuse.
5. Install the fuse compartment in the calibrator.

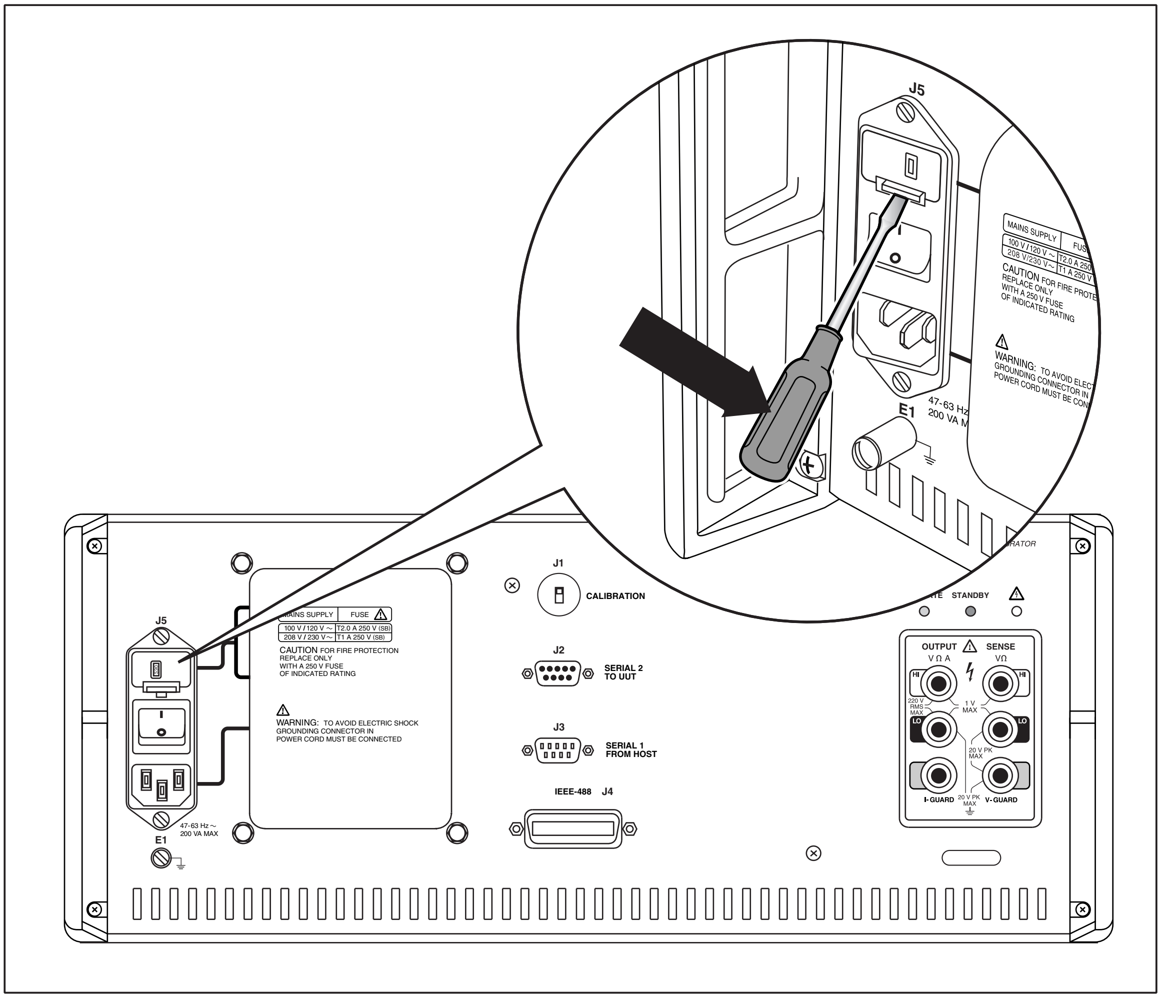

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Figure 4-1. Replacing the Fuse

Cleaning the Air Filter

⚠⚠Caution

Damage caused by overheating may occur if the area around the fan is restricted, the intake air is too warm, or the air filter becomes clogged.

The air filter must be removed and cleaned at least every 30 days, or more frequently if the calibrator is operated in a dusty environment. The air filter is accessible from the rear panel of the Calibrator. To clean the air filter:

1. Disconnect line power.
2. Remove the filter by pulling the filter's retainer downwards (it hinges at the bottom) and removing the filter element.
3. Clean the filter by washing it in soapy water. Rinse and dry it thoroughly before reinstalling.
4. Reinstall the filter.

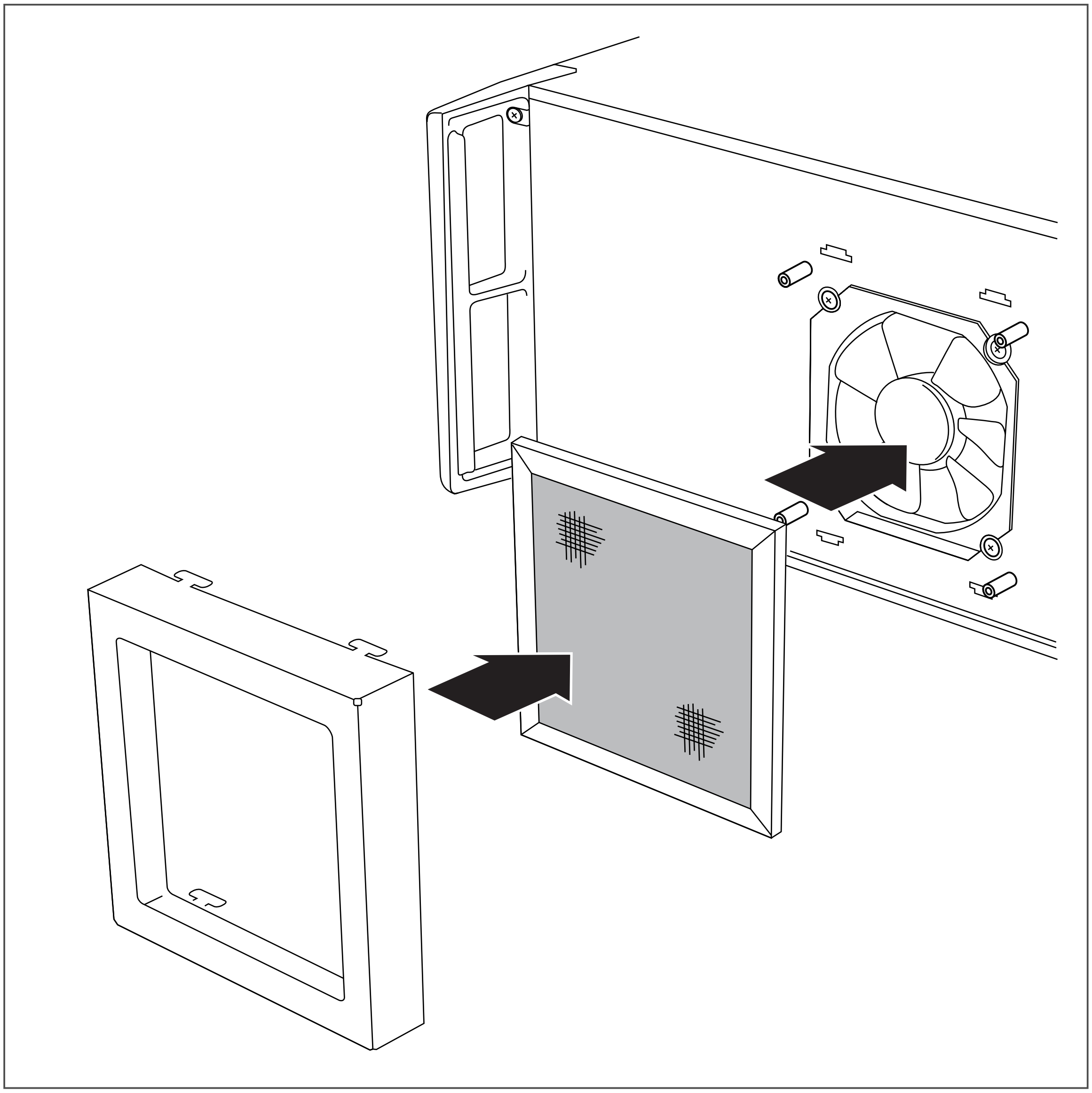

Figure 4-2. Accessing the Air Filter

Replacing PCA Modules

Follow the steps below to replace PCA modules in the Calibrator. Refer to Figure 4-3 for a disassembly illustration and the location of the PCA modules.

1. Turn the Calibrator off and disconnect line power.
2. Remove the six screws holding the top cover in place. Remove the top cover.
3. Remove the two screws holding the guard cover in place. Tilt the guard cover up and leave vertical or remove the guard cover.
4. Remove the required module using the module extractors.

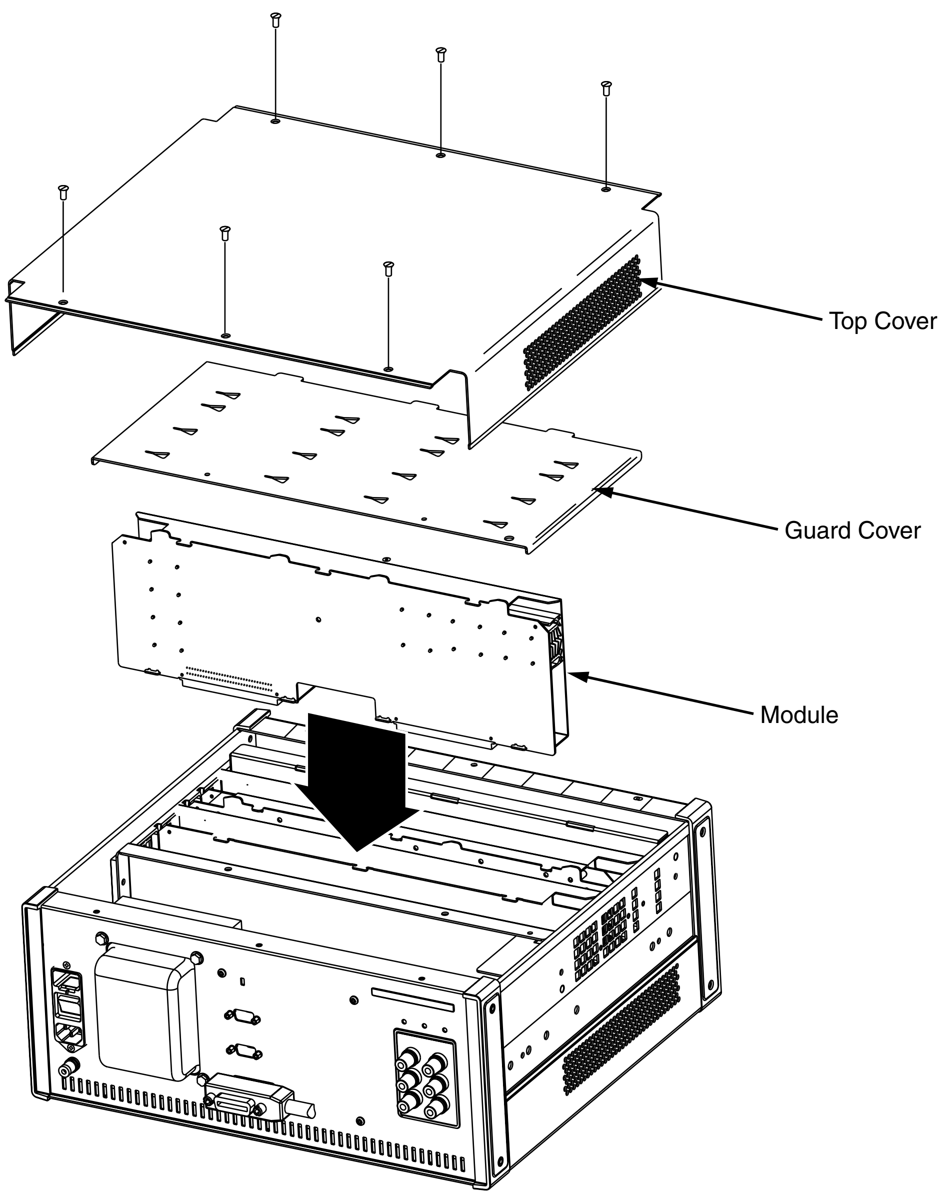

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Figure 4-3. Exploded View of the Calibrator

Cleaning the Exterior

To keep the calibrator looking like new, clean the case using a soft cloth slightly dampened with either water or a non-abrasive mild cleaning solution that is not harmful to plastics.

⚠⚠Caution

Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They can damage the plastic materials used in the Calibrator.

Chapter 5
List of Replaceable Parts

Title **Page**

Introduction

This Chapter contains a list of field replaceable parts for the Calibrator. Parts are listed by assembly. Each assembly is accompanied by an illustration showing the location of each part and its reference designator. The parts lists give the following information:

- An indication if the part is subject to damage by static discharge
- Description
- Fluke item number
- Any special notes (i.e., factory-selected part)

The replaceable parts list is limited to removable module assemblies and ancillary hardware such as screws nuts and structural parts that may become damaged or lost during repair or shipping. The Calibrator is intended to be repaired to the component level by Fluke authorized personnel only. All others are encourage to localize faults to the module assembly and then to exchange the assembly through the Fluke Product Exchange System.

Note

Once parts have been replaced, the Calibrator must be fully adjusted and verified to be within manufacturer's specification before being returned to normal use.

⚠⚠CAUTION

The Calibrator may be damaged by static discharge if improperly handled.

How to Obtain Parts

Listed parts may be ordered directly from Fluke Corporation and its authorized representatives by using the part number. Parts price information is available from the Fluke Corporation or its representatives.

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 containing the part
- Fluke part number
- Description (as given under the DESCRIPTION heading)
- Quantity

Refer to Contacting Fluke earlier in this manual for more information.

Service Centers

All Calibrators delivered to the Navy, contractors and subcontractors for the RTCASS program will be repaired and calibrated at the Fluke Technical Support Center in Everett, Washington. Contact Fluke Technical Support at 1-888-993-5853 or by sending a fax to 1-425-446-6390. The address for the Fluke Technical Support Center is:

Fluke Technical Support Center
1420 75th ST SW
Everett, WA 98203-6256
U. S. A.

Once full production is started the following service centers will also maintain and calibrate the Calibrator in Europe.

FLUKE NEDERLAND B.V.
Customer Support Services
Science Park Eindhoven 5108
5692 EC Son
Netherlands

FLUKE DEUTSCHLAND GMBH
Customer Support Services
Heinrich Hertz Straße 11
D-34123 Kassel
Germany

and in Asia,

FLUKE SOUTH EAST ASIA PTE LTD.
Service Center
83 Clemenceau Avenue
#15-15/06 Ue Square
239920
Singapore

Parts Lists

The following tables list the replaceable parts for the 57LFC System Calibrator. Parts are listed by assembly and alphabetized by reference designator. Each assembly is accompanied by an illustration showing the location of each part and its reference designator.

Table 5-1. Final Assembly

Ref Des	Description	Part Number	Qty
A1	LED PCA	2096773	1
A3	MOTHERBOARD PCA	2048925	1
A5	OHMS PCA	2048887	1
A6	DIGITAL SYNTHESIS PCA	2116745	1
A7	CURRENT , PCA	2048916	1
A8	HIGH VOLTAGE PCA	2048868	1
A9	OUT-GUARD CPU PCA	2110808	1
F1	FUSE,.25X1.25,2A,250V,SLOW	109181	1
F2	FUSE,.25X1.25,1A,250V,SLOW	109272	1
H1	WASHER, LOW THERMAL #8	859939	12
H2	NUT, LOW THERMAL, 8-32	850334	14
H3	NUT,HEX,ELASTIC STOP,STL,10-32,.375	944350	4
H4	SCREW,6-32,.250,PAN,PHILLIPS,STEEL,ZINC-CLEAR,LOCK	152140	17
H5	WASHER,FLAT,STL,.203,.434,.031	110262	4
H6	CONNECTOR, ACC,MICRO-RIBBON,SCREW LOCK	854737	2
H7	SCREW,FHU,P,SS,6-32,.312	867234	2
H8	SCREW,FHU,P,LOCK,MAG SS,6-32,.250	320093	17
H9	NUT,HEX,BR,1/4-28	110619	1
H10	SCREW,6-32,.375,PAN,PHILLIPS,STEEL,ZINC-CLEAR,LOCK	152165	14
H11	SCREW,6-32,1.250,PAN,PHILLIPS,STEEL,ZINC-CLEAR,LOCK	159756	4
H12	SCREW,CAP,SCKT,SS,8-32,.375	295105	20
H13	2 3/4 SCREW 10-32, MODIFIED	2095974	4
H14	CONNECTOR ACCESSORY,D-SUB JACK SCREW,4-40,.250 L,W/FLAT WASHER	1777348	4
H15	WASHER,LOCK,SPLIT,STL,.255,.491,.062	111518	4
LF1	POWER ENTRY MODULE,LINE FILTER,A/C INLET,ON/OFF SWITCH,1-POLE,4A,250VAC,BULK	2065010	1
LF2	POWER ENTRY MODULE,CUSTOM FUSE DRAWER,MARKINGS 100 120 208 230, BULK	2065022	1
MP1	OUTPUT BLOCK DECAL	2100381	1

Table 5-1. Final Assembly (cont)

Ref Des	Description	Part Number	Qty
MP2	BINDING POST-RED	886382	2
MP3	BINDING POST-BLACK	886379	2
MP4	BINDING POST-PURPLE	886361	1
MP5	BINDING POST-BLUE	886366	1
MP6	GASKET, FRONT PANEL	627072	4
MP7	SHIM,TRANSFORMER	625985	1
MP8	HANDLE,INSTRUMENT, GRAY #7	886333	4
MP9	CLAMP,CABLE,.50 ID,ADHESIVE MOUNT	688629	1
MP10	FAN ASSEMBLY	2096806	1
MP11	SHOCK ABSORBER	878983	2
MP12	EXTRUSION, SIDE	2113208	2
MP13	BOTTOM FOOT, MOLDED, GRAY #7	868786	4
MP14	BINDING POST, STUD, PLATED	102707	1
MP15	BINDING HEAD, PLATED	102889	1
MP16	7 INCH CORNER	2065186	4
MP17	AIR FILTER	945287	1
MP18	TRANSFORMER	2066205	1
MP19	INSERT, PLASTIC SIDE	937276	2
MP20	GROUND STRIP,BECU FINGERS,ADHES,.32 W,12.5 L	601762	4
MP21	GROUND STRIP,CU FINGERS,.32,12.50	601770	4
MP22	FRONT PANEL DECAL	2097147	1
TM1	57LFC/AN CD ROM	2103419	1
W1	CABLE ASSEMBLY, MOTHERBOARD	2065343	1
W2	LINE CORD,NORTH AM,10A,5-15/IEC,18/3,SVT,7.5 FT	284174	1
W3	TRANSFORMER GROUND CABLE	2095956	1

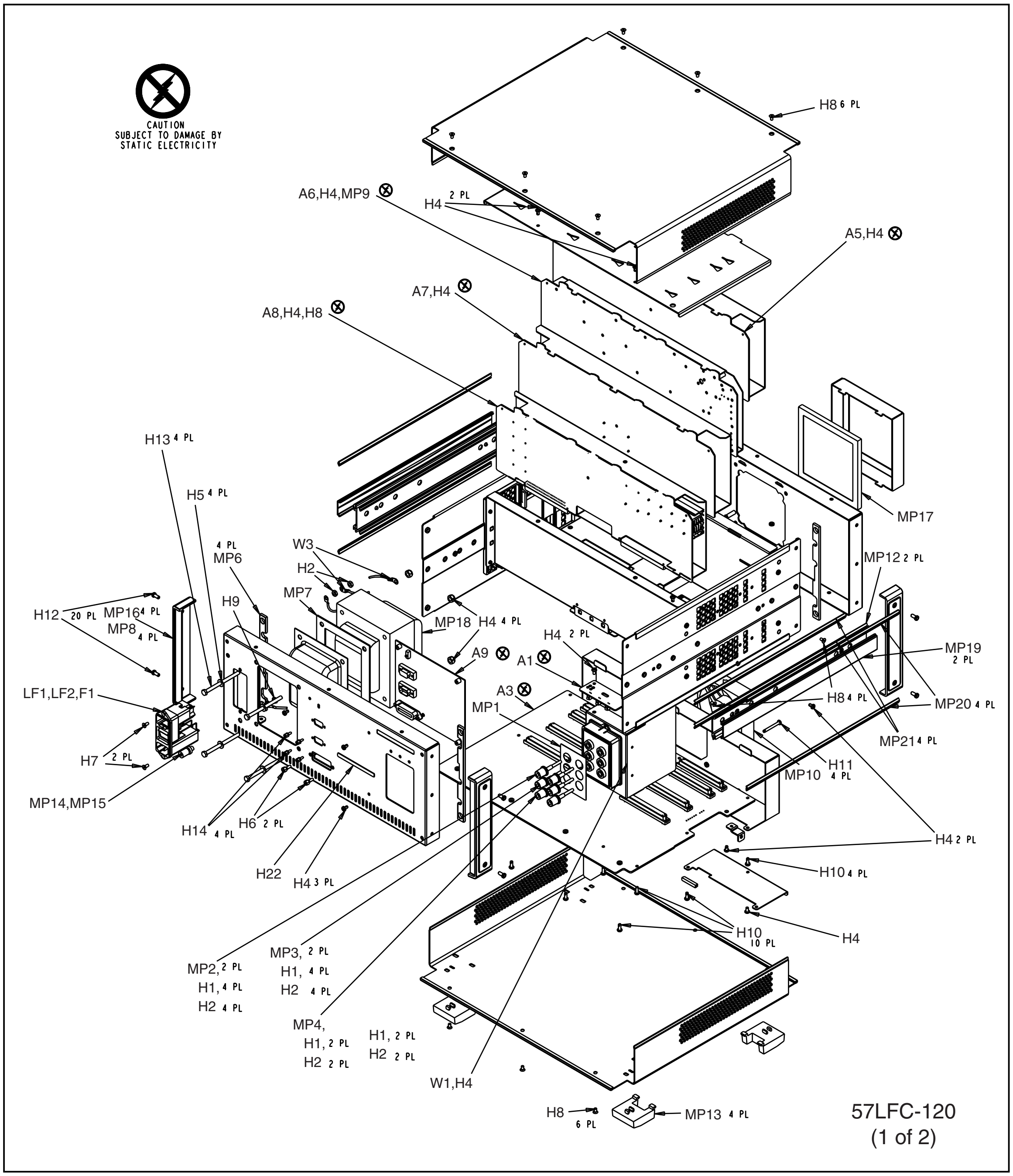

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Figure 5-1. Final Assembly

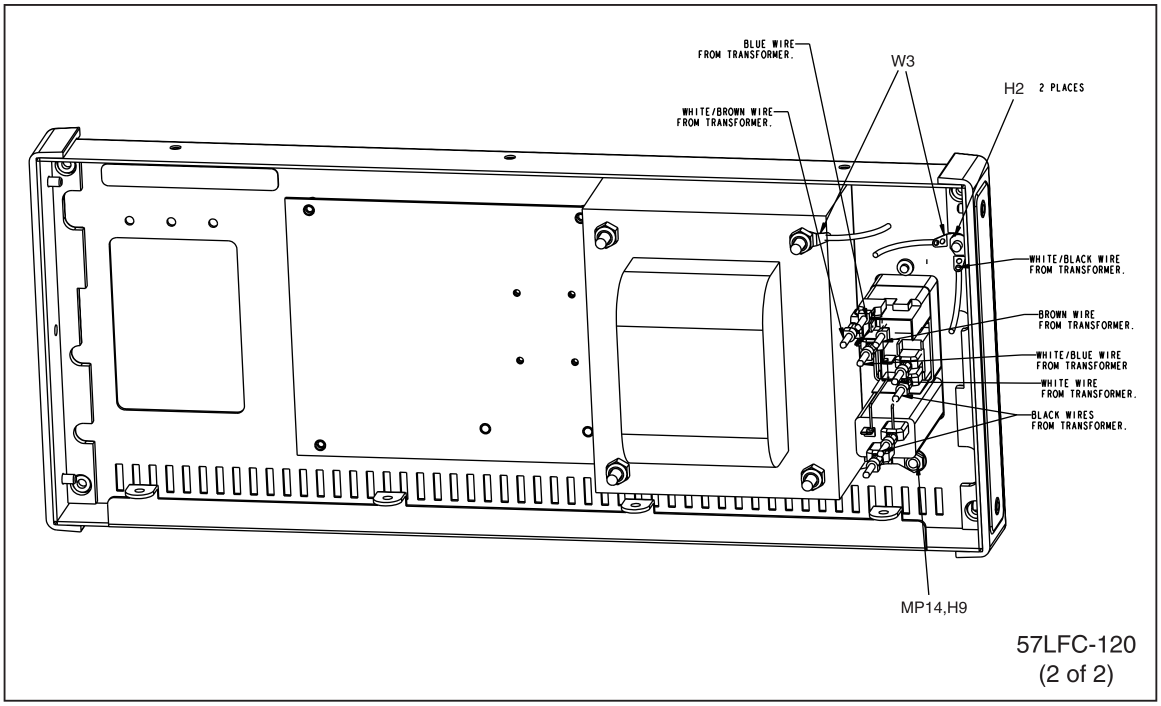

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Figure 5-1. Final Assembly (cont)

Table 5-2. A1 LED PCA

Ref Des	Description	Part Number	Qty
DS1	LED,RED,RIGHT ANGLE,3.0 MCD	927389	1
DS2	LED,YELLOW,HLMP-1401,2.2MCD,10MA,1.5 / 2.4V,60 DEG VIEW ANGLE,T1 RT ANGLE,BULK	914242	1
DS3	LED,GREEN,RIGHT ANGLE,2.6 MCD	944801	1
MP1	LED, PCB	2096764	1
N/A	LED CABLE	2100054	1
N/A	CABLE ACCESSORY,CABLE ACCESS,TIE,4.00L,.10W,.75 DIA	172080	2

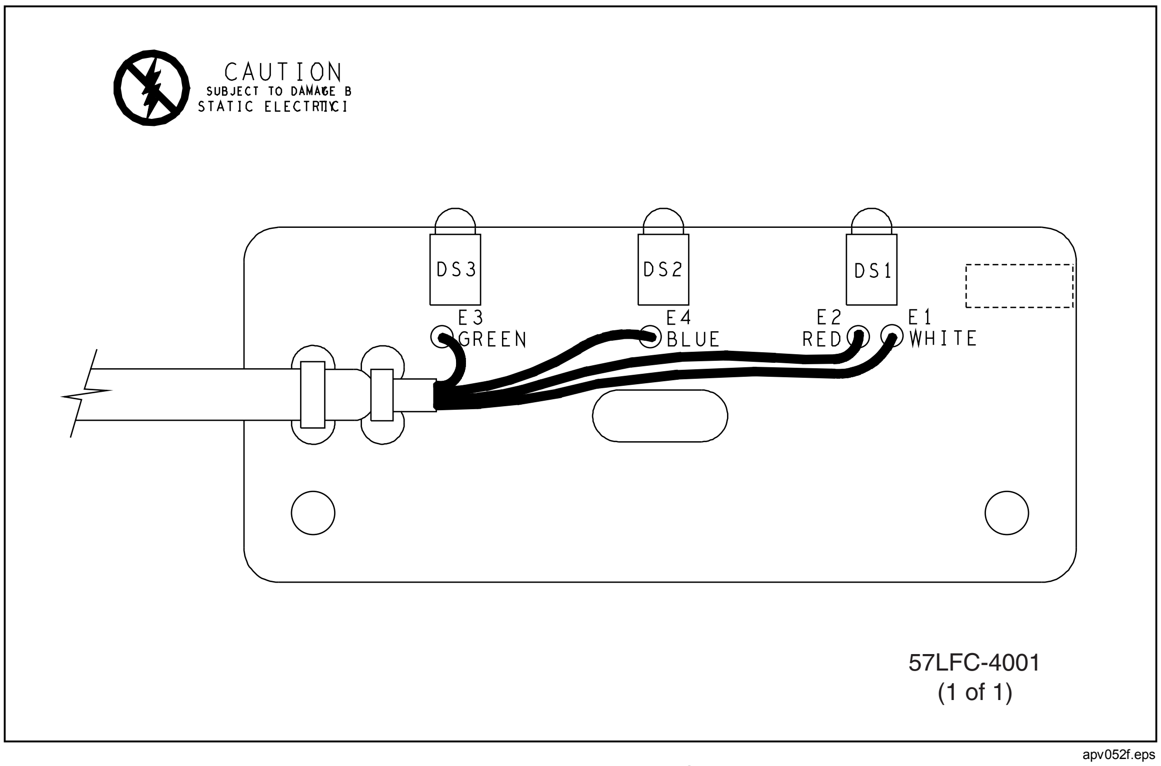

Figure 5-2. A1 LED PCA

Table 5-3. A3 Motherboard PCA

Ref Des	Description	Part Number	Qty
C1 C3 C15 C19	CAPACITOR, SMR,CAP,TA,4.7UF,+-10%,35V,6032	605441	4
C2 C4-6 C8 C11-12 C17-18 C20-27 C29 C32-35 C38 C41 C45-46 C48-49 C51-52 C55-56 C58 C60 C62-68 C75 C79-82 C88-89 C95-96 C99-100 C102-107 C116-120 C122	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,50V,X7R,1206	605292	64
C10 C57 C59	CAPACITOR, CERAMIC,100PF,+-5%,100V,C0G,0805,TAPE	601028	3
C14	CAPACITOR, SMR,CAP,CER,10PF,+-5%,50V,C0G,0805	494781	1
C28 C30-31	CAPACITOR, SMR,CAP,CER,0.22UF,+-10%,25V,X7R,1206	106625	3
C36-37 C50 C108	CAPACITOR, R05A,CAP,AL,47UF,+-20%,50V,SOLV PROOF	822403	4
C39 C43-44 C61 C76 C98	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	6
C40 C42 C77 C85	CAPACITOR, R05A,CAP,AL,100UF,+-20%,16V,SOLV PROOF	816850	4
C47 C70	CAPACITOR, CAP,AL,15000UF,+-20%,16V,25X30	803764	2
C53 C87	CAPACITOR, CAP,AL,47000UF,+-20%,16V	601259	2
C54 C71	CAPACITOR, CERAMIC,0.01UF,+-10%,50V,X7R,0805,TAPE	106146	2
C69 C78 C86	CAPACITOR, CAP,AL,2200UF,+-20%,25V,SOLV PROOF	782383	3
C72 C90 C93-94	CAPACITOR, ELECTROLYTIC,ALUMINUM,3300UF,+-20%,35V,22X25,BULK	2065600	4

Table 5-3. A3 Motherboard PCA (cont)

Ref Des	Description	Part Number	Qty
C73-74 C91-92	CAPACITOR, CAP,AL,47UF,+-20%,400V,SOLV PROOF	782532	4
C83 C101	CAPACITOR, CAP,AL,330UF,+-20%,100V,SOLV PROOF	816785	2
C84 C97 C121	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,100V,X7R,1206	804325	3
C109	CAPACITOR, R05A,CAP,POLYES,1UF,+-10%,50V	733089	1
CR1-2	DIODE,SI,125V,200MA,DO-35	802550	2
CR3 CR5 CR12 CR14 CR16-17 CR20-21 CR23 CR26 CR28-29 CR31 CR34-36 CR38-39 CR41-43 CR48 CR50 CR52-59 CR63 CR68-69 CR89 CR92	DIODE,SI,PN,S1G,400V,1A,1.8US,DO-214AC,TAPE	107573	36
CR4 CR45	DIODE,SI,PN,BAV199,70V,215MA,3US,DUAL,SERIES,SOT-23,TAPE	605805	2
CR6-11 CR13 CR15 CR37 CR40 CR44 CR47 CR79-80 CR88	DIODE,SI,DUAL,50V,250MA,SOT-23	851659	15
CR18-19 CR24-25 CR33 CR49 CR90-91	DIODE,SI,SCHOTTKY,40V,1A,DO-214AB	605821	8

Table 5-3. A3 Motherboard PCA (cont)

Ref Des	Description	Part Number	Qty
CR22 CR27 CR60-61 CR64-65	DIODE,SI,SCHOTTKY,40V,3A,DO-204AE	604546	6
CR46 CR66-67	DIODE,SI,PN,DF01S,100V,1A,BRIDGE,4 PIN SURFACE MOUNT,3530,TAPE	912456	3
CR51 CR62	DIODE BRIDGE,SI,200V,1.5A,SIP	296509	2
CR70-76 CR78	DIODE,SI,1KV,1A,DO-41	707075	8
CR77	DIODE BRIDGE,SI,800V,1A,SIP	341016	1
CR81-82	DIODE,SI,DUAL,70V,50MA,SOT-23	742544	2
CR83-87	DIODE,SI,SCHOTT,DUAL,30V,200MA,SOT-23	942594	5
E12-16	NUT,BROACH,STL,6-32	393785	5
F1-6	FUSE,8X8.5MM,0.2A,250V,SLOW,RADIAL	851949	6
H1-16	RIVET,AL,.089 DIA,.250 L,SEMI-TUBULAR,OVAL HEAD,DEEP HOLE	838482	16
J1	HEADER,2 ROW,2MMCTR,RT ANG,20 PIN	686725	1
J6	HEADER,2 ROW,2MMCTR,RT ANG,20 PIN	686725	1
J105-108 J205-208	CONNECTOR,DIN41612,TYPE C,64 SCKT	807818	8
K1 K3-7 K9-11	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	603001	9
K2	RELAY,ARMATURE,4 FORM C,5V,LATCH	715078	1
K8	RELAY,ARMATURE,2 FORM C,5 VDC,LATCH	910773	1
L1-10	CHOKE,38.4UH,6TURN,6160A-8002,BULK	320911	10
MP1	PCB, MOTHERBOARD	2048831	1
MP15-18	CONNECTOR, ACC,DIN41612,KEY	832733	4
P1	HEADER,1 ROW,.156CTR,8 PIN	385435	1
P2	HEADER,1 ROW,.156CTR,16 PIN	831370	1
P3	CONNECTOR, MATE-N-LOK,HEADER,8 PIN	570515	1
P4	HEADER,1 ROW.100CTR,RT ANG,3 PIN,FRICTION LOCK	2083751	1
P5	HEADER,1 ROW,.100CTR,3 PIN	845334	1
P8	HEADER,1 ROW,.100CTR,4 PIN	631184	1

Table 5-3. A3 Motherboard PCA (cont)

Ref Des	Description	Part Number	Qty
P201	CONNECTOR,HEADER,1 ROW,.156 CTR,RT ANG,LOCKING RAMP,3 PIN,BULK	2137917	1
P202	CONNECTOR,HEADER,1 ROW,.156 CTR,RT ANG,LOCKING RAMP,5 PIN,BULK	2137921	1
Q1-2	TRANSISTOR,SI,PNP,2N3906,40V,200MA,250MHZ,625MW,AMMO BOX,TO-92,TAPE	698233	2
Q3 Q6 Q17	TRANSISTOR,SI,PNP,MMBT3906,40V,200MA,250MHZ,225MW,SOT-23,TAPE	742684	3
Q4-5	TRANSISTOR,SI,NPN,60V,350MW,SOT-23	742676	2
Q7-8	TRANSISTOR,SI,NPN,2N3904,60V,200MA,300MHZ,625MW,AMMO BOX,TO-92,TAPE	698225	2
Q12	TRANSISTOR,SI,NPN,300V,1W,TO-92	722934	1
Q13	TRANSISTOR,SI,PNP,2N5401,160V,600MA,100MHZ,350MW,AMMO BOX,TO-92,TAPE	698274	1
Q18	TRANSISTOR,SI,PNP,2N6520,350V,500MA,40MHZ,625MW,TO-92,TAPE	602961	1
Q19	THYRISTOR,SI,TRIAC,VBO=200V,8.0A	413013	1
R1-2 R9 R12 R14-17 R26 R66-67	RESISTOR, SMR,RES,CERM,2K,+-1%,.125W,100PPM,1206	807172	11
R6	RESISTOR, SMR,RES,CERM,32.4,+-1%,0.1W,100PPM,0805	641974	1
R7 R13 R30 R60 R62 R71 R75	RESISTOR, SMR,RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	7
R5 R8	RESISTOR, SMR,RES,CERM,10,+-1%,.125W,100PPM,1206	867676	2
R11 R32 R53 R58 R69 R79-82 R87 R109-110 R113	RESISTOR, SMR,RES,CERM,4.99K,+-1%,.125W,100PPM,1206	604345	13
R18-19	RESISTOR, SMR,RES,CERM,1K,+-5%,1W,200PPM,2512	601176	2
R20 R27 R111	RESISTOR, CERMET,100,+-1%,0.125W,100PPM,1206,TAPE	867494	3

Table 5-3. A3 Motherboard PCA (cont)

Ref Des	Description	Part Number	Qty
R21 R23 R28 R116	RESISTOR, SMR,RES,CERM,49.9K,+-1%,.125W,100PPM,1206	836379	4
R22	RESISTOR, SMR,RES,CERM,453,+-1%,.125W,100PPM,1206	801415	1
R24 R115	RESISTOR, CERMET,150K,+-1%,0.125W,100PPM,1206,TAPE	867697	2
R25 R29 R33 R78 R83-85 R88 R114	RESISTOR, SMR,RES,CERM,100K,+-1%,.125W,100PPM,1206	769802	9
R31 R117	RESISTOR, SMR,RES,CERM,499K,+-1%,.125W,100PPM,1206	821678	2
R34 R36 R40-41 R59 R68 R70 R73-74 R77 R94-95 R100 R107-108 R112 R118-119	RESISTOR, SMR,RES,CERM,10K,+-1%,.125W,100PPM,1206	769794	18
R35 R72	RESISTOR, SMR,RES,CERM,3.01K,+-1%,.125W,100PPM,1206	604329	2
R42-43 R86 R120-123	RESISTOR, SMR,RES,CERM,1,+-5%,.125W,400PPM,1206	690492	7
R44-45 R48 R57	RESISTOR, SMR,RES,CERM,4.99,+-1%,.125W,400PPM,1206	603271	4
R46-47	RESISTOR, SMR,RES,CERM,2.2M,+-5%,.125W,200PPM,1206	811778	2
R49 R54	RESISTOR, SMR,RES,CERM,100,+-5%,.125W,200PPM,1206	746297	2
R50 R52	RESISTOR, SMR,RES,CERM,200,+-1%,.125W,100PPM,1206	772798	2
R51	RESISTOR, SMR,RES,CERM,604,+-1%,.125W,100PPM,1206	644689	1
R55-56 R61	RESISTOR, SMR,RES,MF,90K,+-0.1%,0.125W,25PPM,1206	106374	3
R63	RESISTOR, METAL FILM,15K,+-0.1%,0.1W,25PPM,0805,TAPE	1274218	1
R64-65 R91-92	RESISTOR, A52R,RES,CF,560K,+-5%,0.5W	640364	4
R76	RESISTOR, A73R,RES,CERM,10K,+-5%,2W,100PPM	650405	1

Table 5-3. A3 Motherboard PCA (cont)

Ref Des	Description	Part Number	Qty
R89-90	RESISTOR, R05A,RES,CF,1,+-5%,0.25W	867866	2
R93	RESISTOR, A73R,RES,CERM,560,+-5%,2W,100PPM	643764	1
R124-125	RESISTOR, SMR,RES,CERM,86.6,+-1%,0.1W,100PPM,0805	106929	2
RT1 RT3-5 RT7-12	THERMISTOR, THERMISTOR,DISC,0.18,25C	875273	10
RT2 RT6	THERMISTOR, PTC,0.02,30V,2W,3A HOLD,6A TRIP,RADIAL,BULK	2075107	2
RV1-5	VARISTOR,22V,+-20%,1.0MA	500777	5
TP7 TP14 TP18 TP24 TP27 TP29	CONNECTOR,TERMINAL,TEST POINT,1510,TAPE	602125	6
U2	IC,OP AMP,AD744J,+-4.5 TO +-18V,2MV OFFSET,6MHZ,HI SLEW RATE,SO8,TAPE	629992	1
U3	IC,CMOS,3-8 LINE DCDR W ENABLE,SOIC	783019	1
U4	IC,CMOS,HEX INVERTER,UNBUFFERED,SOIC	806893	1
U5-6 U8-9 U28-29	IC,BIMOS,4 CHNL DRVR W/LTCH,SOIC	929781	6
U7	IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	866798	1
U10	IC,COMPARATOR,QUAD,14 PIN,SOIC	741561	1
U11 U18	DUAL OP-AMP	1756700	2
U12 U23-24	IC,COMPARATOR,DUAL,LOW PWR,SOIC	837211	3
U13	HEATSINK ASSEMBLY	2114956	1
U14	HEATSINK ASSEMBLY	2114963	1
U15 U19	HEATSINK ASSEMBLY	2114939	2
U16	HEATSINK ASSEMBLY	2114988	1
U17	HEATSINK ASSEMBLY	2114995	1
U20	HEATSINK ASSEMBLY	2114942	1
U21	HEATSINK ASSEMBLY	665562	1
U22	HEATSINK ASSEMBLY	2115019	1
U25	HEATSINK ASSEMBLY	2114921	1

Table 5-3. A3 Motherboard PCA (cont)

Ref Des	Description	Part Number	Qty
U27	IC,ANALOG SWITCH,DG444,+12 TO +-20V,85 OHMS,SPST,QUAD,NC,LOW LEAKAGE,SO16,TAPE	688457	1
U30	IC,TEMP SENSOR,LM35D,4-30V,+-2C,10MV/C,TO-92,BULK	2111629	1
U31	HEATSINK ASSEMBLY WITH 2-MJE15028 XSTRS	2065328	1
U32	HEATSINK ASSEMBLY WITH 2-MJE15029 XSTRS	2065337	1
U33-34	HEATSINK ASSEMBLY	2114974	2
VR1-2	ZENER,UNCOMP,56V,5%,2.2MA,0.4W	832568	2
VR3	,ZENER,COMP,6.4V,2%,20PPM,1MA	419036	1
VR4-5 VR16	ZENER,UNCOMP,MMBZ5245B,15V,5%,8.5MA,225MW,SOT-23,TAPE	837187	3
VR6 VR9	ZENER,UNCOMP,MMBZ5235B,6.8V,5%,20MA,225MW,SOT-23,TAPE	837195	2
VR7-8	ZENER,UNCOMP,MMBZ5251B,22V,5%,5.6MA,225MW,SOT-23,TAPE	831230	2
VR10 VR13	ZENER,UNCOMP,SMBJ12A,12V,5%,1MA,600W,TRANSIENT SUPRESSOR,SMB,TAPE	2002382	2
VR11-12	ZENER,UNCOMP,1.5SMC47A,47V,5%,1MA,4W,TRANSIENT SUPRESSOR,SMC,TAPE	2086534	2
VR14-15	ZENER,UNCOMP,1.5SMC20A,20V,5%,1MA,1.5KW,TRANSIENT SUPRESSOR,SMC,TAPE	2102456	2
VR17	ZENER,UNCOMP,1SMA24CA,24V,5%,1MA,1W,TRANSIENT SUPRESSOR,SMA,TAPE	1572981	1

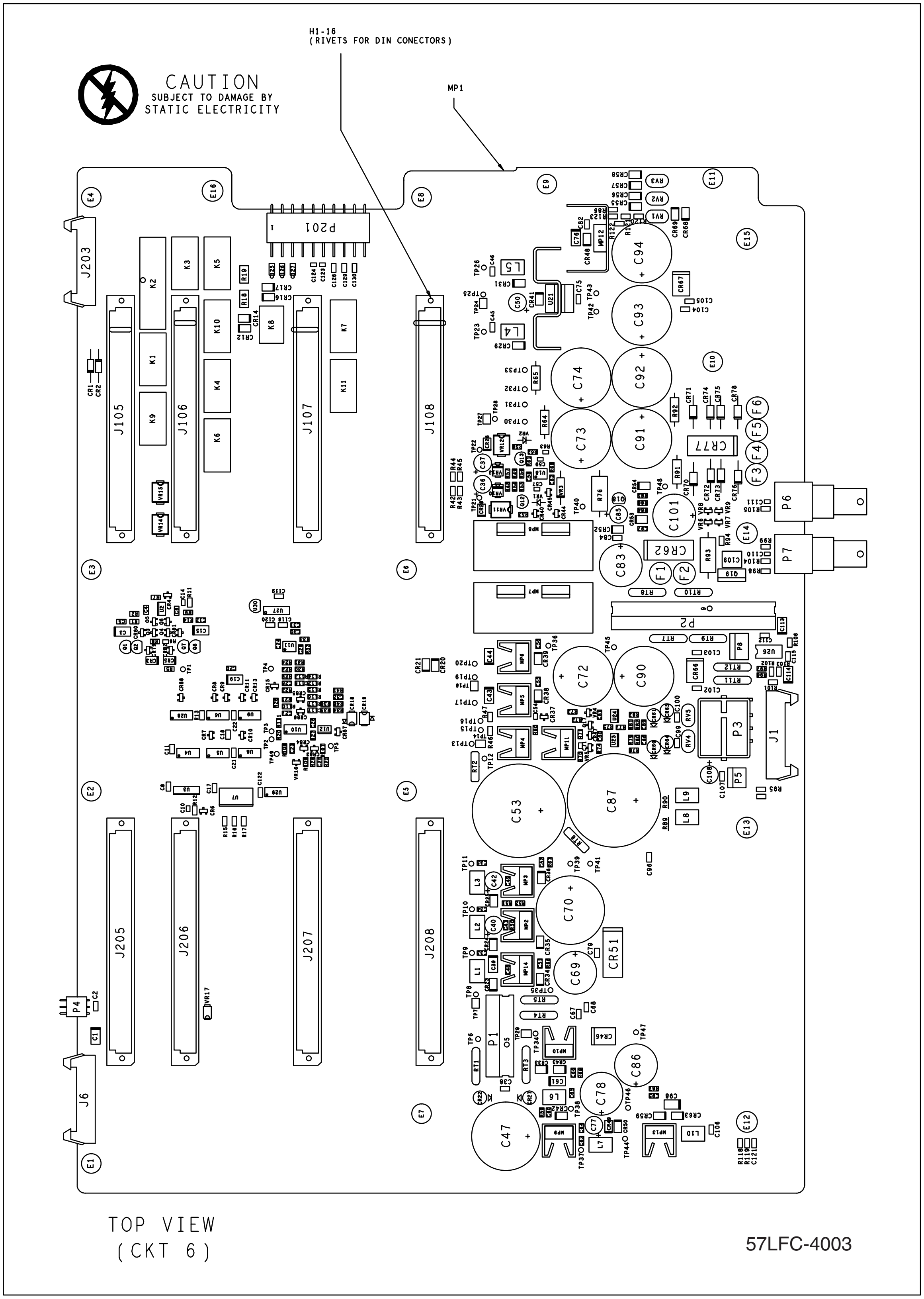

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Figure 5-3. A3 Motherboard PCA

Table 5-4. A5 Ohms PCA

Ref Des	Description	Part Number	Qty
C1 C18 C39 C42 C47-48 C82-83 C85 C88 C96-97	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	12
C2-17 C19-21 C23-36 C38 C40 C43-45 C49 C51-60 C65-66 C69 C71-73 C75 C77-78 C81 C84 C86-87 C89-92 C98-99	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,50V,X7R,1206	605292	68
C22	CAPACITOR, SMR,CAP,CER,0.047UF,+-20%,50V,X7R,1206	782615	1
C37 C74 C76 C93	CAPACITOR, CERAMIC,100PF,+-5%,100V,C0G,0805,TAPE	601028	4
C41 C46 C63-64 C67-68	CAPACITOR,CAP,AL,1000UF,+-20%,16V,SOLV PROOF	837468	6
C79-80 C94-95	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,100V,X7R,1206	804325	4
C100	CAPACITOR, SMR,CAP,CER,68PF,+-2%,50V,C0G,0805	802090	1
CR1-3 CR7-8	SMR,DIODE,SI,DUAL,50V,250MA,SOT-23	851659	5
CR4	DIODE,SI,PN,DF01S,100V,1A,BRIDGE,4 PIN SURFACE MOUNT,3530,TAPE	912456	1
CR5-6	DIODE,MBRS140 SMR,DIODE,SI,SCHOTTKY,40V,1A,DO-214AB	605821	2
CR9-10 CR13 CR16	DIODE,SI,PN,BAV199,70V,215MA,3US,DUAL,SERIES,SOT-23,TAPE	605805	4
CR11 CR15 CR17-18	DIODE,SI,PN,S1G,400V,1A,1.8US,DO-214AC,TAPE	107573	4
H1-4	RIVET,AL,.089 DIA,.344 L,SEMI-TUBULAR,OVAL HEAD	838458	4

Table 5-4. A5 Ohms PCA (cont)

Ref Des	Description	Part Number	Qty
K1 K6-7 K15 K20-23 K25-26 K36-37 K40	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	603001	13
K2-5 K8-14 K16-19 K27-35 K38-39 K41-43	RELAY,ARMATURE,4 FORM C,5V,LATCH	715078	29
K24	RELAY,ARMATURE,2 FORM C,5 VDC,LATCH	910773	1
L1-3	INDUCTOR,BEAD,95 OHMS@100MHZ,1ADC,1MOHM,3612,TAPE	867734	3
MP1	PCB, OHMS	2048822	1
MP4-5	EJECTOR, EJECTOR,PWB,NYLON	494724	2
P105 P205	CONNECTOR, DIN41612,TYPE C,RT ANG,64 PIN	807800	2
Q1	PNP,MPS6562 R05A,TRANSISTOR,SI,PNP,25V,1.5W,T0-92	698290	1
Q2	NPN R05R,TRANSISTOR,SI,NPN,25V,1.5W,SEL,TO-92	685404	1
Q3	MOSFET,P-CHANNEL, TRANSISTOR,SI,P-MOS,ENHANCEMENT,TO-72	741058	1
Q4	MOSFET,SI,N,SD210,30V,50MA,45 OHMS,300MW,DMOS,LOW CAPACITANCE,TO-72,BULK	394122	1
Q5	TRANSISTOR,SI,PNP,2N5401,160V,600MA,100MHZ,350MW,AMMO BOX,TO-92,TAPE	698274	1
Q6	NPN,MPSA42 R05A,TRANSISTOR,SI,NPN,300V,1W,TO-92	722934	1
R1 R4-5 R28	RESISTOR, SMR,RES,CERM,2.2M,+-5%,.125W,200PPM,1206	811778	4
R2 R14 R17 R22 R46-47	RESISTOR, CERMET,100,+-1%,0.125W,100PPM,1206,TAPE	867494	6
R3 R11 R15 R25-26 R31 R42 R65-66	RESISTOR, SMR,RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	9
R6-9 R68-69	RESISTOR, SMR,RES,CERM,10,+-1%,.125W,100PPM,1206	867676	6

Table 5-4. A5 Ohms PCA (cont)

Ref Des	Description	Part Number	Qty
R10 R12-13 R18-21 R30 R48-53 R67	RESISTOR, SMR,RES,CERM,10K,+-1%,.125W,100PPM,1206	769794	15
R16 R23 R43-45 R63	RESISTOR, SMR,RES,CERM,4.99K,+-1%,.125W,100PPM,1206	604345	6
R27	RESISTOR, SMR,RES,MF,10K,+-0.5%,.125W,10PPM,1206	687407	1
R40-41	RESISTOR, SMR,RES,CERM,2K,+-1%,.125W,100PPM,1206	807172	2
R54-55	RESISTOR, SMR,RES,CERM,24.9K,+-1%,.125W,100PPM,1206	867689	2
R56-57 R64	RESISTOR, SMR,RES,CERM,100K,+-1%,.125W,100PPM,1206	769802	3
R58-61	RESISTOR, SMR,RES,CERM,15K,+-1%,.125W,100PPM,1206	769810	4
T1	POWER TRANSFORMER,16.5V-17VCT	625977	1
TP4 TP10	CONNECTOR,TERMINAL,TEST POINT,1510,TAPE	602125	2
U1-16	BIMOS 5800, SMR,IC,BIMOS,4 CHNL DRVR W/LTCH,SOIC	929781	16
U17	CMOS 1151,IC,OP AMP,CHOPPER,DUAL,INT CAPS,8PDIP	929539	1
U18 U20	57LFC-4322,HEATSINK ASSEMBLY	2115004	2
U19	CMOS TLC2652 SMR,IC,OP AMP,CHOPPER STAB,PRECISION,SO8	642741	1
U21-23 U28 U32	IC,ANALOG SWITCH,DG444,+12 TO +-20V,85 OHMS,SPST,QUAD,NC,LOW LEAKAGE,SO16,TAPE	688457	5
U24	BIPOLAR OP284 SMR,IC,OPAMP,DUAL,PRECN,RAIL-RAIL I/O,SO8	642691	1
U25	BIFET AD823 SMR,IC,OP AMP,DUAL,RAIL-RAIL,16 MHZ,SO8	642709	1
U26-27 U31	BIPOLAR AD707K SMR,IC,OPAMP,ULOW DRIFT,LOW NOISE,SO8	887120	3
U33-34	CMOS 74HCU04 SMR,IC,CMOS,HEX INVERTER,UNBUFFERED,SOIC	806893	2
U35 U39	CMOS 74HC374 SMR,IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	866798	2
U36	BIPOLAR 339 SMR,IC,COMPARATOR,QUAD,14 PIN,SOIC	741561	1
U37-38	CMOS 74HC138 SMR,IC,CMOS,3-8 LINE DCDR W ENABLE,SOIC	783019	2
U40	IC,OP AMP,OPA129,+-5 TO +-18V,+-2MV OFFSET,1MHZ,DIFET,SO8,TAPE	1644333	1
U41	IC,OP AMP,AD825,+-5V TO +-15V,2MV OFFSET,18MHZ,JFET,SO8,TAPE	2115379	1
VR1	BIPOLAR 4040 SMR,IC,V REF,SHUNT,2.5 V,1%,150 PPM,SOT23	930065	1

Table 5-4. A5 Ohms PCA (cont)

Ref Des	Description	Part Number	Qty
VR3-4	ZENER,UNCOMP,MMBZ5233B,6V,5%,20MA,225MW,SOT-23,TAPE	837161	2
Z1	THIN FILM, HERM, RESISTANCE REF.	2063764	1
Z2	THIN FILM, HERM, RESISTANCE REF	2063675	1
Z3	THIN FILM, HERM, RESISTANCE REF.	2063701	1
Z4	THIN FILM, HERM, RESISTANCE REF.	2063735	1
Z5	R-NET, THIN FILM, ASSEMBLY	626496	1

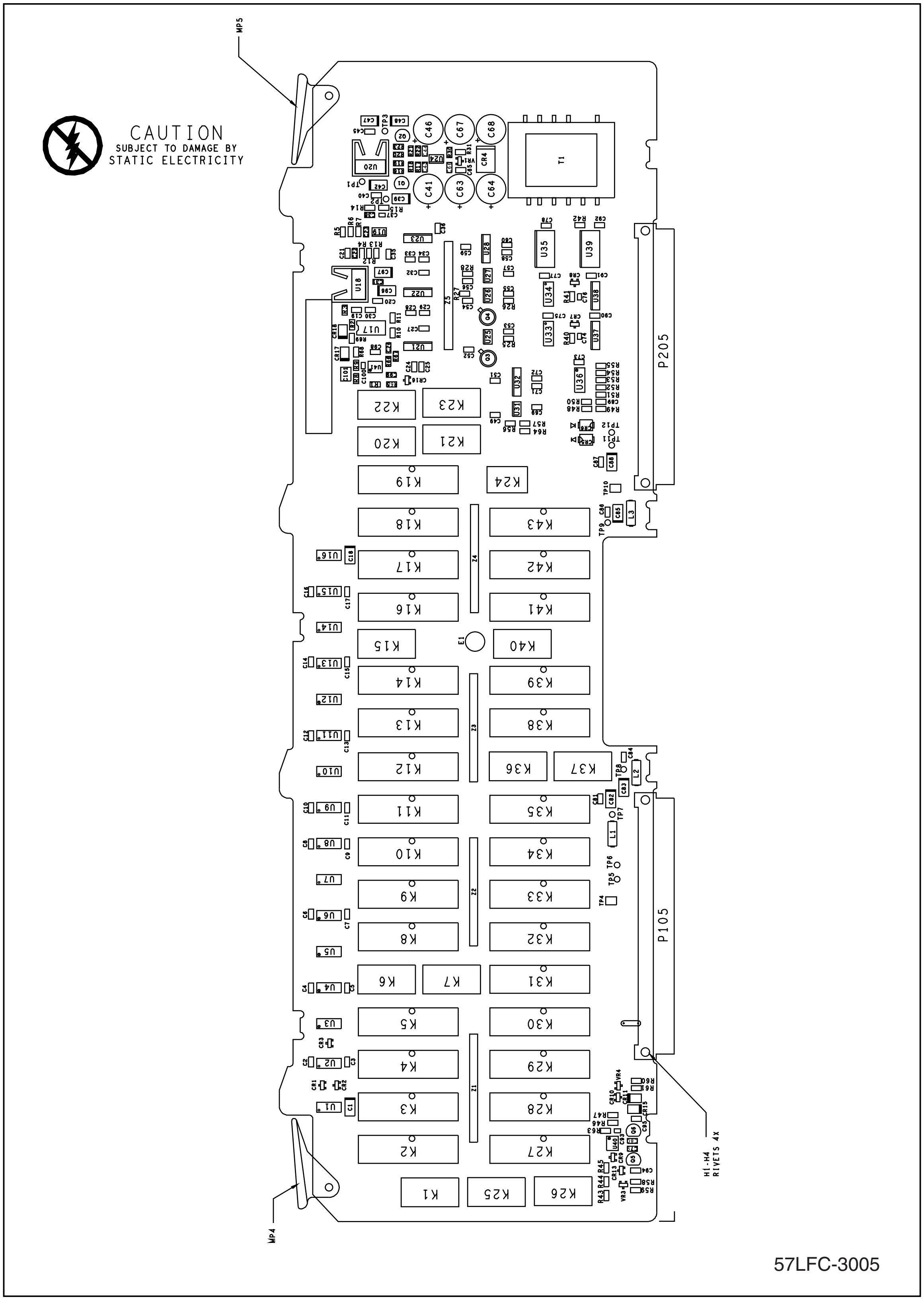

Figure 5-4. A5 Ohms PCA

Table 5-5. A6 Digital Synthesis PCA

Ref Des	Description	Part Number	Qty
C1 C3-6 C8-16 C18-23 C26-28 C42-43 C45-46 C50 C54 C60 C70 C72-77 C79 C81-84 C86-95 C97-101 C104-105 C107-109 C111-116 C119-126 C133-134	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,50V,X7R,0805	690500	78
C2 C35	CAPACITOR, SMR,CAP,CER,10PF,+-5%,50V,C0G,0805	494781	2
C7	CAPACITOR, SMR,CAP,CER,4700PF,+-10%,50V,X7R,1206	832279	1
C17	CAPACITOR, SMR,CAP,CER,3.3PF,+-0.25PF,50V,C0G,0805	942560	1
C24 C41	CAPACITOR, SMR,CAP,CER,33PF,+-5%,50V,C0G,0805	603172	2
C25 C51 C57 C59 C62-68 C96	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	12
C29 C32-33	CAPACITOR, SMR,CAP,CER,2200PF,+-5%,50V,C0G,0805	942524	3
C30-31 C36-37	CAPACITOR, CERAMIC,100PF,+-5%,100V,C0G,0805,TAPE	601028	4
C34	CAPACITOR, SMR,CAP,CER,100PF,+-1%,100V,C0G,1206	644812	1
C38-39	CAPACITOR, SMR,CAP,CER,330PF,+-5%,50V,C0G,0805	512038	2
C40 C117	CAPACITOR, SMR,CAP,CER,1000PF,+-1%,50V,C0G,1206	867668	2
C44	CAPACITOR, CERAMIC,10UF,+-20%,10V,X5R,1210,TAPE	1589417	1

Table 5-5. A6 Digital Synthesis PCA (cont)

Ref Des	Description	Part Number	Qty
C47-48	CAPACITOR, CERAMIC,560PF,+-5%,50V,C0G,0603,TAPE	1555376	2
C49	CAPACITOR, SMR,CAP,CER,0.47UF,+-10%,16V,X7R,0805	690545	1
C52-53	CAPACITOR, SMR,CAP,TA,4.7UF,+-10%,20V,3528	605433	2
C55-56	CAPACITOR, SMR,CAP,CER,1UF,+80-20%,25V,Y5V,1206	605303	2
C58	CAPACITOR, SMR,CAP,TA,33UF,+-20%,16V,6032	691151	1
C61	CAPACITOR, SMR,CAP,CER,56PF,+-5%,50V,C0G,0805	887901	1
C69 C71 C78 C80	CAPACITOR, SMR,CAP,TA,100UF,+-20%,16V,7343	803822	4
C85	CAPACITOR, ELECTROLYTIC,TANTALUM,150UF,+-20%,20V,7260,TAPE	1279156	1
C131-132	CAPACITOR, SMR,CAP,CER,10PF,+-10%,50V,C0G,1206	747311	2
C135	CAPACITOR, SMR,CAP,CER,0.033UF,+-10%,200V,X7R,1206	602547	1
CR1-10 CR12 CR14-15 CR21	DIODE,SI,PN,MMBD1503A,150V,200MA,DUAL,SERIES,LOW LEAKAGE,SOT-23,TAPE	928143	14
CR11	A52R,I-REG DIODE,2MA,10%,DO-7	686714	1
CR16 CR18 CR24-25	DIODE,GF1B, SMR,DIODE,SI,100V,1A,DO-214	912451	4
CR17 CR26	DIODE,SI,PN,DF01S,100V,1A,BRIDGE,4 PIN SURFACE MOUNT,3530,TAPE	912456	2
CR27-28	DIODE,MBRS140 SMR,DIODE,SI,SCHOTTKY,40V,1A,DO-214AB	605821	2
CR29-30	DIODE,SI,SCHOTTKY,BAT54S,30V,200MA,5NS,DUAL-SERIES,SOT-23,TAPE	929745	2
E2	SURGE PROTECTOR,90V,+-20%	198507	1
H12-15	RIVET,AL,.089 DIA,.344 L,SEMI-TUBULAR,OVAL HEAD	838458	4
K1-2 K5 K10 K12 K14 K20-22	RELAY,ARMATURE,2 FORM C,5 VDC,LATCH	910773	9
K13 K17	RELAY,ARMATURE,4 FORM C,5V,LATCH	715078	2

Table 5-5. A6 Digital Synthesis PCA (cont)

Ref Des	Description	Part Number	Qty
K18	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	643178	1
K19	RELAY,ARMATURE,2 FORM A,5VDC,LATCH	642782	1
MP1	PCB, CURRENT	2048846	1
MP2	HEATSINK ASSEMBLY	2112487	1
MP3	HEATSINK ASSEMBLY	2112493	1
MP5-6	EJECTOR,PWB,NYLON	494724	2
MP13	HEAT SINK ASSEMBLY WITH MJE15029 XSTR	2062805	1
MP14	HEAT SINK ASSEMBLY WITH MJE15028 XSTR	2062797	1
P107 P207	CONNECTOR, DIN41612,TYPE C,RT ANG,64 PIN	807800	2
Q1	PNP,PWR,CENU56, TRANSISTOR,SI,PNP,80V,10W,TO-202	495689	1
Q3-4 Q6 Q12 Q14 Q19	TRANSISTOR,SI,PNP,MMBT3906,40V,200MA,250MHZ,225MW,SOT-23,TAPE	742684	6
Q5 Q7 Q9 Q11 Q15-16 Q20	NPN,MMBT3904 SMR,TRANSISTOR,SI,NPN,60V,350MW,SOT-23	742676	7
Q8	NPN,PWR,CENU06, TRANSISTOR,SI,NPN,80V,10W,TO-202	535468	1
Q41-42	FET,DMOS,N-CH R05A,TRANSISTOR,SI,N-DMOS FET,DEPL,TO-92	945050	2
R1	RESISTOR, METAL FOIL,0.1,+-0.1%,1W,10PPM,RADIAL,BULK	2061053	1
R2 R13 R124 R133-134 R154	RESISTOR, SMR,RES,MF,10K,+-0.1%,.125W,25PPM,1206	106366	6
R3 R17-18 R21 R29 R39 R43 R57 R70-71 R85-86 R140 R145 R147 R190 R209	RESISTOR, SMR,RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	17

Table 5-5. A6 Digital Synthesis PCA (cont)

Ref Des	Description	Part Number	Qty
R4 R7 R16 R22 R30-31 R33 R40-41 R46 R59-60 R72-73 R116 R205-206	RESISTOR, CERMET,100,+-1%,0.125W,100PPM,1206,TAPE	867494	17
R5 R12 R14 R25 R27 R45 R58 R66 R75-76 R83-84 R89-90 R106	RESISTOR, SMR,RES,CERM,2K,+-1%,.125W,100PPM,1206	807172	15
R6 R15 R64-65	RESISTOR, SMR,RES,CERM,13K,+-1%,0.1W,100PPM,0805	930164	4
R8 R108	RESISTOR, CERMET,200K,+-1%,0.125W,100PPM,1206,TAPE	783258	2
R9 R28 R156	RESISTOR, SMR,RES,CERM,2.2M,+-5%,.125W,200PPM,1206	811778	3
R10 R87	600202-536,RES RC1206 6.04K 1% 25PPM	1760171	2
R11	RESISTOR, SMR,RES,CERM,270,+-5%,.125W,200PPM,1206	746354	1
R19-20 R52 R155	RESISTOR, SMR,RES,MF,1K,+-0.1%,0.125W,10PPM,1206	929880	4
R23 R32	RESISTOR, SMR,RES,CERM,121,+-1%,.063W,100PPM,0603	689122	2
R24 R34 R61-62	RESISTOR, CERMET,0.060,+-5%,0.5W,100PPM,2010,TAPE	105999	4

Table 5-5 A6 Digital Synthesis PCA (cont)

Ref Des	Description	Part Number	Qty
R26 R54 R56 R69 R93 R102 R137 R143 R163-166 R169-172 R175-176 R193 R197 R199	RESISTOR, SMR,RES,CERM,10K,+-1%,.125W,100PPM,1206	769794	21
R35-36	RESISTOR, SMR,RES,CERM,316,1%,.125W,100PPM,1206	604900	2
R37 R63	RESISTOR, SMR,RES,CERM,2.61K,+-1%,.125W,100PPM,1206	781179	2
R38 R42 R80 R95	RESISTOR, SMR,RES,CERM,698,+-1%,0.1W,100PPM,0805	641156	4
R44 R105 R148	RESISTOR, SMR,RES,CERM,511,+-1%,.125W,100PPM,1206	769869	3
R47-48 R74 R77 R198	RESISTOR, SMR,RES,CERM,110,+-1%,.125W,100PPM,1206	644473	5
R49 R53	RESISTOR, WIREWOUND,1.0,+-0.5%,1W,50PPM,2515,TAPE	1544336	2
R50-51	RESISTOR, SMR,RES,CERM,10,+-1%,.125W,100PPM,1206	867676	2
R55 R91-92 R101 R114 R118-119 R211	RESISTOR, SMR,RES,CERM,4.02K,+-1%,.125W,100PPM,1206	783266	8
R67-68	RESISTOR, SMR,RES,CERM,1M,+-1%,.125W,100PPM,1206	836387	2
R78-79	RESISTOR, CERMET,47.5,+-1%,0.1W,100PPM,0805,TAPE	802006	2
R81-82	RESISTOR, SMR,RES,CERM,4.99K,+-1%,.125W,100PPM,1206	604345	2
R88	RESISTOR, SMR,RES,CERM,4.32K,+-1%,.063W,100PPM,0603	605250	1

Table 5-5. A6 Digital Synthesis PCA (cont)

Ref Des	Description	Part Number	Qty
R96-99	RESISTOR, SMR,RES,CERM,49.9K,+-1%,.125W,100PPM,1206	836379	4
R100 R103	RESISTOR, SMR,RES,CERM,4.99K,+-1%,0.1W,100PPM,0805	928767	2
R104	RESISTOR, SMR,RES,CERM,49.9,+-1%,0.1W,100PPM,0805	604923	1
R107	RESISTOR, SMR,RES,CERM,1M,+-5%,.063W,200PPM,0603	604998	1
R115 R117 R120-121	RESISTOR, SMR,RES,CERM,10K,+-1%,0.1W,100PPM,0805	928791	4
R146	RESISTOR, SMR,RES,CERM,1.8K,+-5%,.125W,200PPM,1206	746453	1
R159 R173	RESISTOR, SMR,RES,CERM,6.98K,+-1%,.125W,100PPM,1206	929919	2
R186	RESISTOR, SMR,RES,CERM,301,+-1%,.125W,100PPM,1206	644598	1
R207-208	RESISTOR, SMR,RES,CERM,49.9,+-1%,0.25W,100PPM,1210	929674	2
RT2	THERMISTOR, SMR,THERMISTOR,3,25,8055	642519	1
T1	POWER TRANSFORMER,16.5V-43.6VCT	627031	1
TP2-4 TP6-10 TP18-25	CONNECTOR,TERMINAL,TEST POINT,1510,TAPE	602125	16
U1	CMOS 74AC04 SMR,IC,CMOS,HEX INVERTER,SOIC	838417	1
U2	CMOS 74HC138 SMR,IC,CMOS,3-8 LINE DCDR W ENABLE,SOIC	783019	1
U3 U5	CMOS 74HC374 SMR,IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	866798	2
U4 U24	CMOS 74ACT175 SMR,IC,CMOS,QUAD D F/F,+EDG TRG,SOIC	944132	2
U6 U8-9 U11-12 U14	BIMOS 5800, SMR,IC,BIMOS,4 CHNL DRVR W/LTCH,SOIC	929781	6
U7 U13 U17 U29 U32	IC,OP AMP,AD744J,+-4.5 TO +-18V,2MV OFFSET,6MHZ,HI SLEW RATE,SO8,TAPE	929992	5
U10 U23 U25-26 U28 U47	IC,ANALOG SWITCH,DG444,+12 TO +-20V,85 OHMS,SPST,QUAD,NC,SO16,TAPE	875232	6
U16	BIFET LF412A ,IC,OP AMP,DUAL,LO OFFST VOLT,LO-DRIFT	851704	1
U18	BIPOLAR OP27G SMR,IC,OP AMP,ULOW NOISE,LOW VOS,SO8	687282	1
U19	BIFET TL062 SMR,IC,OP AMP,DUAL,JFET,LOW POWER,SOIC	806794	1

Table 5-5. A6 Digital Synthesis PCA (cont)

Ref Des	Description	Part Number	Qty
U20	BIPOLAR LM393 SMR,IC,COMPARATOR,DUAL,LOW PWR,SOIC	837211	1
U21 U44 U58-59	BIFET AD823 SMR,IC,OP AMP,DUAL,RAIL-RAIL,16 MHZ,SO8	642709	4
U27	IC,ANALOG SWITCH,ADG431,5-44V,24 OHMS,SPST,NO,SO16,TAPE	689844	1
U30 U34 U38	RELAY, SMR,RELAY,SOLID STATE,1FORM A,80VDC,120MA	687217	3
U31 U37	IC,OP AMP,LT1630,2.7V TO +-15V,525UV OFFSET,15MHZ,R-R,S-S,DUAL,SO8,TAPE	2075118	2
U33 U48 U52-53	IC,OP AMP,LTC1150,+-16V,10UV OFFSET,2.5MHZ,ZERO-DRIFT,CHOPPER,DIP8,TUBE	2051666	4
U35	BIPOLAR OP284 SMR,IC,OPAMP,DUAL,PRECN,RAIL-RAIL I/O,SO8	642691	1
U45	ISOLATOR,OPTO SMR,ISOLATOR,OPTO,LED TO TRANSISTOR,SOIC	929281	1
U49	BIFET LF356N, IC,OP AMP,JFET INPUT,8 PIN DIP	472779	1
U50	IC,VOLTAGE REGULATOR,LINEAR,LM2990,-15V,1A,LDO,TO-220,TUBE	2111724	1
U51	BIPOLAR 2940, IC,VOLT REG,LDO,+15 V,1.0 A,TO-220	602748	1
VR1 VR5	ZENER,UNCOMP,MMBZ5237B,8.2V,5%,20MA,225MW,SOT-23,TAPE	837146	2
VR2	ZENER,UNCOMP,MMBZ5231B,5.1V,5%,20MA,225MW,SOT-23,TAPE	837179	1
VR3-4	ZENER 1N5908, ZENER,TRANS SUPPRESSOR,6V	508655	2
W1 W5-7 W14-15 W22	CONNECTOR,JUMPER,COPPER,TIN,1206,SURFACE MOUNT,T/R	2061468	7
Z2	SUBSTRATE ASSY, 5500A-4R02T-H	945316	1
Z4	THIN FILM, HERM, RESISTANCE REF.	2094985	1

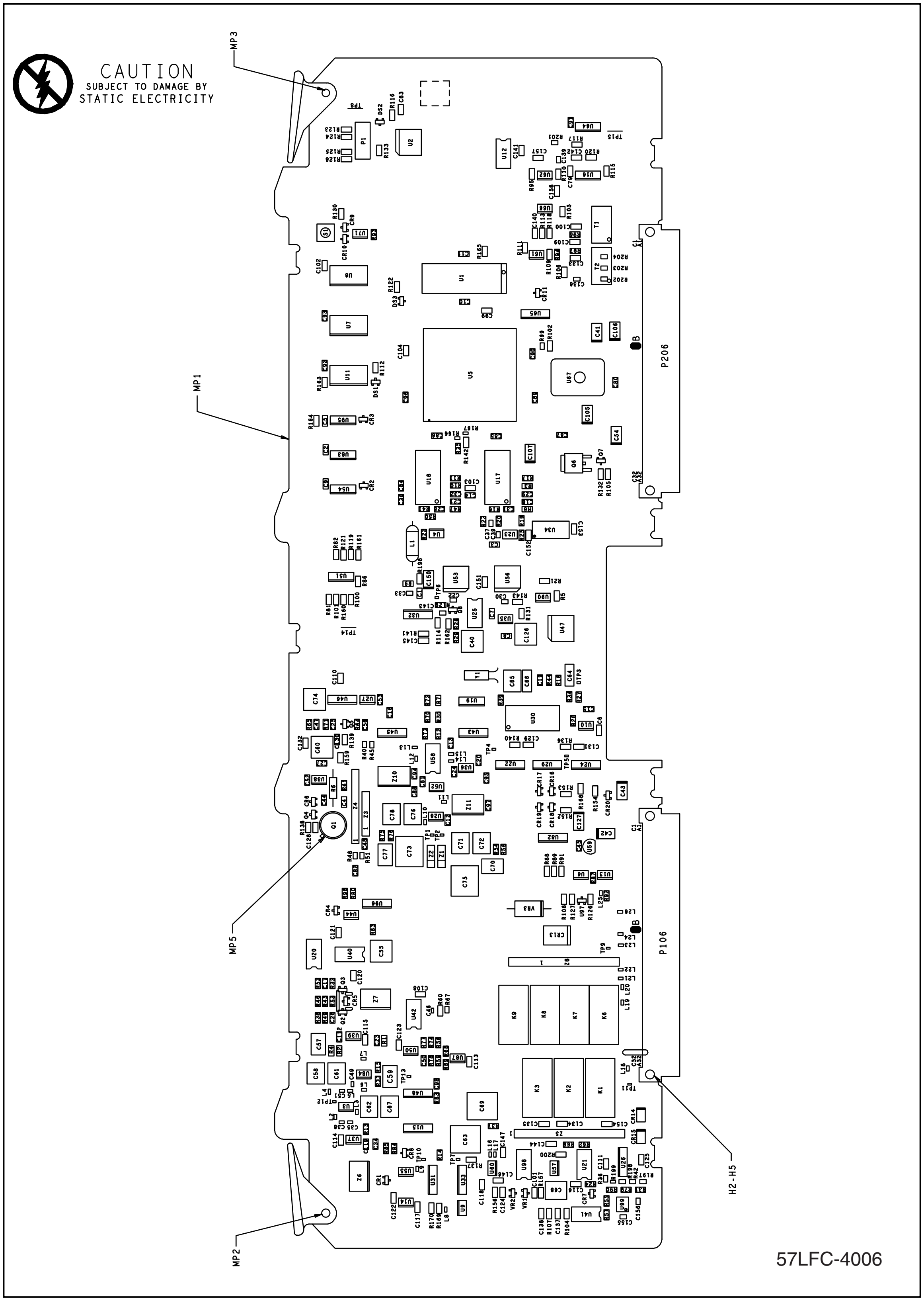

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Figure 5-5. A6 Digital Synthesis PCA

Table 5-6. A7 Current PCA

Ref Des	Description	Part Number	Qty
A7A101	ISOTHERMAL PCA		1
C1 C3-6 C8-16 C18-23 C26-28 C42-43 C45-46 C50 C54 C60 C70 C72-77 C79 C81-84 C86-95 C97-101 C104-105 C107-109 C111-116 C119-126 C133-134	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,50V,X7R,0805	690500	78
C2 C35	CAPACITOR, SMR,CAP,CER,10PF,+-5%,50V,C0G,0805	494781	2
C7	CAPACITOR, SMR,CAP,CER,4700PF,+-10%,50V,X7R,1206	832279	1
C17	CAPACITOR, SMR,CAP,CER,3.3PF,+-0.25PF,50V,C0G,0805	942560	1
C24 C41	CAPACITOR, SMR,CAP,CER,33PF,+-5%,50V,C0G,0805	603172	2
C25 C51 C57 C59 C62-68 C96	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	12
C29 C32-33	CAPACITOR, SMR,CAP,CER,2200PF,+-5%,50V,C0G,0805	942524	3
C30-31 C36-37	CAPACITOR, CERAMIC,100PF,+-5%,100V,C0G,0805,TAPE	601028	4
C34	CAPACITOR, SMR,CAP,CER,100PF,+-1%,100V,C0G,1206	644812	1

Table 5-6. A7 Current PCA (cont)

Ref Des	Description	Part Number	Qty
C38-39	CAPACITOR, SMR,CAP,CER,330PF,+-5%,50V,C0G,0805	512038	2
C40 C117	CAPACITOR, SMR,CAP,CER,1000PF,+-1%,50V,C0G,1206	867668	2
C44	CAPACITOR, CERAMIC,10UF,+-20%,10V,X5R,1210,TAPE	1589417	1
C47-48	CAPACITOR, CERAMIC,560PF,+-5%,50V,C0G,0603,TAPE	1555376	2
C49	CAPACITOR, SMR,CAP,CER,0.47UF,+-10%,16V,X7R,0805	690545	1
C52-53	CAPACITOR, SMR,CAP,TA,4.7UF,+-10%,20V,3528	605433	2
C55-56	CAPACITOR, SMR,CAP,CER,1UF,+80-20%,25V,Y5V,1206	605303	2
C58	CAPACITOR, SMR,CAP,TA,33UF,+-20%,16V,6032	691151	1
C61	CAPACITOR, SMR,CAP,CER,56PF,+-5%,50V,C0G,0805	887901	1
C69 C71 C78 C80	CAPACITOR, SMR,CAP,TA,100UF,+-20%,16V,7343	803822	4
C85	CAPACITOR, ELECTROLYTIC,TANTALUM,150UF,+-20%,20V,7260,TAPE	1279156	1
C102-103	CAPACITOR, CAP,AL,470UF,+-20%,35V,SOLV PROOF	756700	2
C110	CAPACITOR, SMR,CAP,CER,3900PF,+-5%,25V,C0G,0805	690560	1
C129-130	CAPACITOR, SMR,CAP,CER,0.047UF,+-20%,50V,X7R,1206	782615	2
C131-132	CAPACITOR, SMR,CAP,CER,10PF,+-10%,50V,C0G,1206	747311	2
C135	CAPACITOR, SMR,CAP,CER,0.033UF,+-10%,200V,X7R,1206	602547	1
CR1-10 CR12 CR14-15 CR21	DIODE,SI,PN,MMBD1503A,150V,200MA,DUAL,SERIES,LOW LEAKAGE,SOT-23,TAPE	928143	14
CR11	DIODE,2MA,10%,DO-7	686714	1
CR16 CR18 CR24-25	DIODE,SI,100V,1A,DO-214	912451	4
CR17 CR26	DIODE,SI,PN,DF01S,100V,1A,BRIDGE,4 PIN SURFACE MOUNT,3530,TAPE	912456	2
CR27-28	DIODE,SI,SCHOTTKY,40V,1A,DO-214AB	605821	2
CR29-30	DIODE,SI,SCHOTTKY,BAT54S,30V,200MA,5NS,DUAL-SERIES,SOT-23,TAPE	929745	2

Table 5-6. A7 Current PCA (cont)

Ref Des	Description	Part Number	Qty
E2	SURGE PROTECTOR,90V,+-20%	198507	1
H12-15	RIVET,AL,.089 DIA,.344 L,SEMI-TUBULAR,OVAL HEAD	838458	4
K1-2 K5 K10 K12 K14 K20-22	RELAY,ARMATURE,2 FORM C,5 VDC,LATCH	910773	9
K13 K17	RELAY,ARMATURE,4 FORM C,5V,LATCH	715078	2
K18	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	643178	1
K19	RELAY,ARMATURE,2 FORM A,5VDC,LATCH	642782	1
MP1	PCB, CURRENT	2048846	1
MP2	HEATSINK ASSEMBLY	2112487	1
MP3	HEATSINK ASSEMBLY	2112493	1
MP5-6	EJECTOR,PWB,NYLON	494724	2
MP13	HEAT SINK ASSEMBLY WITH MJE15029 XSTR	2062805	1
MP14	HEAT SINK ASSEMBLY WITH MJE15028 XSTR	2062797	1
P107 P207	CONNECTOR, DIN41612,TYPE C,RT ANG,64 PIN	807800	2
Q1	TRANSISTOR,SI,PNP,80V,10W,TO-202	495689	1
Q3-4 Q6 Q12 Q14 Q19	TRANSISTOR,SI,PNP,MMBT3906,40V,200MA,250MHZ,225MW,SOT-23,TAPE	742684	6
Q5 Q7 Q9 Q11 Q15-16 Q20	TRANSISTOR,SI,NPN,60V,350MW,SOT-23	742676	7
Q8	TRANSISTOR,SI,NPN,80V,10W,TO-202	535468	1
Q41-42	TRANSISTOR,SI,N-DMOS FET,DEPL,TO-92	945050	2
R1	RESISTOR, METAL FOIL,0.1,+-0.1%,1W,10PPM,RADIAL,BULK	2061053	1
R2 R13 R124 R133-134 R154	RESISTOR, SMR,RES,MF,10K,+-0.1%,.125W,25PPM,1206	106366	6

Table 5-6. A7 Current PCA (cont)

R3 R17-18 R21 R29 R39 R43 R57 R70-71 R85-86 R140 R145 R147 R190 R209	RESISTOR, SMR,RES,CERM,1K,+-1%,.125W,100PPM,1206	783241	17
R4 R7 R16 R22 R30-31 R33 R40-41 R46 R59-60 R72-73 R116 R205-206	RESISTOR,CERMET,100,+-1%,0.125W,100PPM,1206,TAPE	867494	17
R5 R12 R14 R25 R27 R45 R58 R66 R75-76 R83-84 R89-90 R106	RESISTOR, SMR,RES,CERM,2K,+-1%,.125W,100PPM,1206	807172	15
R6 R15 R64-65	RESISTOR, SMR,RES,CERM,13K,+-1%,0.1W,100PPM,0805	930164	4
R8 R108	RESISTOR, CERMET,200K,+-1%,0.125W,100PPM,1206,TAPE	783258	2
R9 R28 R156	RESISTOR, SMR,RES,CERM,2.2M,+-5%,.125W,200PPM,1206	811778	3
R10 R87	RESISTOR, RC1206 6.04K 1% 25PPM	1760171	2
R11	RESISTOR, SMR,RES,CERM,270,+-5%,.125W,200PPM,1206	746354	1

Table 5-6. A7 Current PCA (cont)

Ref Des	Description	Part Number	Qty
R19-20 R52 R155	RESISTOR, SMR,RES,MF,1K,+-0.1%,0.125W,10PPM,1206	929880	4
R23 R32	RESISTOR, SMR,RES,CERM,121,+-1%,.063W,100PPM,0603	689122	2
R24 R34 R61-62	RESISTOR, CERMET,0.060,+-5%,0.5W,100PPM,2010,TAPE	105999	4
R26 R54 R56 R69 R93 R102 R137 R143 R163-166 R169-172 R175-176 R193 R197 R199	RESISTOR, SMR,RES,CERM,10K,+-1%,.125W,100PPM,1206	769794	21
R35-36	RESISTOR, SMR,RES,CERM,316,1%,.125W,100PPM,1206	604900	2
R37 R63	RESISTOR, SMR,RES,CERM,2.61K,+-1%,.125W,100PPM,1206	781179	2
R38 R42 R80 R95	RESISTOR, SMR,RES,CERM,698,+-1%,0.1W,100PPM,0805	641156	4
R44 R105 R148	RESISTOR, SMR,RES,CERM,511,+-1%,.125W,100PPM,1206	769869	3
R47-48 R74 R77 R198	RESISTOR, SMR,RES,CERM,110,+-1%,.125W,100PPM,1206	644473	5
R49 R53	RESISTOR, WIREWOUND,1.0,+-0.5%,1W,50PPM,2515,TAPE	1544336	2
R50-51	RESISTOR, SMR,RES,CERM,10,+-1%,.125W,100PPM,1206	867676	2

Table 5-6. A7 Current PCA (cont)

Ref Des	Description	Part Number	Qty
R55 R91-92 R101 R114 R118-119 R211	RESISTOR, SMR,RES,CERM,4.02K,+-1%,.125W,100PPM,1206	783266	8
R67-68	RESISTOR, SMR,RES,CERM,1M,+-1%,.125W,100PPM,1206	836387	2
R78-79	RESISTOR, CERMET,47.5,+-1%,0.1W,100PPM,0805,TAPE	802006	2
R81-82	RESISTOR, SMR,RES,CERM,4.99K,+-1%,.125W,100PPM,1206	604345	2
R88	RESISTOR, SMR,RES,CERM,4.32K,+-1%,.063W,100PPM,0603	605250	1
R96-99	RESISTOR, SMR,RES,CERM,49.9K,+-1%,.125W,100PPM,1206	836379	4
R100 R103	RESISTOR, SMR,RES,CERM,4.99K,+-1%,0.1W,100PPM,0805	928767	2
R104	RESISTOR, SMR,RES,CERM,49.9,+-1%,0.1W,100PPM,0805	604923	1
R107	RESISTOR, SMR,RES,CERM,1M,+-5%,.063W,200PPM,0603	604998	1
R115 R117 R120-121	RESISTOR, SMR,RES,CERM,10K,+-1%,0.1W,100PPM,0805	928791	4
R146	RESISTOR, SMR,RES,CERM,1.8K,+-5%,.125W,200PPM,1206	746453	1
R159 R173	RESISTOR, SMR,RES,CERM,6.98K,+-1%,.125W,100PPM,1206	929919	2
R186	RESISTOR, SMR,RES,CERM,301,+-1%,.125W,100PPM,1206	644598	1
R207-208	RESISTOR, SMR,RES,CERM,49.9,+-1%,0.25W,100PPM,1210	929674	2
T1	POWER TRANSFORMER,16.5V-43.6VCT	627031	1
TP2-4 TP6-10 TP18-25	CONNECTOR,TERMINAL,TEST POINT,1510,TAPE	602125	16
U1	SMR,IC,CMOS,HEX INVERTER,SOIC	838417	1
U2	SMR,IC,CMOS,3-8 LINE DCDR W ENABLE,SOIC	783019	1
U3 U5	CMOS 74HC374 SMR,IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	866798	2
U4 U24	SMR,IC,CMOS,QUAD D F/F,+EDG TRG,SOIC	944132	2
U6 U8-9 U11-12 U14	IC,BIMOS,4 CHNL DRVR W/LTCH,SOIC	929781	6

Table 5-6. A7 Current PCA (cont)

Ref Des	Description	Part Number	Qty
U7 U13 U17 U29 U32	IC,OP AMP,AD744J,+-4.5 TO +-18V,2MV OFFSET,6MHZ,HI SLEW RATE,SO8,TAPE	929992	5
U10 U23 U25-26 U28 U47	IC,ANALOG SWITCH,DG444,+12 TO +-20V,85 OHMS,SPST,QUAD,NC,SO16,TAPE	875232	6
U16	BIFET LF412A, IC,OP AMP,DUAL,LO OFFST VOLT,LO-DRIFT	851704	1
U18	BIPOLAR OP27G, SMR,IC,OP AMP,ULOW NOISE,LOW VOS,SO8	687282	1
U19	SMR,IC,OP AMP,DUAL,JFET,LOW POWER,SOIC	806794	1
U20	BIPOLAR LM393, SMR,IC,COMPARATOR,DUAL,LOW PWR,SOIC	837211	1
U21 U44 U58-59	BIFET AD823, SMR,IC,OP AMP,DUAL,RAIL-RAIL,16 MHZ,SO8	642709	4
U27	IC,ANALOG SWITCH,ADG431,5-44V,24 OHMS,SPST,NO,SO16,TAPE	689844	1
U30 U34 U38	RELAY,SOLID STATE,1FORM A,80VDC,120MA	687217	3
U31 U37	IC,OP AMP,LT1630,2.7V TO +-15V,525UV OFFSET,15MHZ,R-R,S-S,DUAL,SO8,TAPE	2075118	2
U33 U48 U52-53	IC,OP AMP,LTC1150,+-16V,10UV OFFSET,2.5MHZ,ZERO-DRIFT,CHOPPER,DIP8,TUBE	2051666	4
U35	BIPOLAR OP284, SMR,IC,OPAMP,DUAL,PRECN,RAIL-RAIL I/O,SO8	642691	1
U45	ISOLATOR,OPTO,LED TO TRANSISTOR,SOIC	929281	1
U49	BIFET LF356N, IC,OP AMP,JFET INPUT,8 PIN DIP	472779	1
U50	IC,VOLTAGE REGULATOR,LINEAR,LM2990,-15V,1A,LDO,TO-220,TUBE	2111724	1
U51	BIPOLAR 2940, IC,VOLT REG,LDO,+15 V,1.0 A,TO-220	602748	1
VR1 VR5	ZENER,UNCOMP,MMBZ5237B,8.2V,5%,20MA,225MW,SOT-23,TAPE	837146	2
VR2	ZENER,UNCOMP,MMBZ5231B,5.1V,5%,20MA,225MW,SOT-23,TAPE	837179	1
VR3-4	ZENER,TRANS SUPPRESSOR,6V	508655	2
W1 W5-7 W14-15 W22	CONNECTOR,JUMPER,COPPER,TIN,1206,SURFACE MOUNT,T/R	2061468	7
Z2	SUBSTRATE ASSEMBLY	945316	1
Z4	THIN FILM, HERM, RESISTANCE REF.	2094985	1

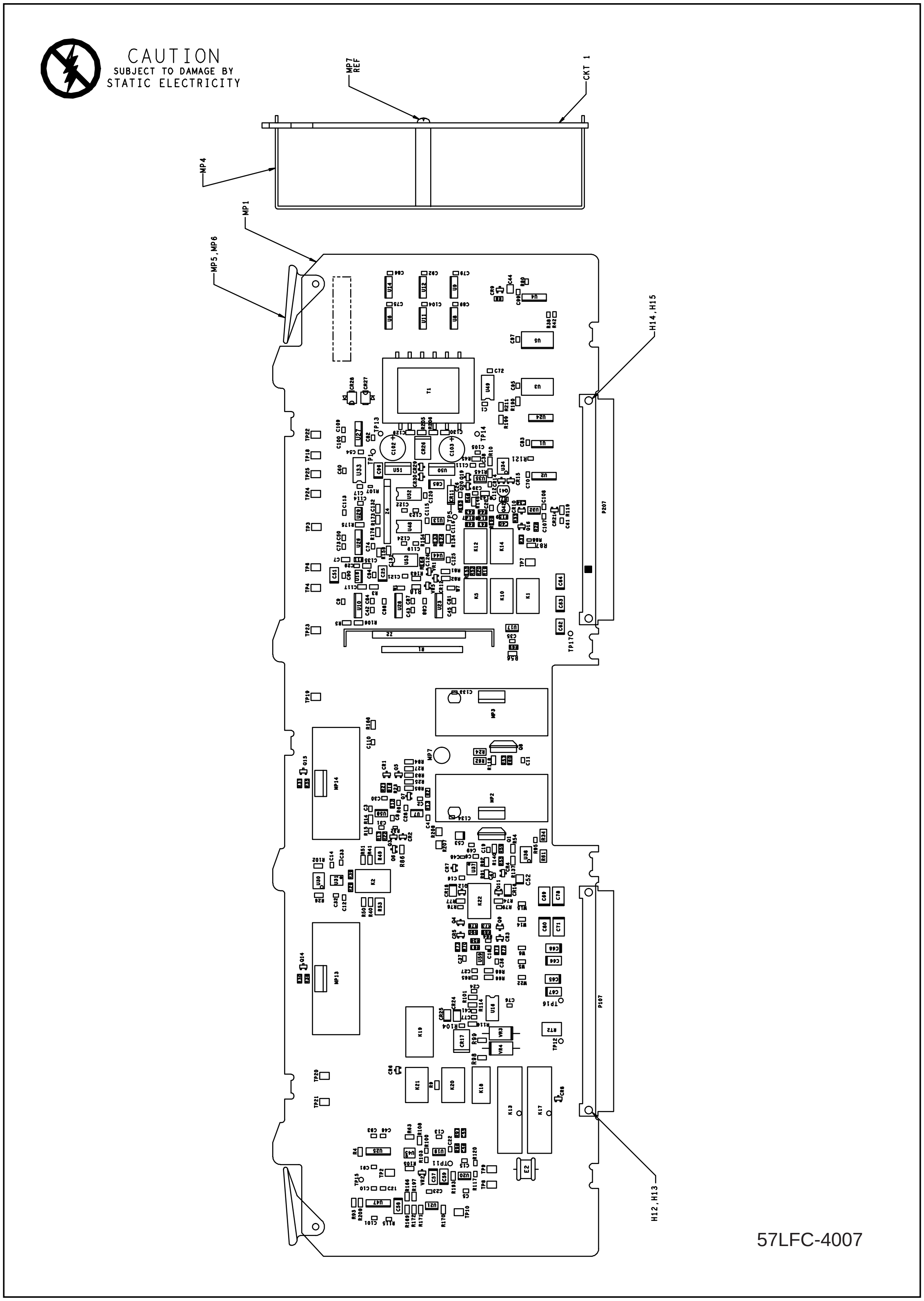

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Figure 5-6. A7 Current PCA

Table 5-7. A8 High Voltage PCA

Ref Des	Description	Part Number	Qty
A10	ISOTHERMAL PCA		1
C1 C2 C8 C34	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,100V,X7R,1206	804325	4
C3 C4 C5 C11 C26 C28 C30 C32 C36 C39 C40 C53 C54 C57 C58 C60 C62 C63 C64 C66 C67 C68 C70 C71 C72 C73 C74 C76 C83 C84 C85 C86 C87 C88 C89 C90	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,50V,X7R,0805	690500	36

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
C6 C7 C10 C12 C13 C37 C38 C41	CAPACITOR, CAP,AL,3.3UF,+30-20%,450V	782524	8
C9 C35	CAPACITOR, CAP,AL,10UF,+-20%,160V,SOLV PROOF	817064	2
C14 C42 C61	CAPACITOR, SMR,CAP,CER,100PF,+-5%,50V,C0G,0805	514133	3
C15 C43 C65 C69 C91 C92	CAPACITOR, FILM,POLYESTER,1.0UF,+-10%,50V,7360,TAPE	2063474	6
C16 C44	CAPACITOR, SMR,CAP,TA,100UF,+-20%,10V,7343	929877	2
C17 C25	CAPACITOR, CAP,CER,0.02UF,+-20%,500V,Z5U	407403	2
C18 C24 C45	CAPACITOR, CERAMIC,22PF,+-5%,1000V,C0G,1808,TAPE	2062822	3
C19 C46 C47 C49	CAPACITOR, FILM,POLYPHENYLENE SULFIDE,0.22UF,+-20%,50V,7360,TAPE	1546405	4
C20 C23	CAPACITOR, R05R,CAP,TA,15UF,+-20%,20V	807610	2
C21 C22	CAPACITOR, SMR,CAP,POLYES,0.47UF,+-10%,50V,7360	802519	2
C27	CAPACITOR, SMR,CAP,CER,10PF,+-5%,50V,C0G,0805	494781	1
C29	CAPACITOR, SMR,CAP,CER,470PF,+-1%,50V,C0G,0805	929476	1
C31 C33 C81 C82	CAPACITOR, SMR,CAP,CER,47PF,+-5%,50V,C0G,0805	494633	4
C48	CAPACITOR, CERAMIC,10PF,+-2%,1000V,C0G,1808,TAPE	1579905	1

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
C50	CAPACITOR, SMR,CAP,TA,1UF,+-20%,35V,3528	866970	1
C51	CAPACITOR, SMR,CAP,CER,22PF,+-1%,50V,C0G,0805	867663	1
C52	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,50V,X7R,1206	605292	1
C55 C56 C59 C75	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	4
C77 C78 C79 C80	CAPACITOR,CERAMIC,0.1UF,+-10%,25V,X7R,0805,TAPE	942529	4
CR1 CR2 CR4 CR5 CR16 CR17 CR22 CR23 CR25 CR27 CR29 CR30 CR36 CR37 CR39 CR47 CR49 CR50 CR51 CR52 CR53 CR58 CR59 CR60 CR61	DIODE,SI,PN,BAV99,70V,215MA,6NS,DUAL,SERIES,SOT-23,TAPE	742320	25
CR3 CR6 CR10 CR11 CR12 CR13 CR54 CR55 CR56 CR57	DIODE,SI,PN,S1G,400V,1A,1.8US,DO-214AC,TAPE	107573	10

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
CR7 CR8 CR9 CR14 CR15 CR18 CR19 CR20 CR40 CR41 CR62 CR63	DIODE,SI,PN,GF1M,1000V,1A,SMB,TAPE	2060197	12
CR21 CR38 CR46	CURRENT REGULATOR DIODE,CCLM1000,1.1MA,20%,1.7-100V,SOD80,TAPE	2043974	3
CR26 CR43 CR44 CR45	DIODE,MURS120 SMR,DIODE,SI,ULTRAFAST,200V,1A,SMB	944264	4
CR31 CR32 CR65 CR66	DIODE,SI,PN,BAV199,70V,215MA,3US,DUAL,SERIES,SOT-23,TAPE	605805	4
CR35 CR48	DIODE,MBRS140 SMR,DIODE,SI,SCHOTTKY,40V,1A,DO-214AB	605821	2
CR42	CURRENT REGULATOR DIODE,CCLM2000,2MA,16%,2.3-100V,SOD80,TAPE	2119594	1
F1 F2	FUSE,8X8.5MM,0.2A,250V,SLOW,RADIAL	851949	2
K1 K2 K3 K4	RELAY,ARMATURE,2 FORM C,5VDC,LATCH	603001	4
L1	CHOKE,6TURN	320911	1
L2	INDUCTOR,1.5UH,+-5%,128MHZ,SHLD	413856	1
MP1	PCB, HIGH VOLTAGE	2048854	1
MP2 MP5	HEATSINK ASSEMBLY	2070059	2
MP3 MP14	HEATSINK ASSEMBLY	2070067	2
MP4	HEATSINK ASSEMBLY	2070032	1

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
MP6 MP9	HEATSINK ASSEMBLY	2117189	2
MP7 MP11	HEATSINK ASSEMBLY	2117192	2
MP8	HEATSINK ASSEMBLY	2070044	1
MP10	HEATSINK ASSEMBLY	2070836	1
MP12	HEATSINK ASSEMBLY	665448	1
MP13	HEATSINK ASSEMBLY	2070849	1
MP15 MP16	EJECTOR,PWB,NYLON	494724	2
P18 P28	CONNECTOR,CONN,DIN41612,TYPE C,RT ANG,64 PIN	807800	2
Q03 Q09 Q19 Q26 Q31 Q47 Q49 Q59	NPN,MMBT3904 SMR,TRANSISTOR,SI,NPN,60V,350MW,SOT-23	742676	8
Q6 Q8 Q28 Q30 Q32 Q39 Q53 Q54 Q55 Q60	TRANSISTOR,SI,PNP,MMBT3906,40V,200MA,250MHZ,225MW,SOT-23,TAPE	742684	10
Q10 Q11 Q35 Q56	TRANSISTOR,SI,PNP,150V,300MW,TO-92	266619	4
Q12 Q34 Q36	TRANSISTOR,SI,NPN,2N5551,180V,600MA,100MHZ,625MW,TO-92,TAPE	1791849	3
Q13 Q14 Q61 Q62	TRANSISTOR,SI,PNP,MJD350,300V,500MA,1.56W,D-PAK,TAPE	2063630	4

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
Q15 Q16 Q63 Q64	TRANSISTOR,SI,NPN,MJD340,300V,500MA,1.56W,D-PAK,TAPE	2063627	4
Q17 Q18 Q20 Q41	FET,DMOS,N-CH R05A,TRANSISTOR,SI,N-DMOS,500V,TO-92	782490	4
Q21 Q37 Q38 Q40	MOSFET,P-CHN R05A,TRANSISTOR,SI,P-MOS,500V,TO-92	782508	4
Q23 Q24	TRANSISTOR,SI,PNP,2N6520,350V,500MA,40MHZ,625MW,TO-92,TAPE	602961	2
Q43 Q58	TRANSISTOR,SI,NPN,350V,625MW,TO-92	853994	2
Q45 Q50 Q51	TRANSISTOR,SI,NPN,2N3904,60V,200MA,300MHZ,625MW,AMMO BOX,TO-92,TAPE	698225	3
Q46	TRANSISTOR,SI,PNP,12V,625MW,TO-92	831446	1
Q48	N-CHANNEL MOSFET ENHANCEMENT	1756473	1
Q66	MOSFET,SI,N,IRF820,500V,2.5A,3 OHMS,50W,TO-220,BULK	782540	1
Q67	FET,PWR,P,MTP2P50 ,TRANSISTOR,SI,P-MOS,POWER,500V,TO-220	782482	1
R1 R2 R102 R111	RESISTOR, SMR,RES,CERM,470,+-5%,.125W,200PPM,1206	740506	4
R3 R9	RESISTOR, SMR,RES,CERM,27,+-5%,.125W,200PPM,1206	807735	2
R4 R6 R8 R10	RESISTOR, CERMET,10,+-5%,0.25W,200PPM,1206,TAPE	2060987	4
R5 R7	RESISTOR, SMR,RES,CERM,22,+-5%,.125W,200PPM,1206	746230	2

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
R11 R12 R49 R57 R129 R131 R133 R138 R144 R212 R234	RESISTOR, SMR,RES,CERM,1K,+-1%,0.1W,100PPM,0805	928713	11
R22 R23 R24 R25 R26 R27 R28 R29 R95 R96 R98 R99 R100 R101 R103 R104 R107 R108 R109 R110 R113 R114 R116 R117	RESISTOR, CERMET,68K,+-2%,0.75W,200PPM,2010,TAPE	2062916	24

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
R30 R58 R134 R149 R159 R160 R164 R165 R171 R172 R203 R204 R205 R214 R244 R250	RESISTOR, SMR,RES,CERM,10K,+-1%,0.1W,100PPM,0805	928791	16
R36 R73 R74 R157 R216 R217	RESISTOR, CERMET,110,+-5%,0.75W,200PPM,2010,TAPE	2060968	6
R37 R39 R40 R85 R87 R89 R218 R220 R222 R229 R230 R231	RESISTOR, CERMET,150K,+-5%,0.25W,200PPM,1206,TAPE	2060922	12

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
R38 R41 R42 R43 R76 R78 R81 R84 R219 R221 R223 R224 R225 R226 R227 R228	RESISTOR, CERMET,56K,+-5%,0.75W,200PPM,2010,TAPE	2060910	16
R44 R142	RESISTOR, SMR,RES,CERM,150,+-5%,.125W,200PPM,1206	746313	2
R45 R46	RESISTOR, CERMET,10K,+-5%,0.25W,200PPM,1210,TAPE	1597827	2
R48 R50 R51 R52 R53 R54 R55 R56	RESISTOR, CERMET,120K,+-1%,0.25W,100PPM,1206,TAPE	2062893	8
R61 R62 R63 R64 R150 R151 R152 R153	RESISTOR, CERMET,280K,+-5%,0.25W,200PPM,1206,TAPE	2060979	8
R65 R66 R67 R70 R71 R72	RESISTOR, CERMET,10,+-10%,1W,200PPM,2512,TAPE	2113674	6
R68 R156 R158	RESISTOR, CERMET,33.2K,+-1%,0.1W,100PPM,0805,TAPE	943345	3

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
R69 R155	RESISTOR, METAL FILM,48.7K,+-0.1%,0.1W,25PPM,0805,TAPE	1544262	2
R75 R136 R137 R140 R154 R162 R207	RESISTOR, SMR,RES,CERM,100K,+-1%,0.1W,100PPM,0805	928866	7
R77 R163	RESISTOR, CERMET,3.16K,+-1%,0.1W,100PPM,0805,TAPE	943019	2
R79 R80 R82 R166 R167 R170	RESISTOR, CERMET,330K,+-5%,0.25W,200PPM,1206,TAPE	2060931	6
R83 R86 R173 R178	RESISTOR, CERMET,9.1K,+-5%,0.1W,200PPM,0805,TAPE	2060946	4
R88 R179	RESISTOR, CERMET,8.2,+-1%,0.25W,100PPM,1206,TAPE	2123526	2
R90 R232	RESISTOR, CERMET,3.3,+-1%,0.25W,100PPM,1206,TAPE	2113688	2
R91 R92 R93 R180 R181 R182	RESISTOR, CERMET,27K,+-5%,0.125W,200PPM,1206,TAPE	740530	6
R94 R97 R112 R115	RESISTOR, CERMET,18.2,+-1%,1W,100PPM,2512,TAPE	2052279	4
R118 R190 R191	RESISTOR, SMR,RES,CERM,47,+-5%,.125W,200PPM,1206	746263	3
R119 R120 R121 R122	RESISTOR, CERMET,15K,+-5%,0.75W,200PPM,2010,TAPE	2090984	4
R123	RESISTOR, SMR,RES,CERM,2.2K,+-5%,.125W,200PPM,1206	746479	1

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
R124	RESISTOR, CERMET,3.92K,+-1%,0.125W,100PPM,0805,TAPE	1591284	1
R125 R127	RESISTOR, BULK METAL FOIL,100K,+-0.1%,0.6W,0.6PPM,RADIAL,BULK	2114847	2
R126 R198	RESISTOR, CERMET,220,+-1%,0.25W,100PPM,1206,TAPE	2063572	2
R128	RESISTOR, SMR,RES,CERM,30.9K,+-1%,0.1W,100PPM,0805	928838	1
R130 R215 R233 R243 R249	RESISTOR, CERMET,4.75K,+-1%,0.1W,100PPM,0805,TAPE	2063107	5
R132 R139 R213	RESISTOR, CERMET,2K,+-1%,0.1W,100PPM,0805,TAPE	928742	3
R135 R147 R206	RESISTOR, CERMET,237,+-1%,0.1W,100PPM,0805,TAPE	801990	3
R141	RESISTOR, SMR,RES,CERM,13.3K,+-1%,0.1W,100PPM,0805	928809	1
R143	RESISTOR, SMR,RES,CERM,10,+-5%,1W,200PPM,2512	886705	1
R145 R146	RESISTOR, BULK METAL FOIL,10K,+-0.1%,0.6W,0.6PPM,RADIAL,BULK	2114858	2
R148	RESISTOR, SMR,RES,MF,1K,+-0.1%,0.1W,50PPM,0805	802469	1
R161	RESISTOR, SMR,RES,CERM,301K,+-1%,0.1W,100PPM,0805	602711	1
R168 R169	RESISTOR, SMR,RES,CERM,200K,+-1%,0.1W,100PPM,0805	928882	2
R174 R175 R176 R177	RESISTOR, SMR,RES,CERM,15K,+-1%,.125W,100PPM,1206	769810	4
R183 R185	RESISTOR, SMR,RES,CERM,100,+-1%,1W,100PPM,2512	691394	2
R184	RESISTOR, SMR,RES,CERM,332,+-1%,.125W,100PPM,1206	644614	1
R186 R187 R188 R189	RESISTOR, CERMET,100,+-1%,0.25W,100PPM,1206,TAPE	2090991	4
R192	RESISTOR, SMR,RES,CERM,1.5K,+-1%,.125W,100PPM,1206	810630	1
R193	RESISTOR, SMR,RES,CERM,432,+-1%,.125W,100PPM,1206	811885	1

Table 5-7 A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
R194	RESISTOR, SMR,RES,CERM,86.6,+-1%,0.1W,100PPM,0805	106929	1
R195	RESISTOR, CERMET,3.57K,+-1%,0.1W,100PPM,0805,TAPE	943022	1
R196	RESISTOR, CERMET,750,+-1%,0.1W,100PPM,0805,TAPE	1292158	1
R197	RESISTOR, VARIABLE,CERMET,2K,+-20%,0.25W,SINGLE TURN,TOP ADJ,4MM,TAPE	1292409	1
R199 R201 R210	RESISTOR, SMR,RES,CERM,2.43K,+-1%,0.1W,100PPM,0805	928754	3
R200	RESISTOR, SMR,RES,CERM,27.4K,+-1%,0.1W,100PPM,0805	930185	1
R202	RESISTOR, SMR,RES,CERM,18.2K,+-1%,0.1W,100PPM,0805	930177	1
R208	RESISTOR, SMR,RES,CERM,1.5K,+-1%,0.1W,100PPM,0805	688884	1
R211 R264 R265	RESISTOR, SMR,RES,CERM,3.32K,+-1%,0.1W,100PPM,0805	930099	3
R235 R236	RESISTOR, CERMET,24.3K,+-1%,0.1W,100PPM,0805,TAPE	943071	2
R240 R241 R246 R247	RESISTOR, SMR,RES,MF,10K,+-0.1%,0.1W,25PPM,0805	650389	4
R242 R248 R252 R253 R254 R255	RESISTOR, SMR,RES,CERM,249K,+-1%,.125W,100PPM,1206	821306	6
R245 R251	RESISTOR, SMR,RES,CERM,2K,+-1%,.125W,100PPM,1206	807172	2
R256 R257 R258 R259	RESISTOR, CERMET,2.21K,+-1%,0.1W,100PPM,0805,TAPE	928747	4
R260 R261	RESISTOR, CERMET,5.6,+-1%,0.25W,100PPM,1206,TAPE	2113695	2
R277 R278	RESISTOR, CERMET,10M,+-1%,0.1W,400PPM,0805,TAPE	943659	2
RT001 RT002	THERMISTOR,DISC,POS,47,+-20%,25C	604139	2
S1	WIRE,JUMPER,TEF,22AWG,WHT,.200	529776	2

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
TP1 TP2 TP3 TP4 TP5 TP6 TP7 TP8 TP9 TP10 TP11 TP12 TP13 TP14 TP15 TP16 TP17 TP18	CONNECTOR, TERMINAL,TEST POINT,1510,TAPE	602125	18
U1 U2	BIFET LF353, SMR,IC,OP AMP,DUAL,JFET INPUT,SO8	688579	2
U3 U5	IC,OP AMP,OPA637,+-4.5V TO +-18V,250UV OFFSET,80MHZ,HI-SPEED,DIFET,SO8,TAPE	2091008	2
U4 U11	CMOS LTC1150, SMR,IC,OP AMP,CHOPPER,+/-15V,INT CAPS,SO8	107565	2
U6	CMOS 74HCU04, SMR,IC,CMOS,HEX INVERTER,UNBUFFERED,SOIC	806893	1
U7	CMOS 74HC138, SMR,IC,CMOS,3-8 LINE DCDR W ENABLE,SOIC	783019	1
U8	BIPOLAR 339, SMR,IC,COMPARATOR,QUAD,14 PIN,SOIC	741561	1
U9	BIPOLAR LM393, SMR,IC,COMPARATOR,DUAL,LOW PWR,SOIC	837211	1
U10 U20	IC,ANALOG SWITCH,DG413,3-44V,35 OHMS,SPST,QUAD,2NC,2NO,SO16,TAPE	1563433	2
U12 U13	BIMOS 5800, SMR,IC,BIMOS,4 CHNL DRVR W/LTCH,SOIC	929781	2
U14 U17	CMOS 74HC374 SMR,IC,CMOS,OCTAL D F/F,+EDG TRG,SOIC	866798	2
U15 U16	IC,OP AMP,OP196,3-12V,300UV OFFSET,350KHZ,R/R,S/S,SO8,TAPE	2101052	2
U19	IC,ANALOG SWITCH,DG408,+-15V,100 OHMS,8-1 MULTIPLEXER,SO16,TAPE	2101034	1
U21 U24	IC,OP AMP,AD744J,+-4.5 TO +-18V,2MV OFFSET,6MHZ,HI SLEW RATE,SO8,TAPE	929992	2

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
U22 U23	IC,VOLTAGE REFERENCE,ZRB500,5V,1%,50PPM/C,150UA,SOT-23,TAPE	2101029	2
VR1 VR2 VR4 VR11 VR12 VR14 VR17 VR20 VR21 VR33 VR34 VR35 VR38 VR39 VR40 VR46 VR49 VR51	ZENER,UNCOMP,MMSZ5240B,10V,5%,20MA,500MW,SOD-123,TAPE	2060235	18
VR3 VR5 VR6 VR7 VR13 VR28 VR29 VR44 VR45 VR47	ZENER,UNCOMP,BZG03-C150,150V,8%,5MA,1.25W,SOD106,TAPE	2060212	10
VR8 VR26 VR27 VR30	ZENER,UNCOMP,MMBZ5237B,8.2V,5%,20MA,225MW,SOT-23,TAPE	837146	4
VR9 VR10 VR31 VR32	ZENER,UNCOMP,BZG03-C200,200V,6%,5MA,1.25W,SOD106,TAPE	2113707	4
VR15 VR16 VR18	ZENER,UNCOMP,MMSZ5245B,15V,5%,8.5MA,500MW,SOD-123,TAPE	2062810	3
VR19	ZENER,UNCOMP,MMSZ5226B,3.3V,5%,20MA,500MW,SOD-123,TAPE	641925	1

Table 5-7. A8 High Voltage PCA (cont)

Ref Des	Description	Part Number	Qty
VR22 VR23 VR24 VR25 VR41 VR42 VR43 VR48 VR50	ZENER,UNCOMP,MMBZ5231B,5.1V,5%,20MA,225MW,SOT-23,TAPE	837179	9
VR36 VR37	ZENER,UNCOMP,MMSZ5263B,56V,5%,2.2MA,500MW,SOD-123,TAPE	2060247	2
VR54 VR55	ZENER,UNCOMP,MMBZ5240B,10V,5%,20MA,225MW,SOT-23,TAPE	783704	2
VR56 VR59	ZENER 1N6456A A52R,ZENER,TRANS SUPPRESSOR,400V,5%	845003	2
VR57 VR58	ZENER,UNCOMP,1.5SMC47A,47V,5%,1MA,4W,TRANSIENT SUPRESSOR,SMC,TAPE	2086534	2

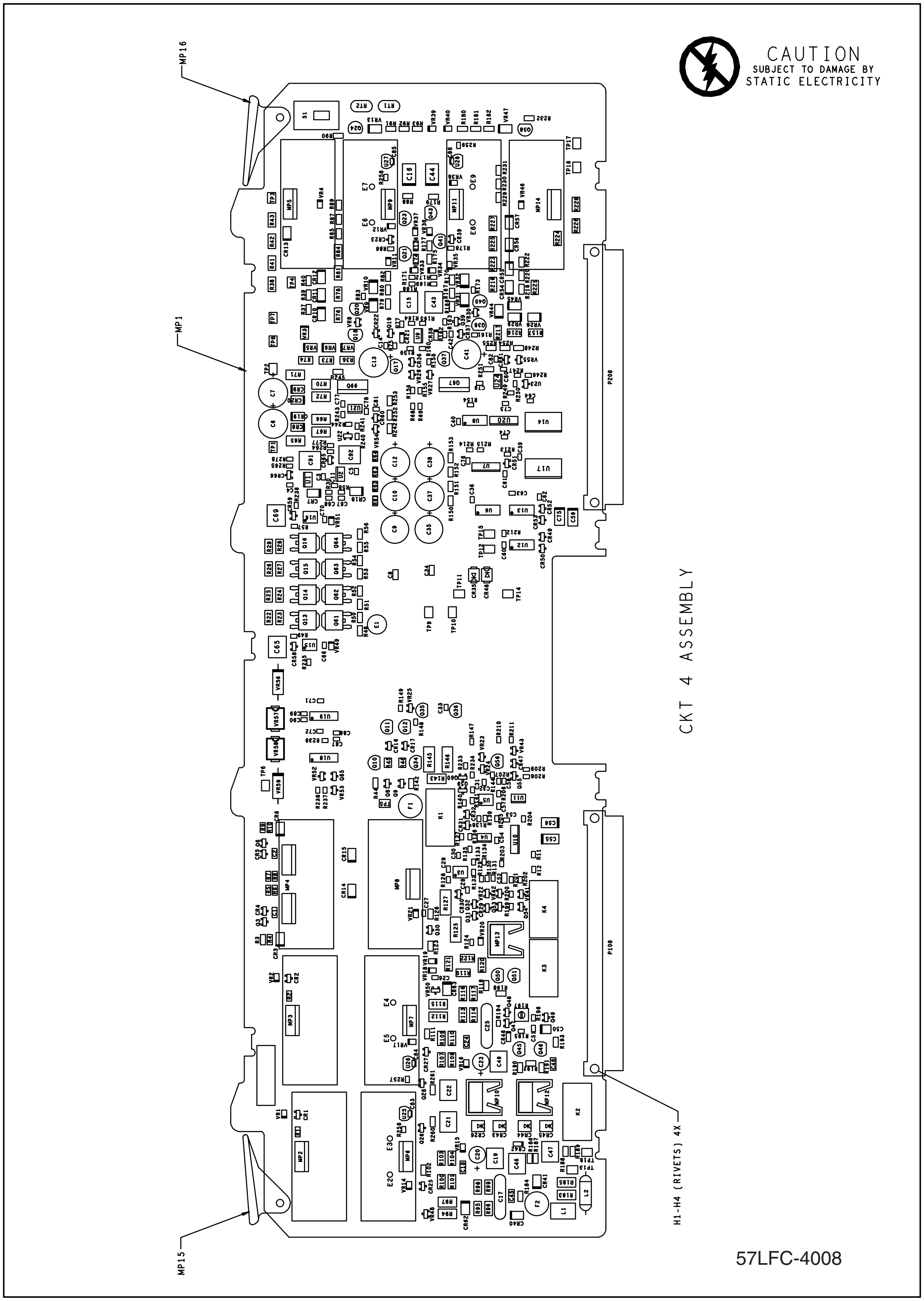

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Figure 5-7. A8 High Voltage PCA

Table 5-8. A9 Out-Guard CPU PCA

Ref Des	Description	Part Number	Qty
BT1	BATTERY,PRIMARY,LITHIUM-MNO2,3.0V,0.560AH,CR2450,COIN,PC PINS,24X5MM,BULK	821439	1
C1-2	CAPACITOR, SMR,CAP,CER,22PF,+-10%,50V,C0G,1206	740563	2
C3-4	CAPACITOR, SMR,CAP,CER,22PF,+-10%,50V,C0G,1206	740563	2
C5 C7-8 C11-12 C15-16 C18-21 C25-26 C31-32 C36-38 C42-44 C47-49 C53	CAPACITOR, SMR,CAP,CER,0.01UF,+-10%,50V,X7R,0603	644838	25
C6 C23 C30 C39 C46 C55 C64 C66	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,25V,X7R,1206	747287	8
C9	CAPACITOR, SMR,CAP,CER,100PF,+-10%,50V,C0G,1206	740571	1
C13	CAPACITOR, SMR,CAP,TA,47UF,+-20%,16V,7343	644994	1
C17	CAPACITOR, SMR,CAP,CER,1000PF,+-10%,50V,X7R,0805	484378	1
C24 C28-29	CAPACITOR, SMR,CAP,CER,0.01UF,+-10%,50V,X7R,0603	644838	3

Table 5-8. A9 Out-Guard PCA (cont)

Ref Des	Description	Part Number	Qty
C27 C45 C50-52 C54 C67	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	7
C33-35	CAPACITOR, SMR,CAP,CER,100PF,+-10%,500V,C0G,1206	691508	3
C40-41 C72-73	CAPACITOR, SMR,CAP,CER,0.1UF,+-10%,25V,X7R,1206	747287	4
C56-63	CAPACITOR, SMR,CAP,CER,100PF,+-10%,500V,C0G,1206	691508	8
C65 C68-70	CAPACITOR, SMR,CAP,TA,10UF,+-20%,25V,6032	927814	4
C71	CAPACITOR, SMR,CAP,CER,330PF,+-5%,50V,C0G,0805	512038	1
H1-2	SCREW,6-32,.250,PAN,PHILLIPS,STEEL,ZINC-CLEAR,LOCK	152140	2
J1	CABLE,2MM,FLAT,20PIN	626066	1
J2	CONNECTOR, CONN,D-SUB,PWB,9 PIN	944256	1
J4	CONNECTOR, CONN,MICRO-RIBBON,REC,PWB,24 POS	851675	1
L1-8	INDUCTOR,BEAD,70 OHMS@100MHZ,200MADC,500MOHM,1206,TAPE	944558	8
L9-24	INDUCTOR,BEAD,70 OHMS@100MHZ,200MADC,500MOHM,1206,TAPE	944558	16
MP1-2	STANDOFF,ROUND,6-32,.220 HEIGHT,.250 OD,BRASS,SWAGE,.062 PANEL THK	261727	2
MP3-5	SPACER,SWAGE,.250 RND,BR,6-32,.250	446351	3
MP6	RUBBER,PAD,PORON,.75,.75,.125,SSA	690495	1
P3	CONNECTOR, D-SUB,PWB,9 SCKT	942581	1
R1	RESISTOR, SMR,RES,MF,10K,+-0.1%,.125W,25PPM,1206	106366	1

Table 5-8. A9 Out-Guard PCA (cont)

Ref Des	Description	Part Number	Qty
R2 R4 R56-57	RESISTOR, SMR,RES,CERM,2K,+-5%,.125W,200PPM,1206	746461	4
R3 R55 R58	RESISTOR, SMR,RES,CERM,2K,+-5%,.125W,200PPM,1206	746461	3
R5	RESISTOR, CERMET,JUMPER,0,+0.05 MAX,0.063W,0603,TAPE	604394	1
R6 R13	RESISTOR, SMR,RES,CERM,51.1,+-1%,.125W,100PPM,1206	806422	2
R7 R11	RESISTOR, SMR,RES,CERM,499,+-1%,.125W,100PPM,1206	867833	2
R8-9 R19 R34 R37 R54 R59-60	RESISTOR,SMR,RES,CERM,3K,+-5%,.125W,200PPM,1206	746511	8
R14-15	RESISTOR, SMR,RES,CERM,27,+-5%,.125W,200PPM,1206	807735	2
R17	RESISTOR, SMR,RES,CERM,1K,+-5%,.125W,200PPM,1206	745992	1
R18	RESISTOR, SMR,RES,CERM,390,+-5%,.125W,200PPM,1206	740498	1
R20	RESISTOR, SMR,RES,CERM,3.6K,+-5%,.125W,200PPM,1206	746537	1
R21	RESISTOR, SMR,RES,CERM,10.7K,+-1%,0.1W,100PPM,0805	930037	1
R22	RESISTOR, SMR,RES,CERM,1K,+-5%,.125W,200PPM,1206	745992	1
S2	SWITCH,SLIDE,SPDT,LOW PROFILE	911250	1
U1	SMR,IC,CMOS,MICROPROCESSOR SUPERVISOR,SO8	929224	1
U2	SMR,IC,TTL,DUAL RS422 DRVR/RCV W/3ST,SOIC	913827	1
U3	REAL TIME CLOCK MODULE,RTC64613A,PARALLEL I/O,W/CRYSTAL,SO24,TAPE	914036	1
U4	IC,VOLTAGE REGULATOR,LINEAR,LP2980,5V,50MA,LDO,LO PWR,W/SHUT DOWN,SOT-23-5,TAPE	944996	1
U5	IC,MEMORY,FLASH,28F004,4MB,512KX8,5V,80NS,BOTTOM BOOT,PROGRAMMED,U5,TSOP40,TRAY	689232	1

Table 5-8. A9 Out-Guard PCA (cont)

Ref Des	Description	Part Number	Qty
U6	IC,MEMORY,FLASH,28F004,4MB,512KX8,5V,80NS,BOTTOM BOOT,PROGRAMMED,U6,TSOP40,TRAY	689239	1
U7	IC, LOGIC, 7SZ04, 1.8V-5.5V, INVERTER, SC70-5, TAPE	1541155	1
U8	CMOS 7SZ125 SMR,IC,CMOS,SINGLE BUFFER W/3-ST,SOT-23-5	690765	1
U9	CMOS 7SZ126 SMR,IC,CMOS,SINGLE BUFFER W/3-ST,SOT-23-5	689304	1
U10	IC,MICROPROCESSOR,68306,16 BIT,5V,16MHZ,INTEGRATED,PQFP132,TRAY	929083	1
U11	IC, LOGIC, 7SZ04, 1.8V-5.5V, INVERTER, SC70-5, TAPE	1541155	1
U14	CMOS 68C681 SM,IC,CMOS,DUAL CHANNEL UART,PLCC	866785	1
U19-20	IC,INTERFACE,LT1781,DUAL RS-232 LINE DRIVER/RECEIVER,+-15KV ESD,SOICW16,TAPE	2101104	2
U21	SMR,IC,NMOS,GPIB CONTROLLER,PLCC	887190	1
U24	SMR,IC,LSTTL,OCTAL GPIB XCVR,SOIC	831651	1
U25	SMR,IC,LSTTL,OCTAL GPIB XCVR,SOIC	831669	1
U32-35	IC,MEMORY,SRAM,K6T1008,1MB,128KX8,5V,100NS,SO32,TAPE	914101	4
Y1	CRYSTAL,12.288MHZ,50/100PPM,20PF,PLASTIC ENCAPSULATED,SMD,TAPE	913942	1
Y2	CRYSTAL,3.6864MHZ,100/100PPM,20PF,PLASTIC ENCAPSULATED,SMD,TAPE	929240	1
Z1-2	RESISTOR, SMR,RES,CERM,ARRAY,4 PIN,2 RES,1K,+-5%	644861	2

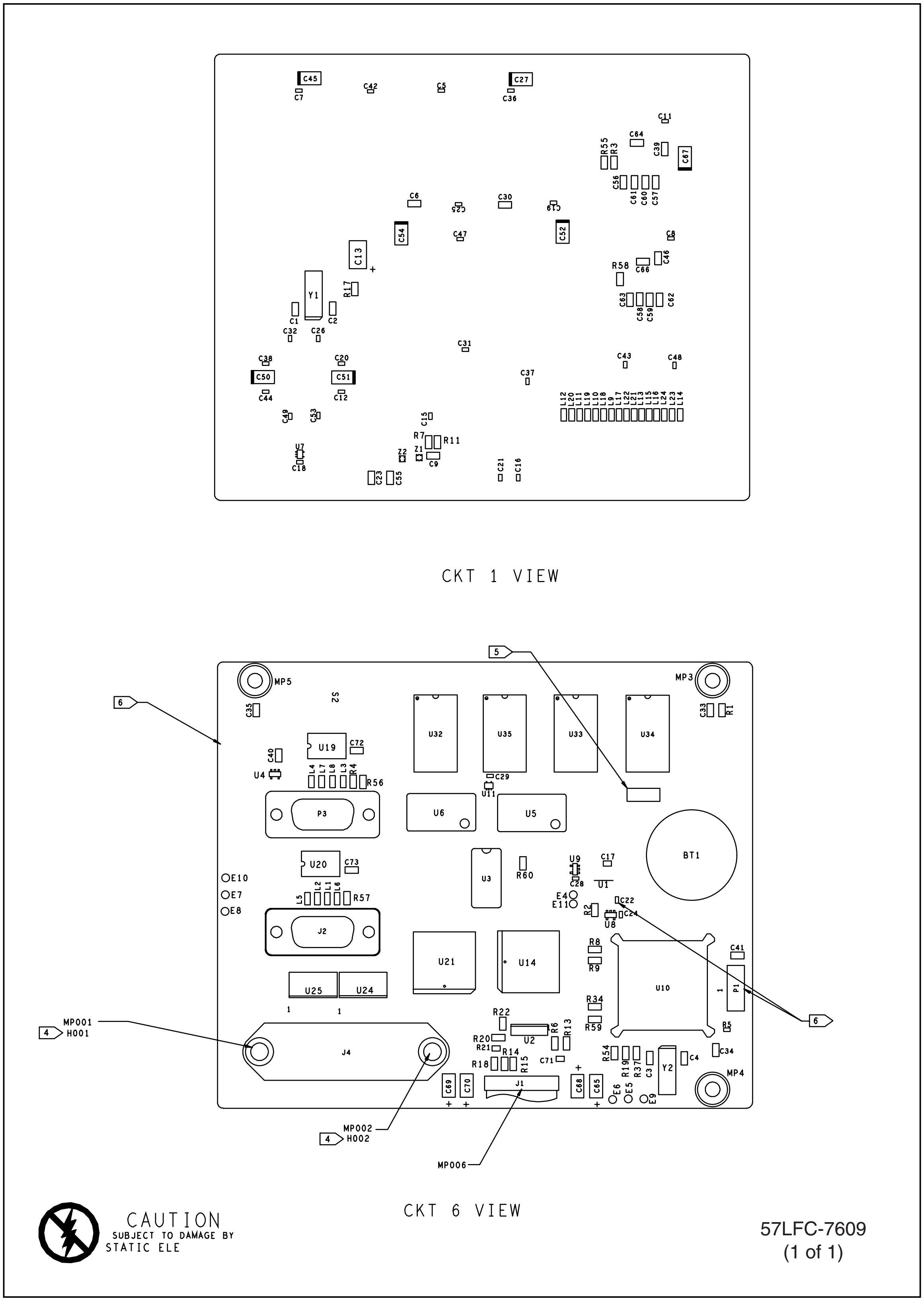

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Figure 5-8. A9 Out-Guard PCA

Chapter 6
Schematic Diagrams

Figure	Title	Page

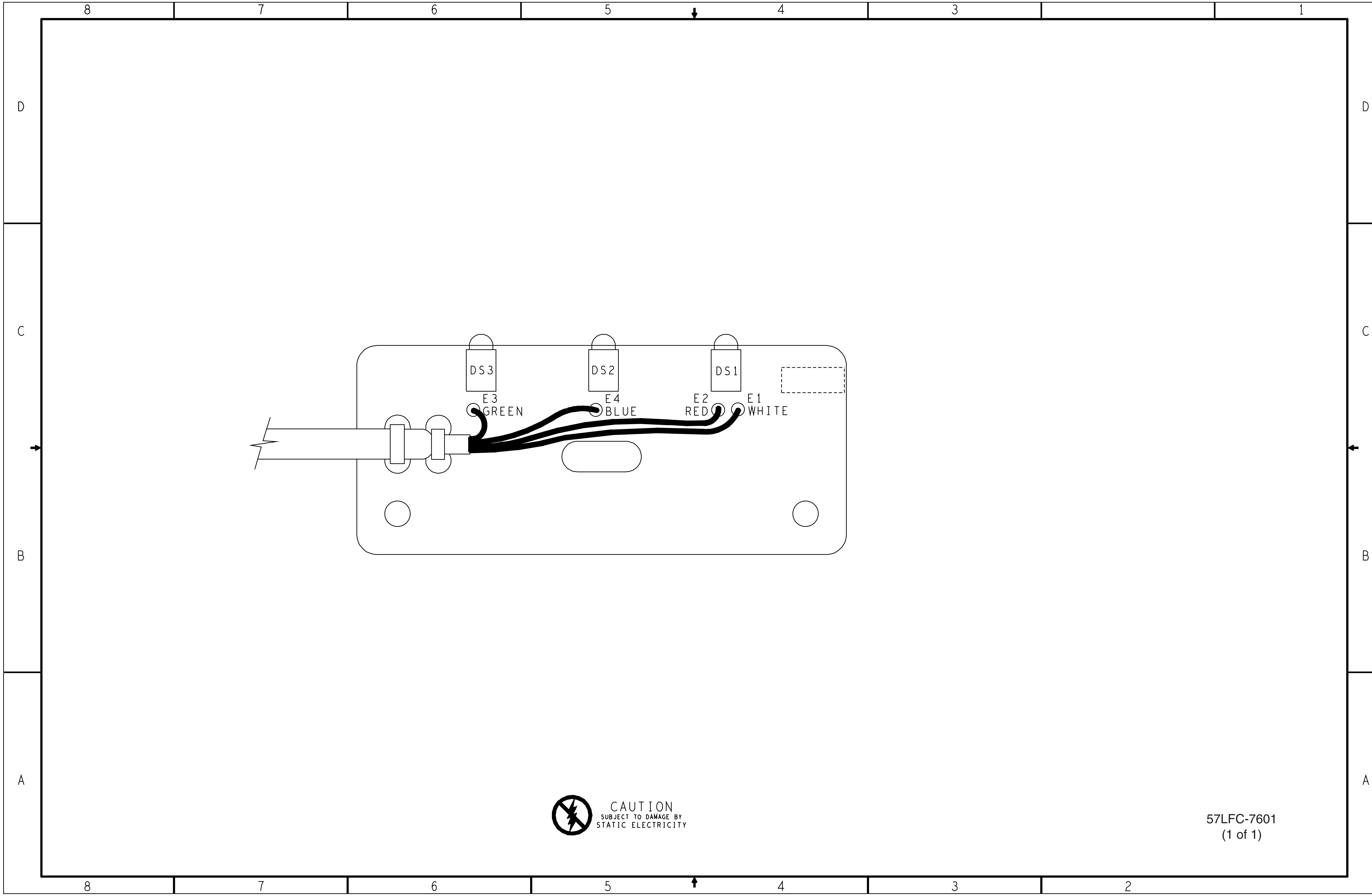


Figure 6-1. A1 LED PCA

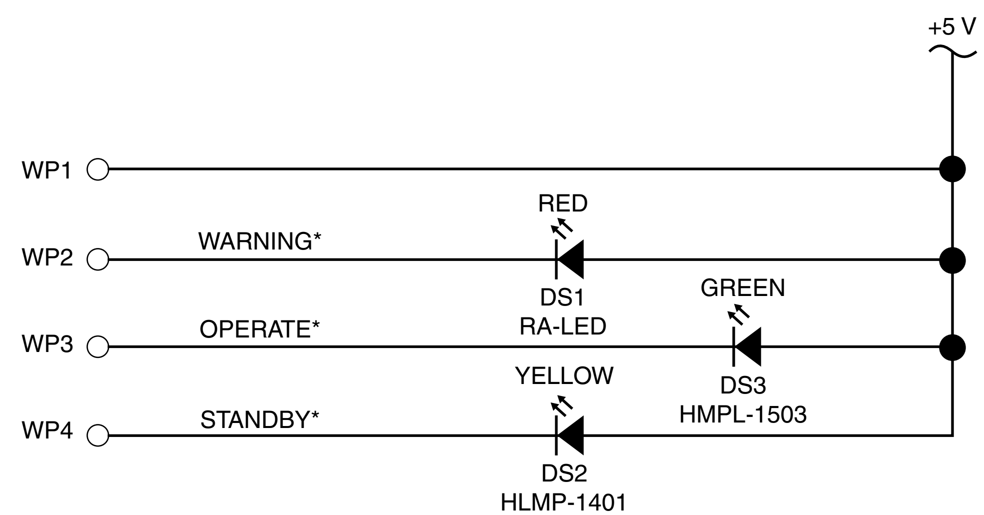


Figure 6-1. A1 LED PCA (cont)

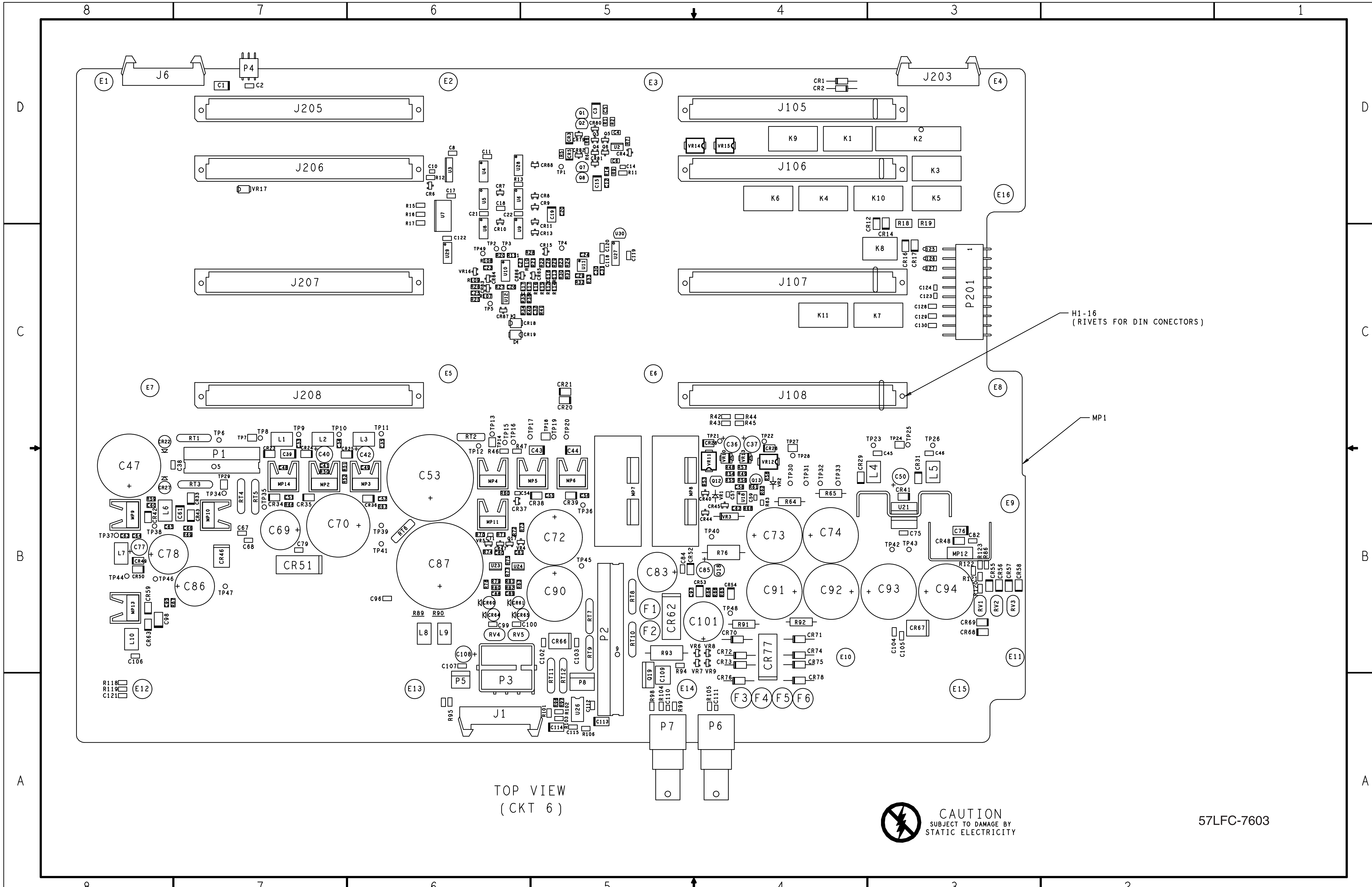
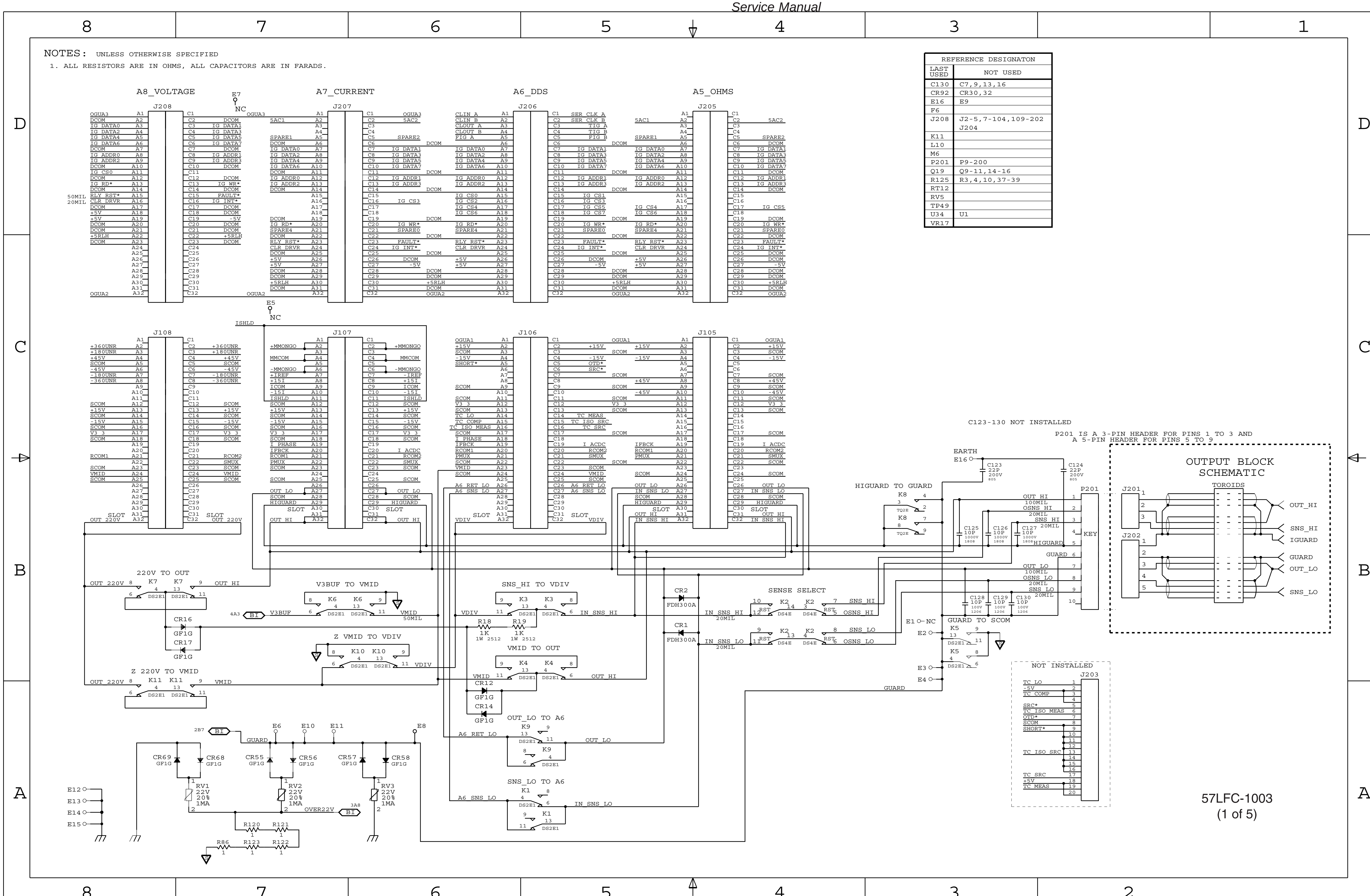


Figure 6-2. A3 Motherboard PCA



REFERENCE DESIGNATON	
LAST USED	NOT USED
C130	C7,9,13,16
CR92	CR30,32
E16	E9
F6	
J208	J2-5,7-104,109-202 J204
K11	
L10	
M6	
P201	P9-200
Q19	Q9-11,14-16
R125	R3,4,10,37-39
RT12	
RV5	
TP49	
U34	U1
VR17	

Figure 6-2. A3 Motherboard PCA (cont)

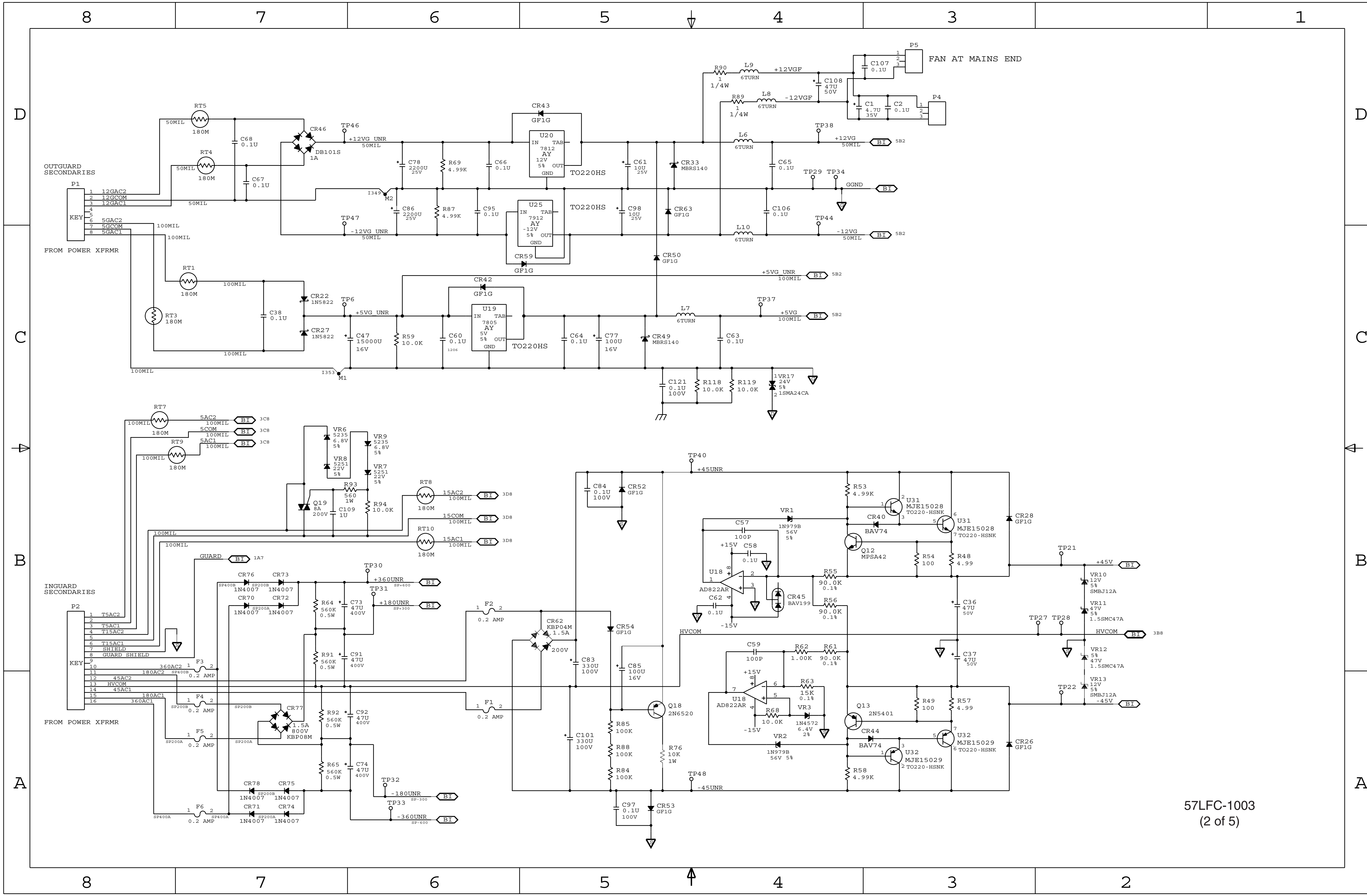


Figure 6-2. A3 Motherboard PCA (cont)

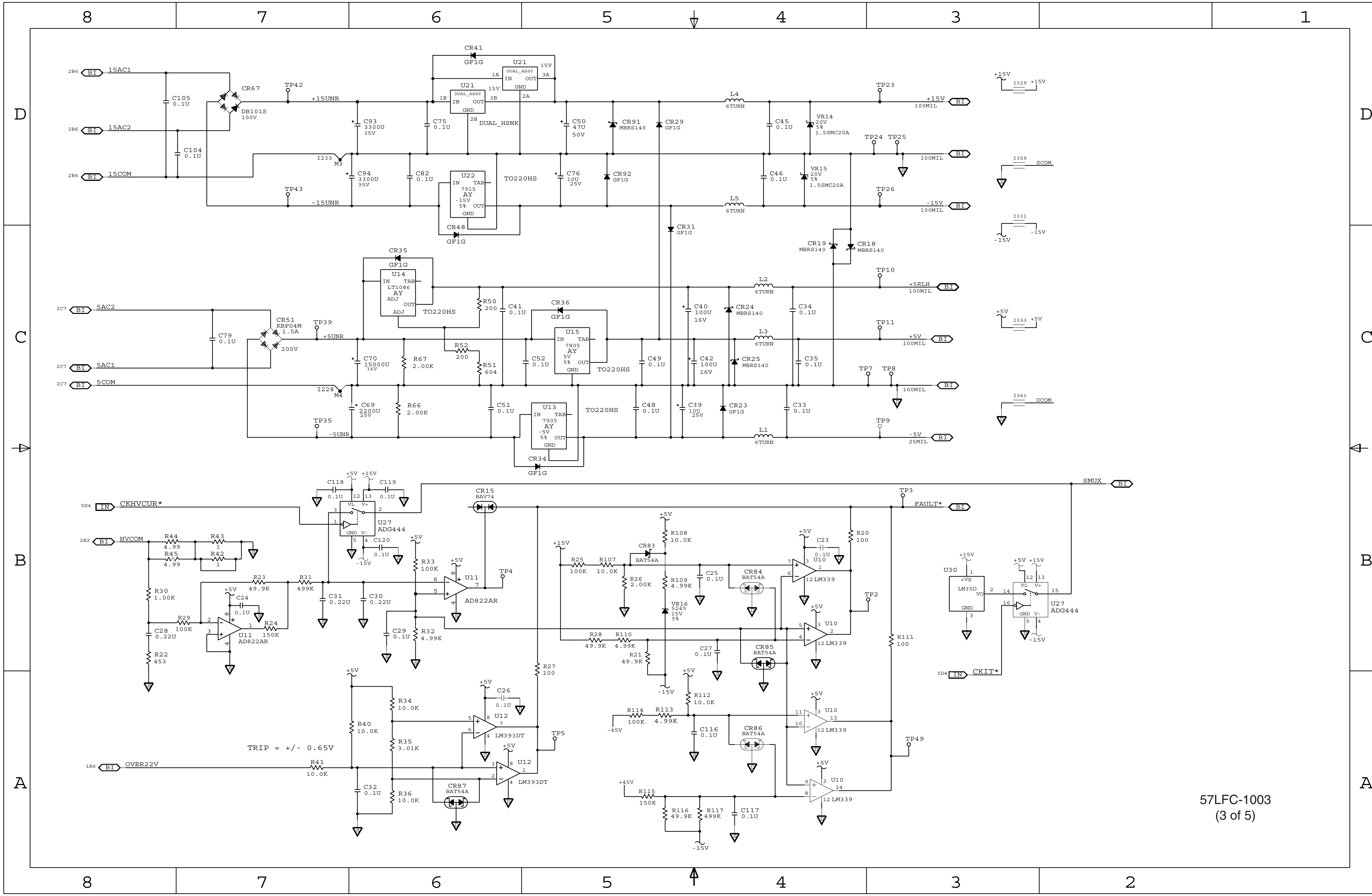


Figure 6-2. A3 Motherboard PCA (cont)

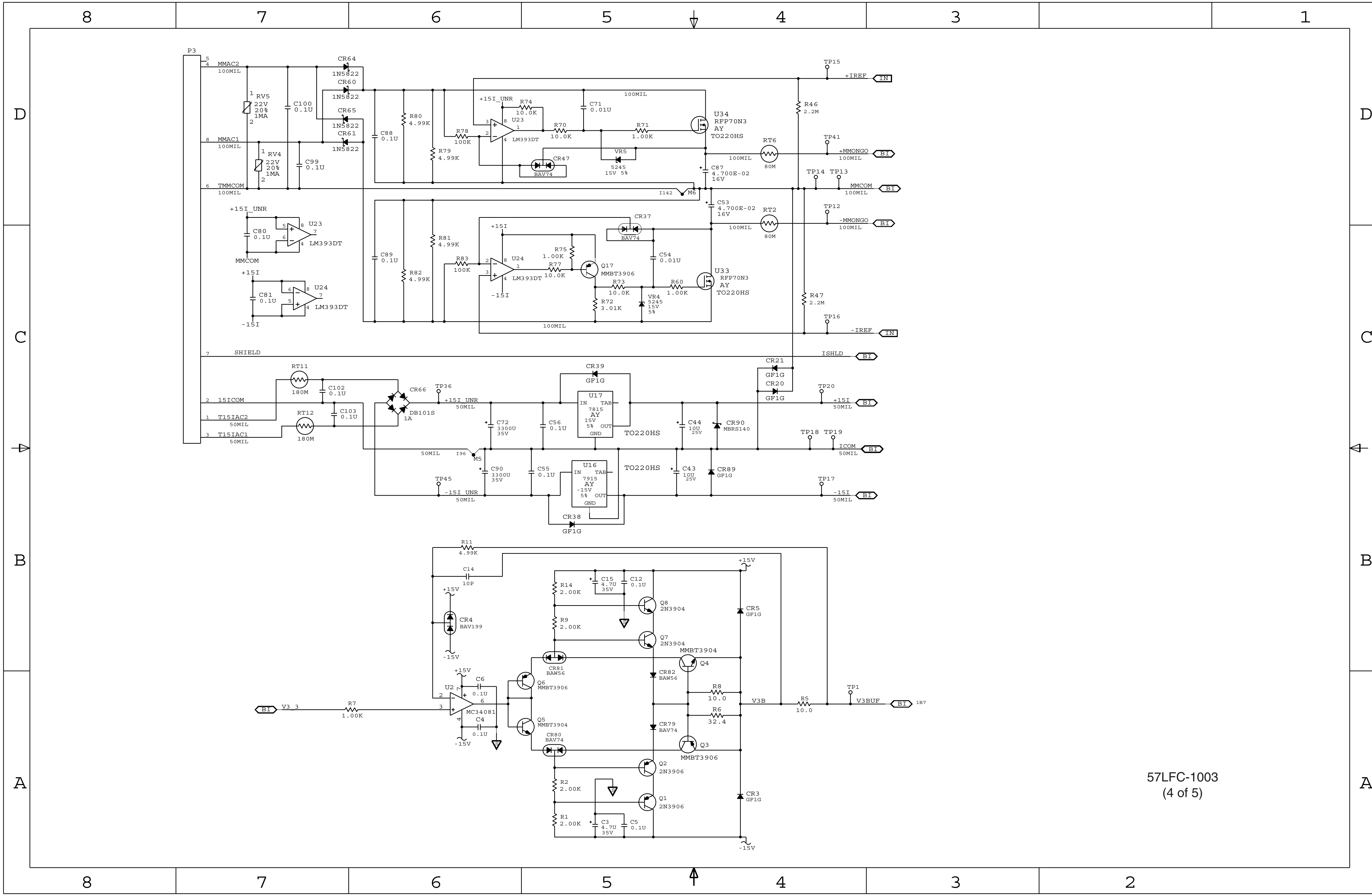


Figure 6-2. A3 Motherboard PCA (cont)

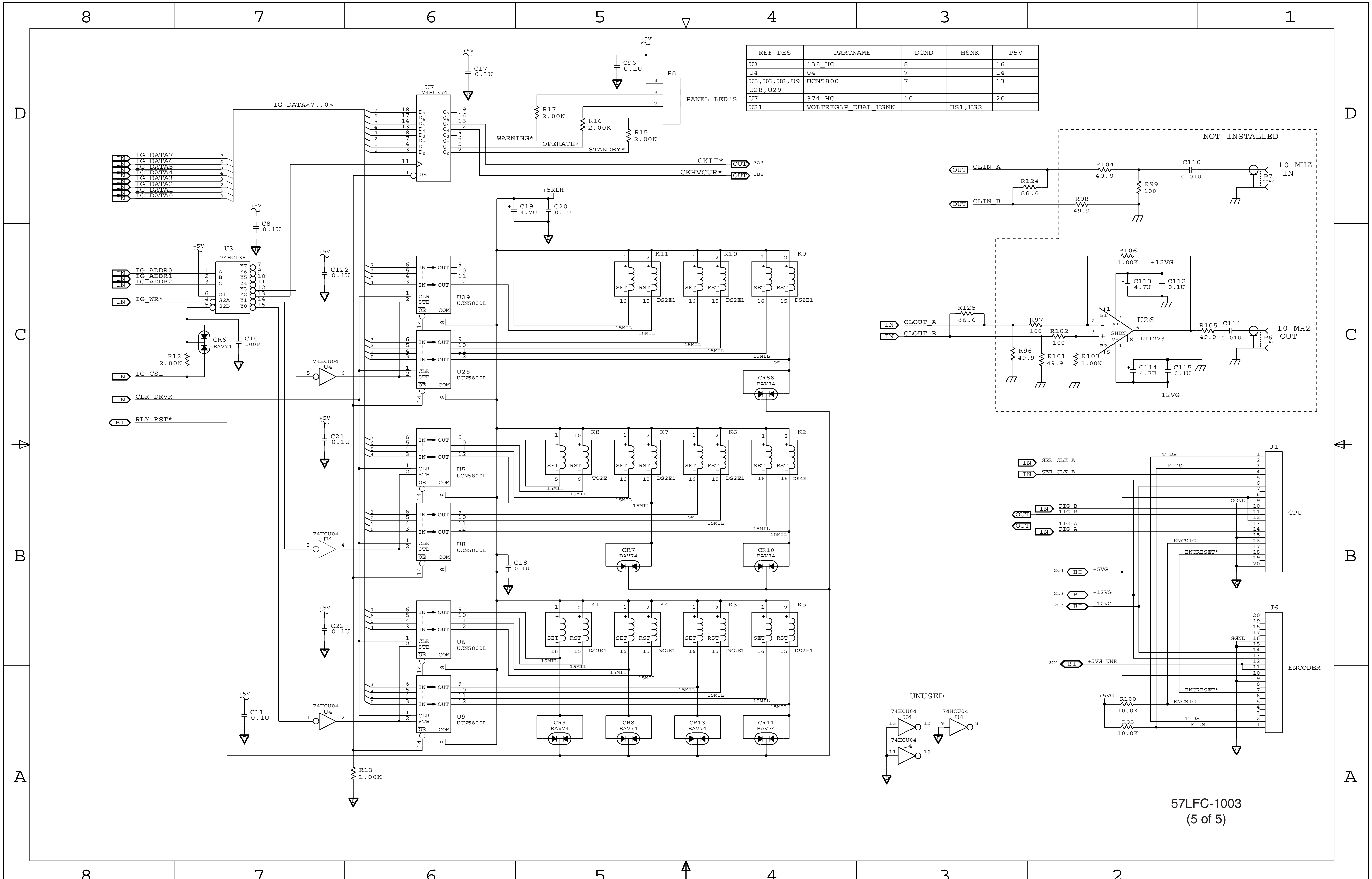


Figure 6-2. A3 Motherboard PCA (cont)

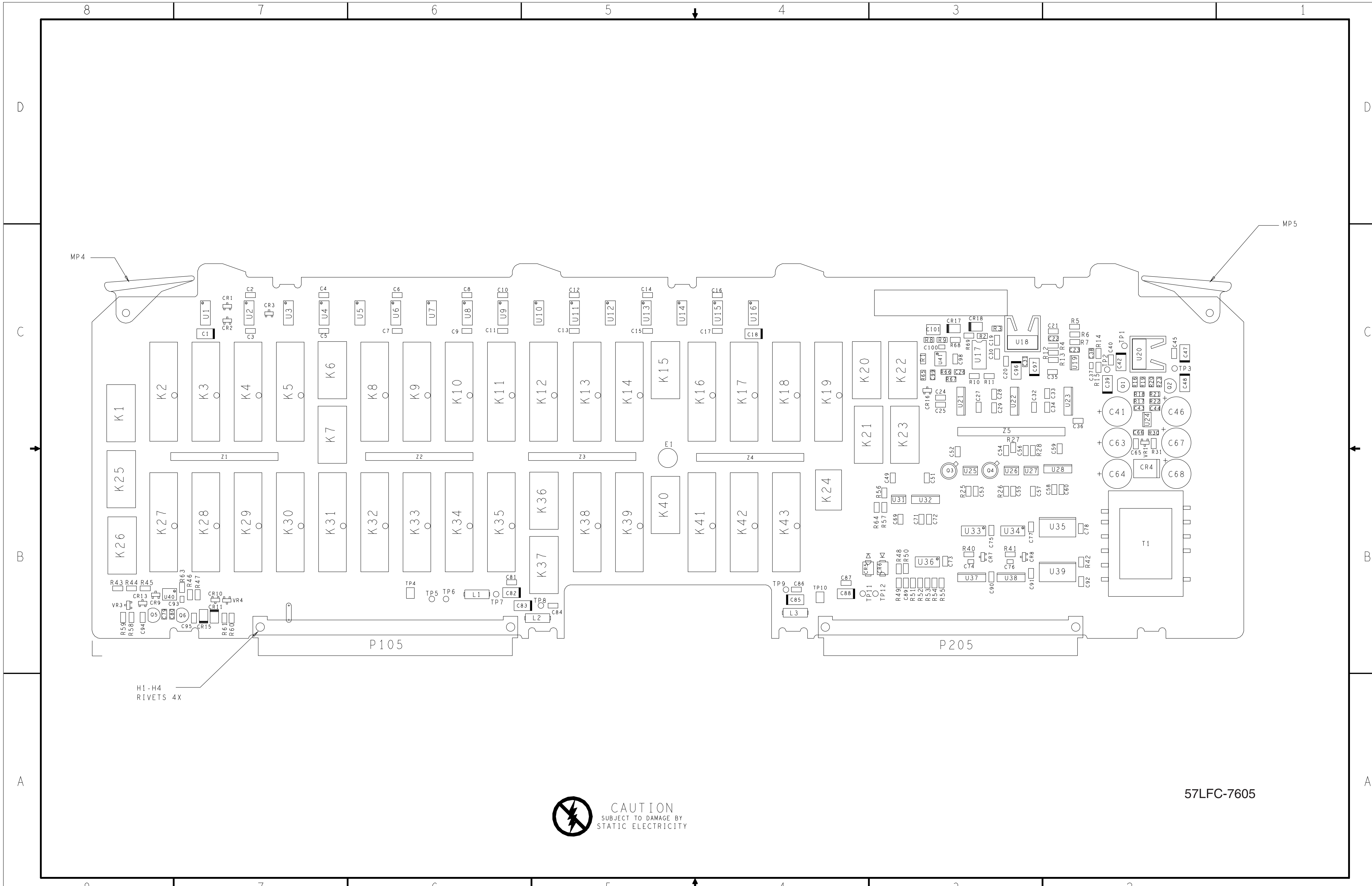
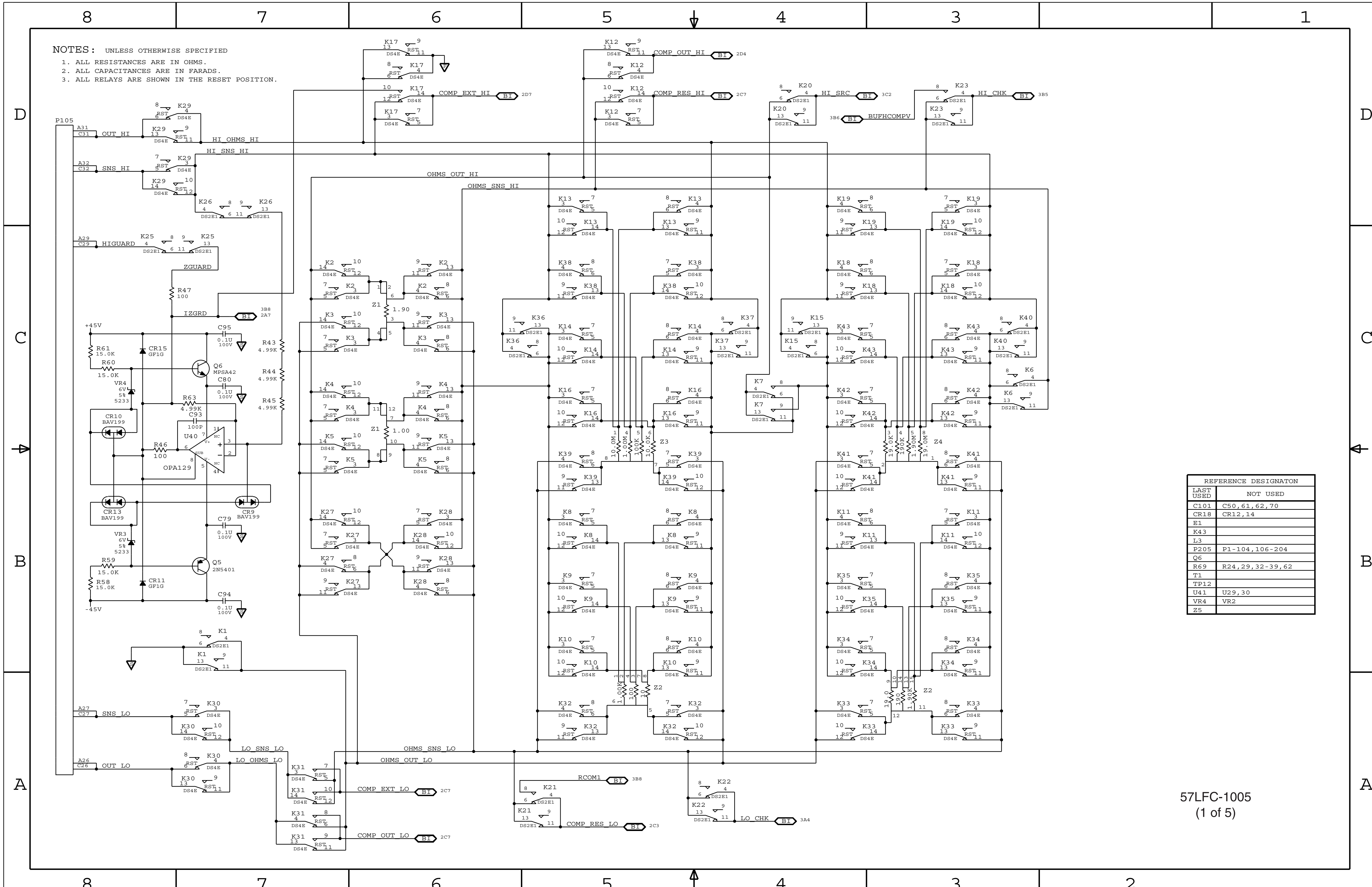


Figure 6-3. A5 Ohms PCA



REFERENCE DESIGNATON	
LAST USED	NOT USED
C101	C50,61,62,70
CR18	CR12,14
E1	
K43	
L3	
P205	P1-104,106-204
Q6	
R69	R24,29,32-39,62
T1	
TP12	
U41	U29,30
VR4	VR2
Z5	

Figure 6-3. A5 Ohms PCA (cont)

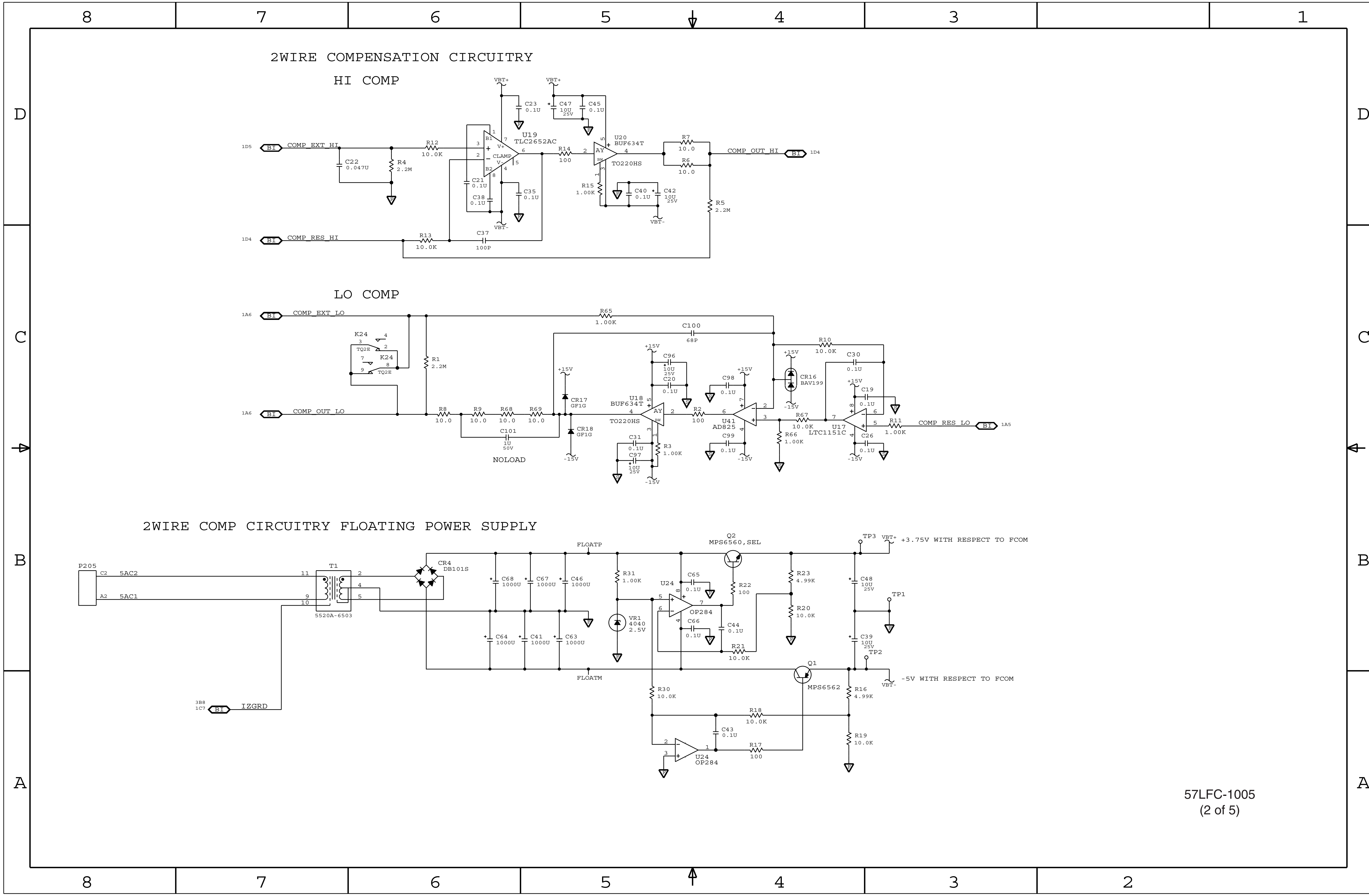


Figure 6-3. A5 Ohms PCA (cont)

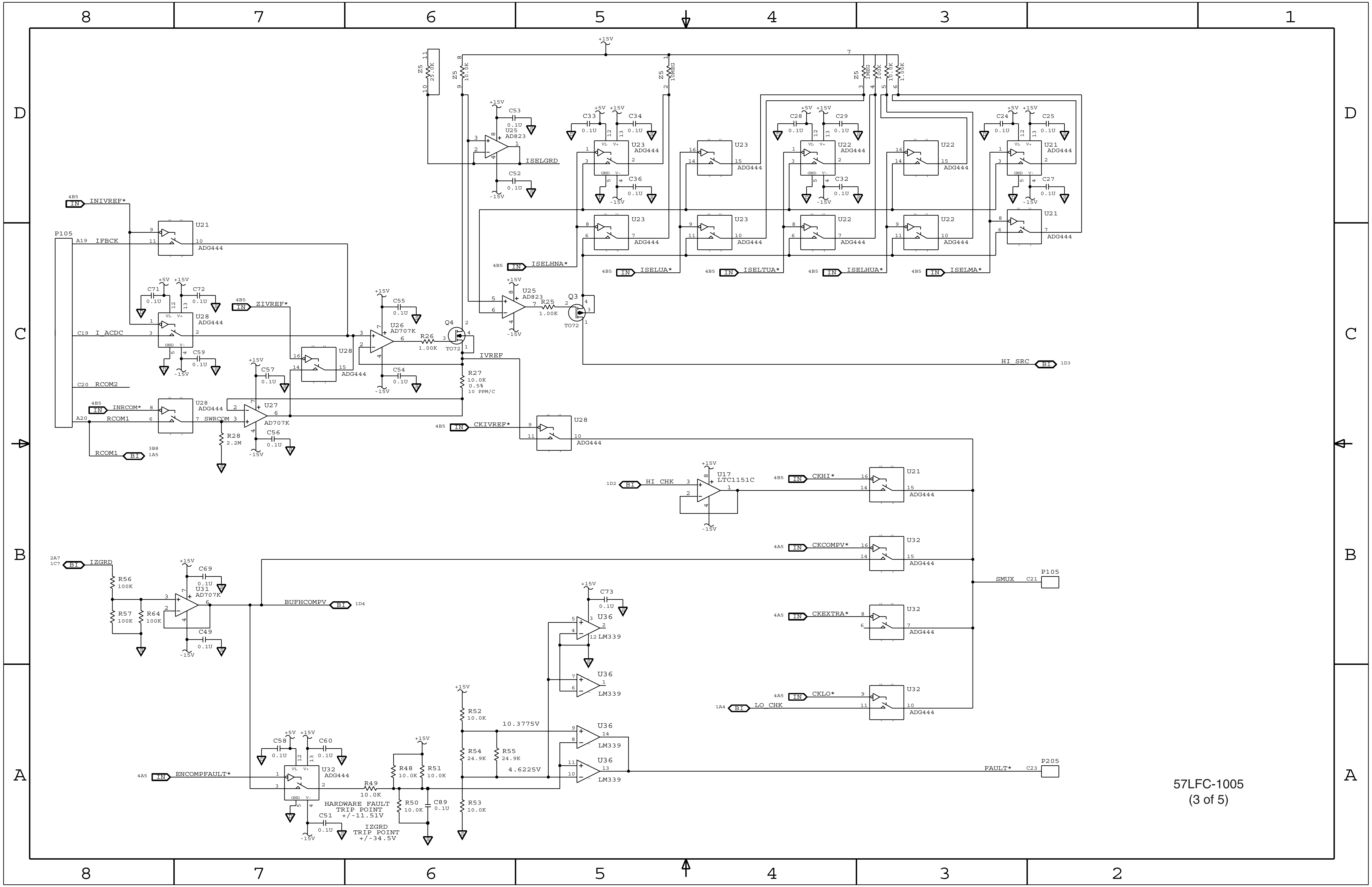


Figure 6-3. A5 Ohms PCA (cont)

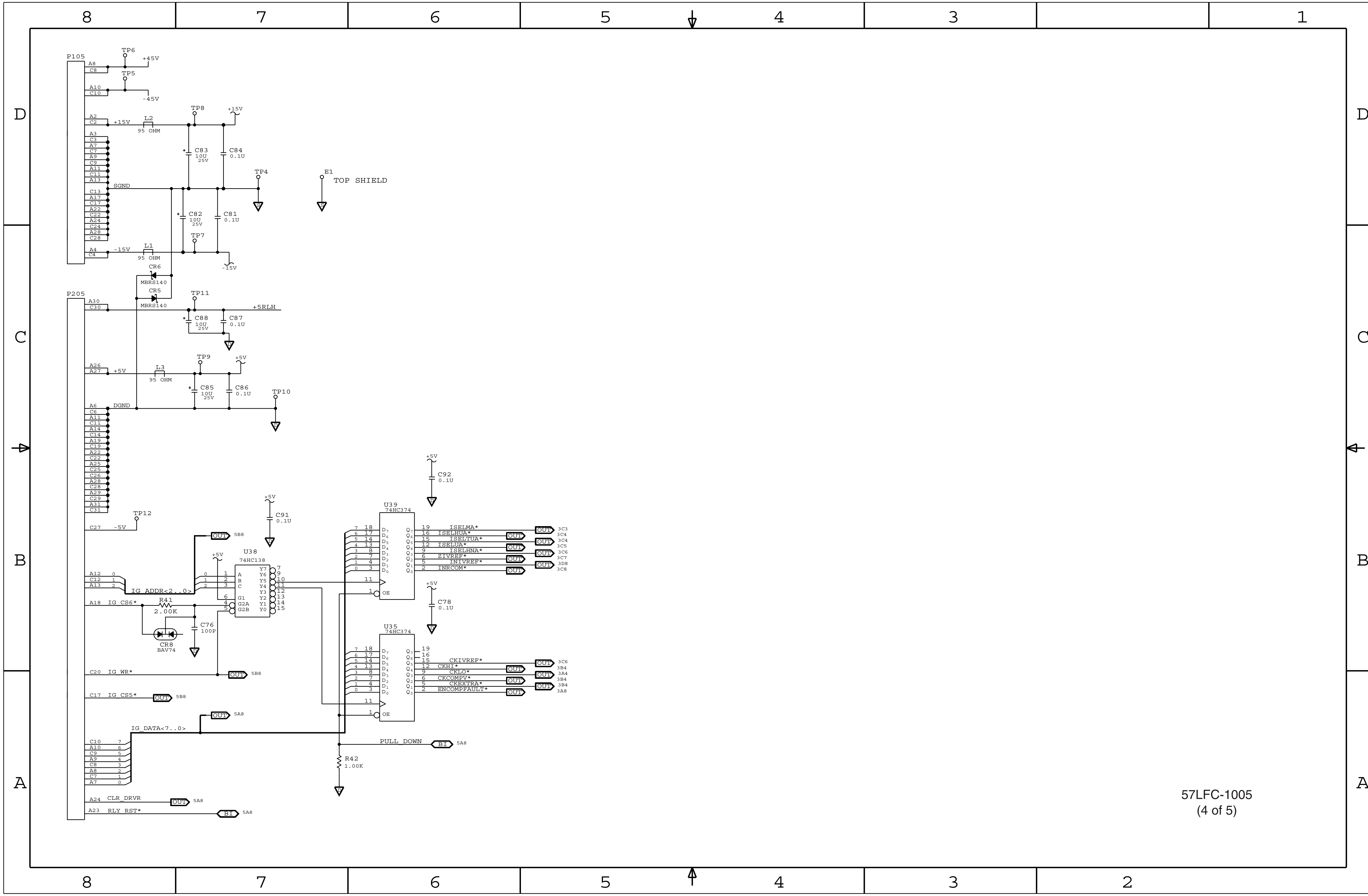


Figure 6-3. A5 Ohms PCA (cont)

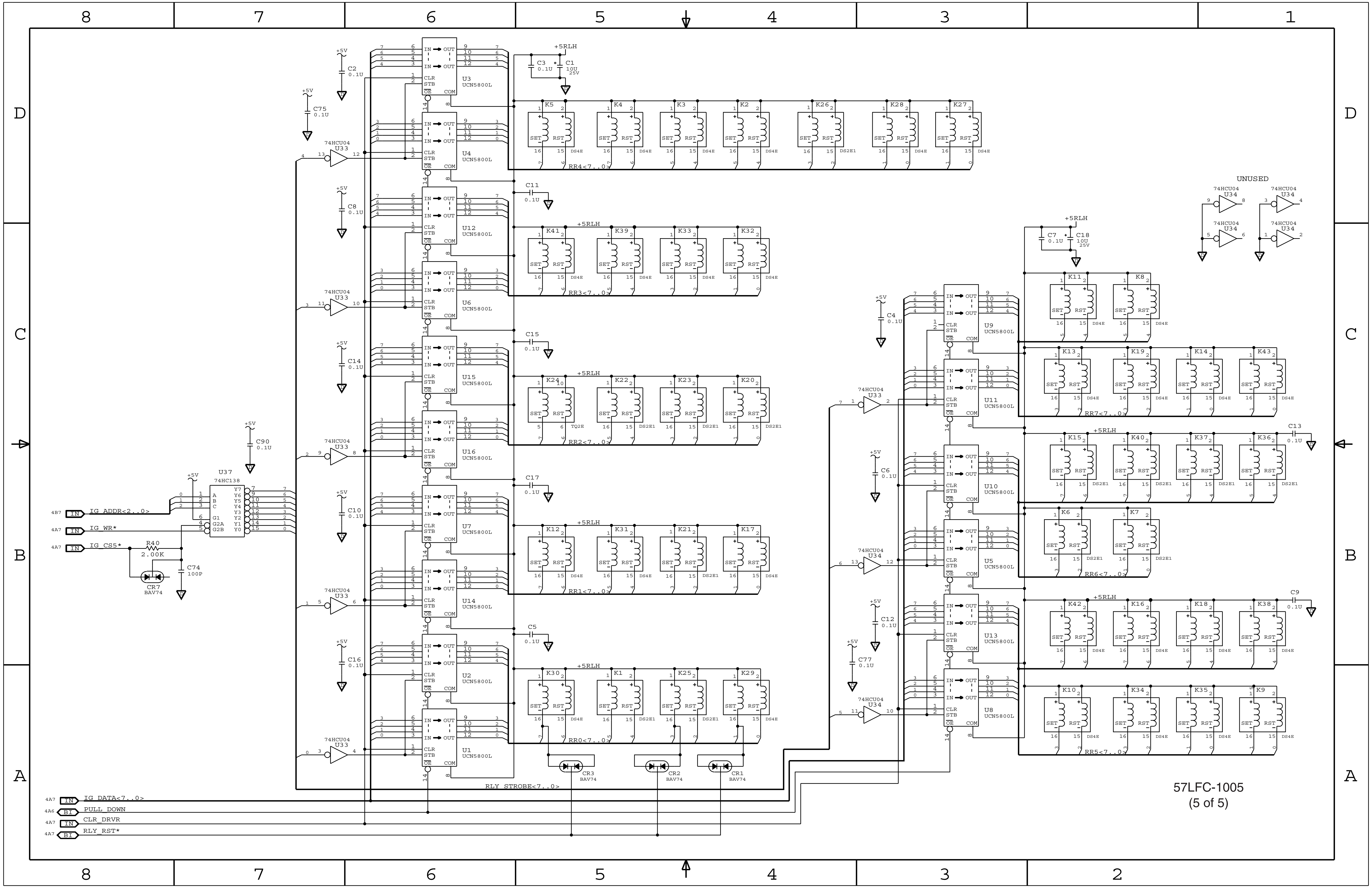


Figure 6-3. A5 Ohms PCA (cont)

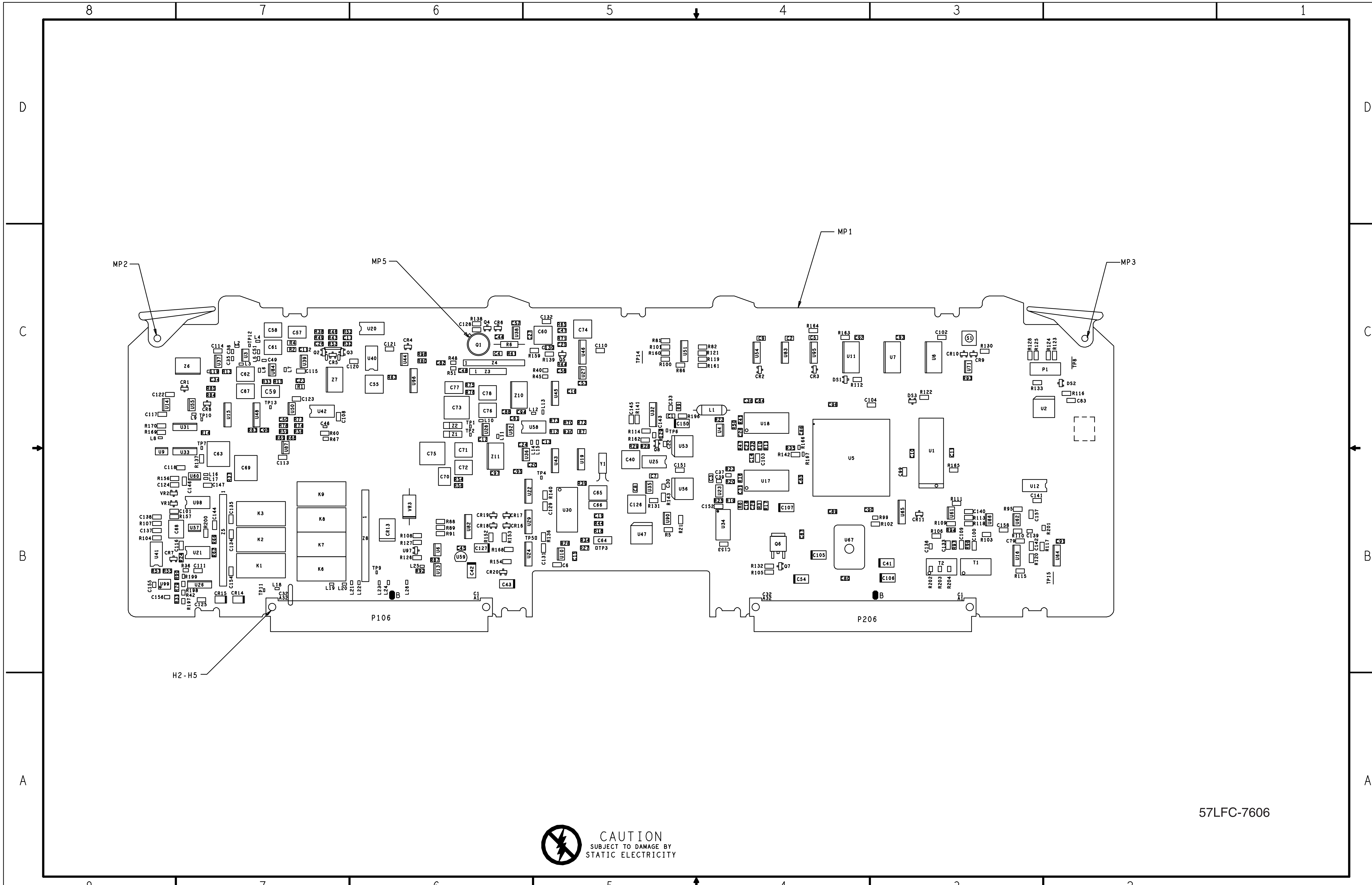
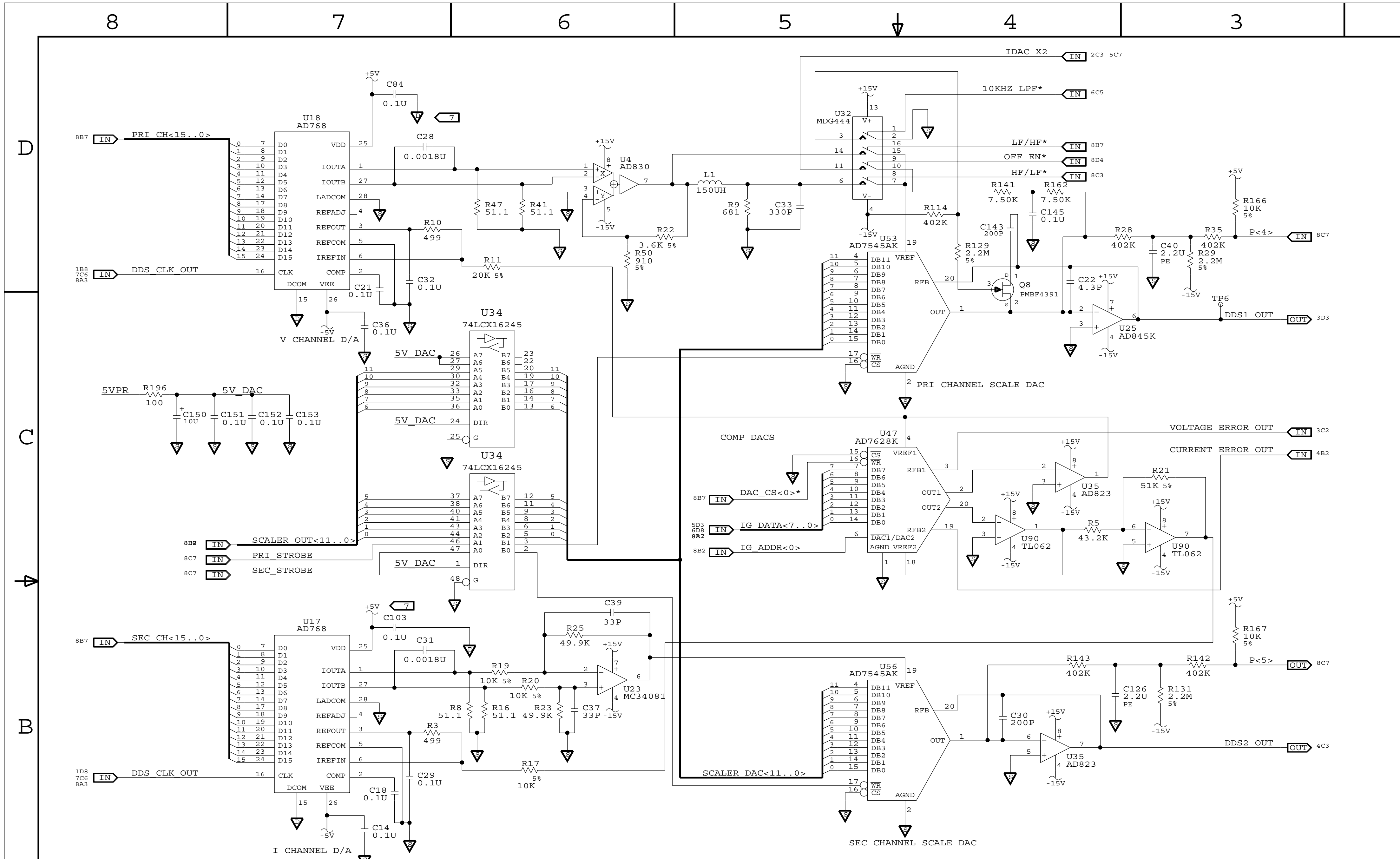


Figure 6-4. A6 Digital Synthesis PCA



REF DES	PARTNAME	5VPR	5V_DAC	DGND	P5V	P15V	SGND
U1	7C4098			12,34	11,33		
U2	EPC1_PLCC			10	18,20		
U7,U8,U11	374_HC			10	20		
U12	EPC1_DIP			5	7,8		
U15,U22,U24 U26,U29 U31-33,U46 U48,U82	MDG444	12					5
U16	00_AC			7	14		
U19	04	14					7
U34	16245_LCX		7,18,31 42				4,10,15 21,28,34 39,45
U43,U45,U96	DG444	12					5
U47	AD7628K					17	5
U53,U56	AD7545A		18				3
U54,U83,U95	UCN5800			7	13		
U64	14			7	14		
U65	DS8923A			6	3		

REFERENCE DESIGNATON	
LAST USED	NOT USED
C158	C148,149
CR20	CR12
DS3	
K9	K4,5
L30	
M3	
P206	P2-105,107-205
Q8	
R204	R134,135,144-151 R155,158,171-195
S1	
T2	
TP15	
U99	U49,63,68-70,72-81 U85,86,88,89,91-94
VR3	
Y1	
Z11	Z9

NOTES: UNLESS OTHERWISE SPECIFIED

1. RESISTORS ARE IN OHMS, 1% TOLERANCE, CERM OR MF SURFACE-MOUNT.
2. NON-POLARIZED CAPACITORS ARE CERAMIC, 25V, 50V OR 100V SURFACE-MOUNT. POLARIZED CAPACITORS ARE TANTALUM.

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Figure 6-4. A6 Digital Synthesis PCA (cont)

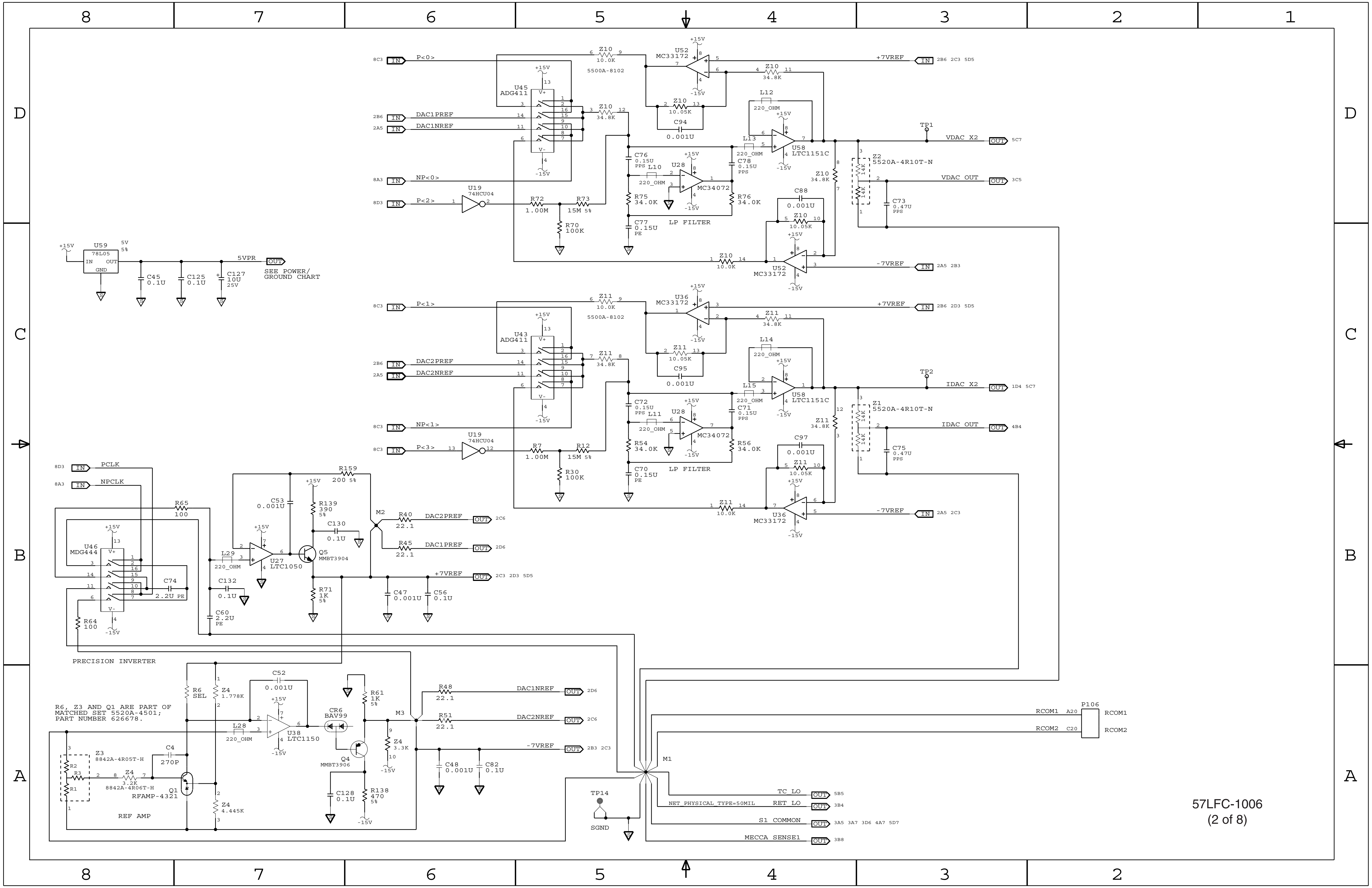

Figure 6-4. A6 Digital Synthesis PCA (cont)

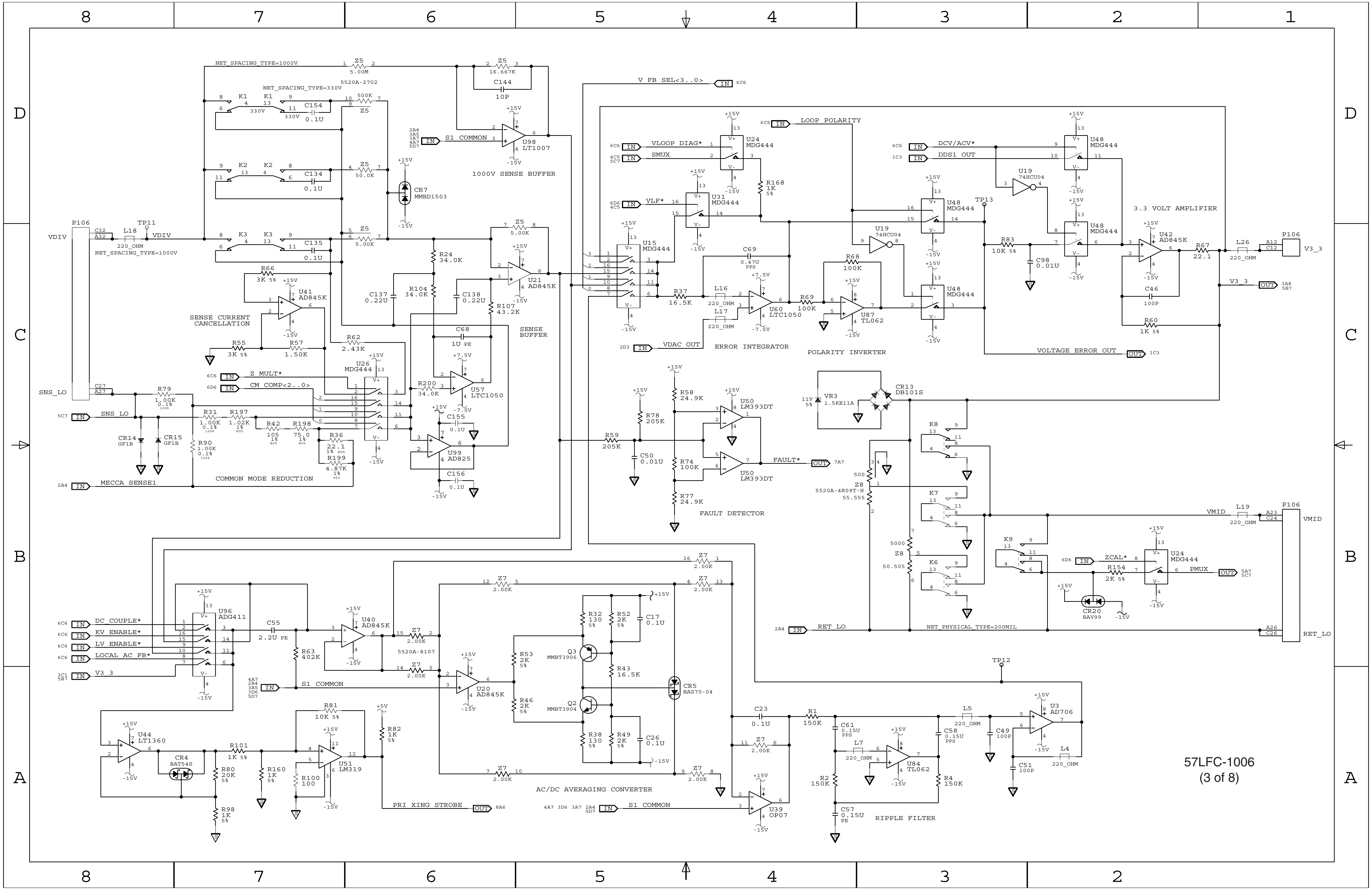

Figure 6-4. A6 Digital Synthesis PCA (cont)

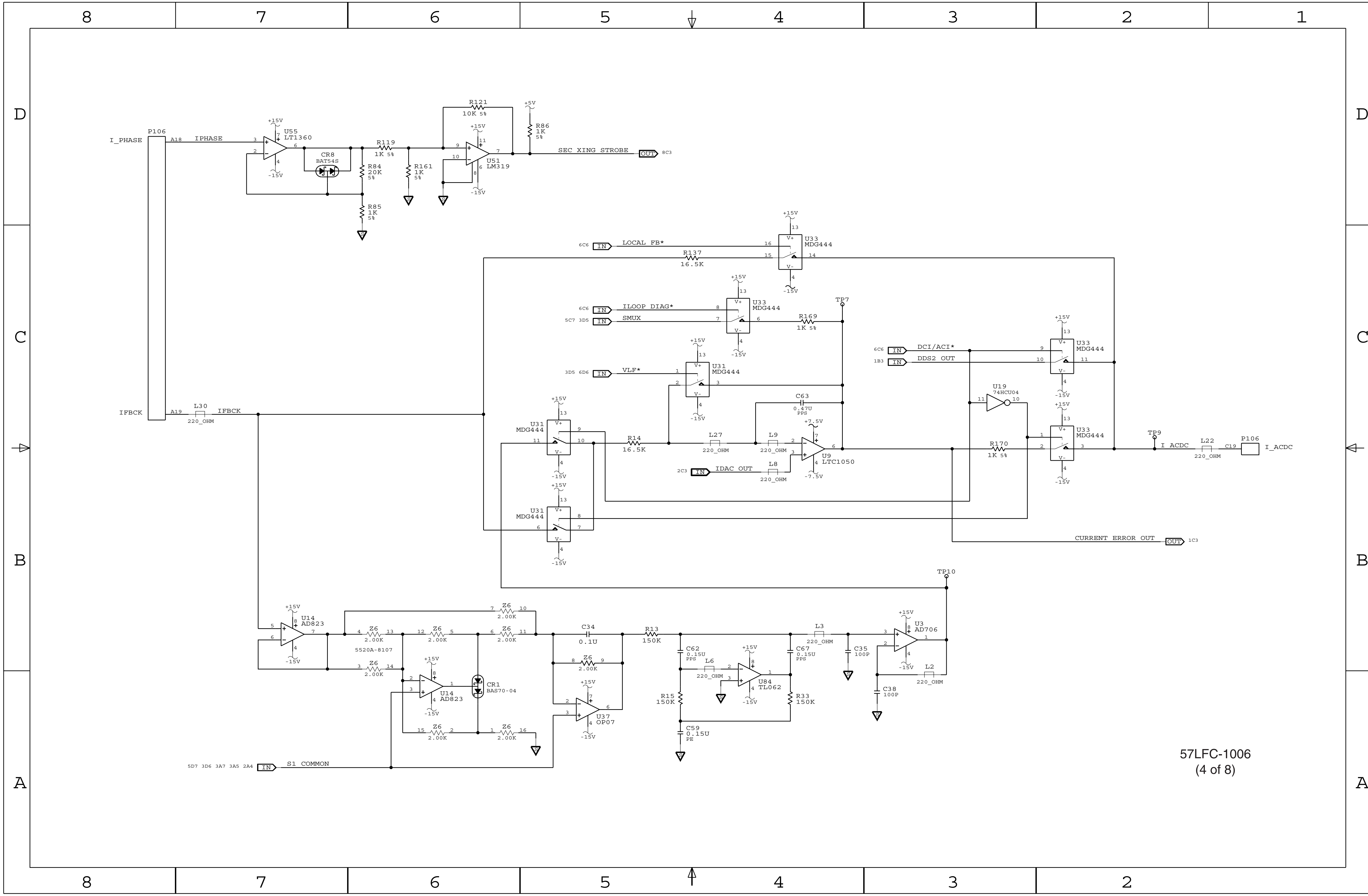

Figure 6-4. A6 Digital Synthesis PCA (cont)

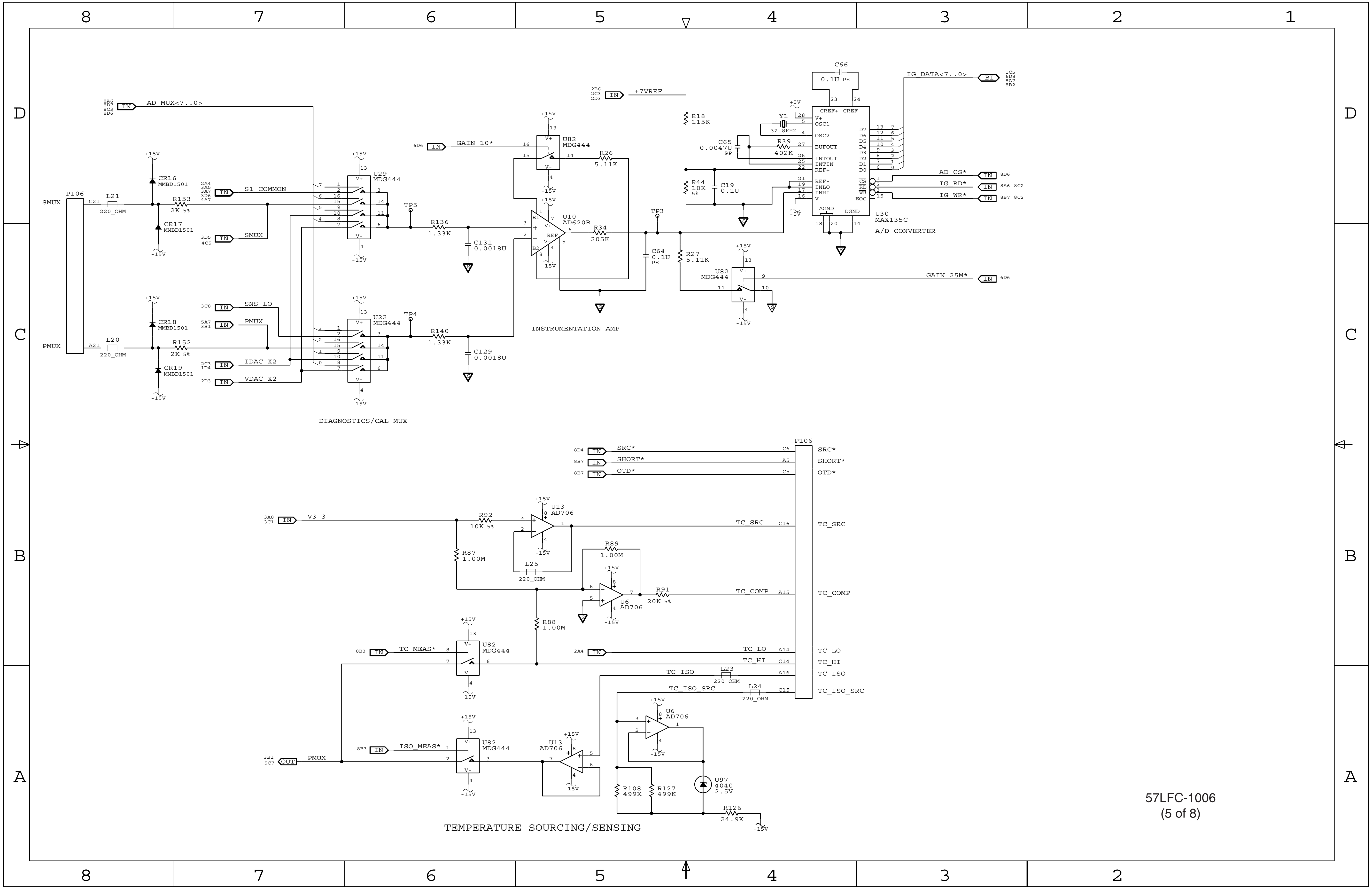

Figure 6-4. A6 Digital Synthesis PCA (cont)

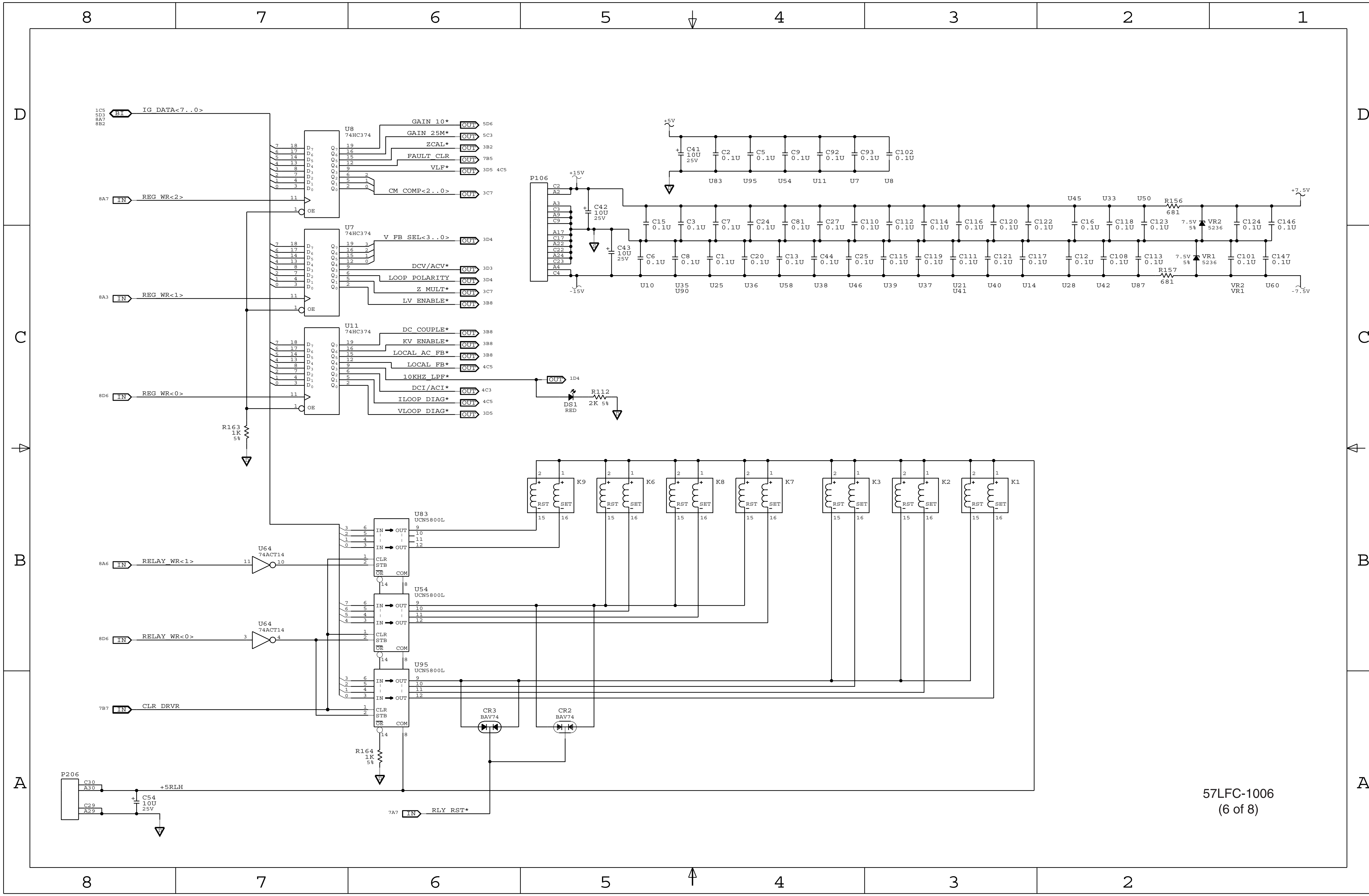

Figure 6-4. A6 Digital Synthesis PCA (cont)

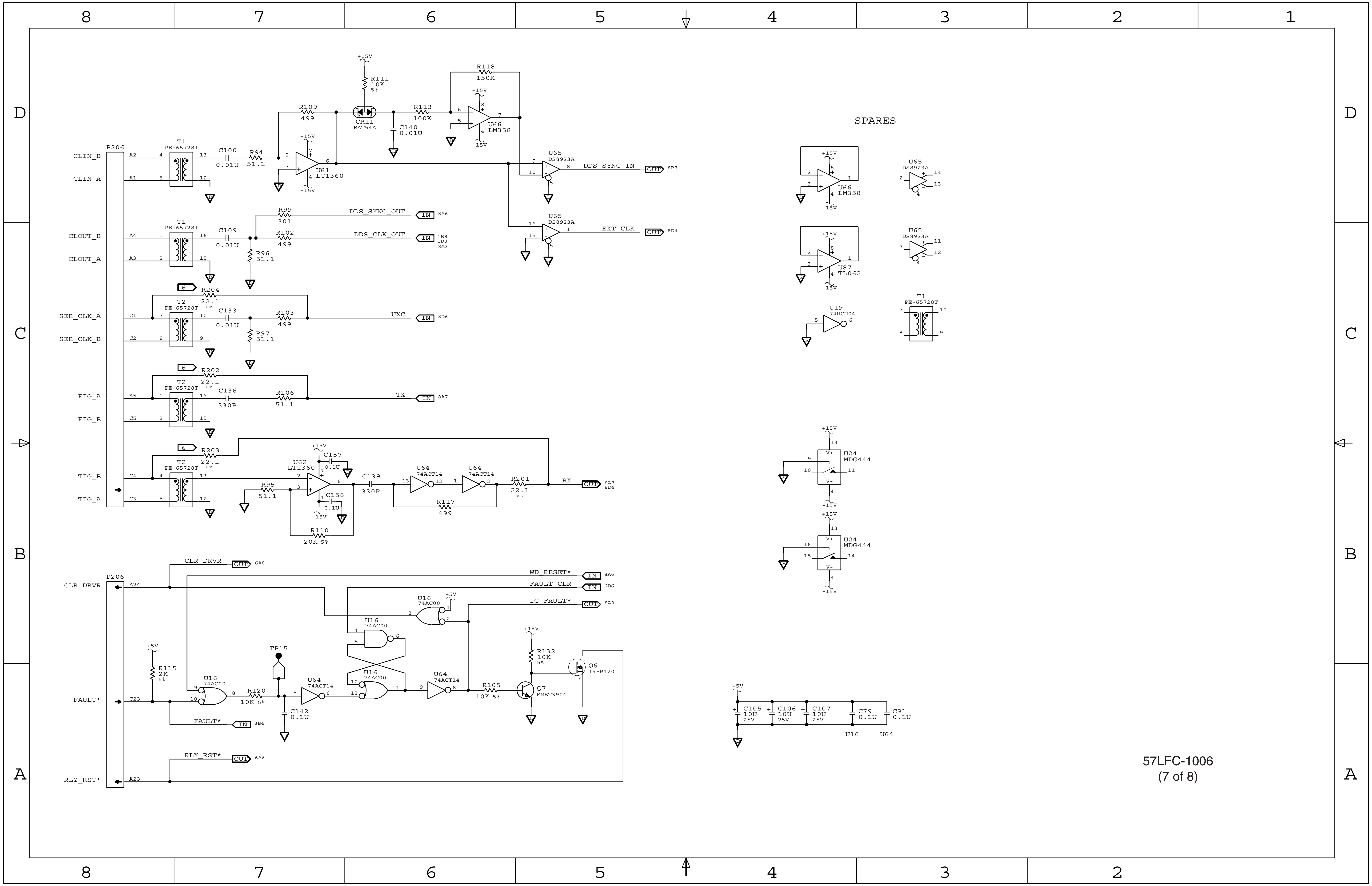

Figure 6-4. A6 Digital Synthesis PCA (cont)

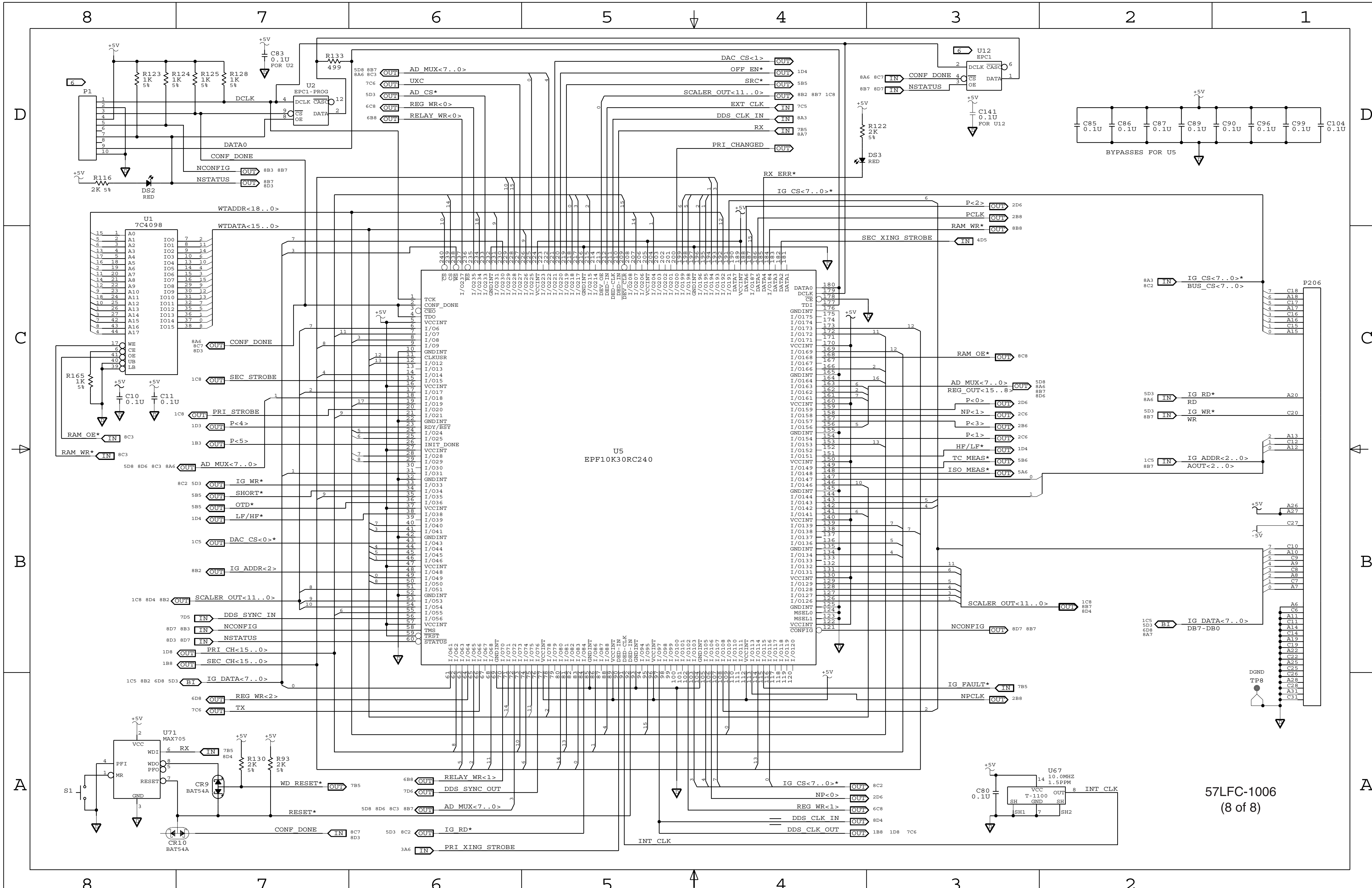

Figure 6-4. A6 Digital Synthesis PCA (cont)

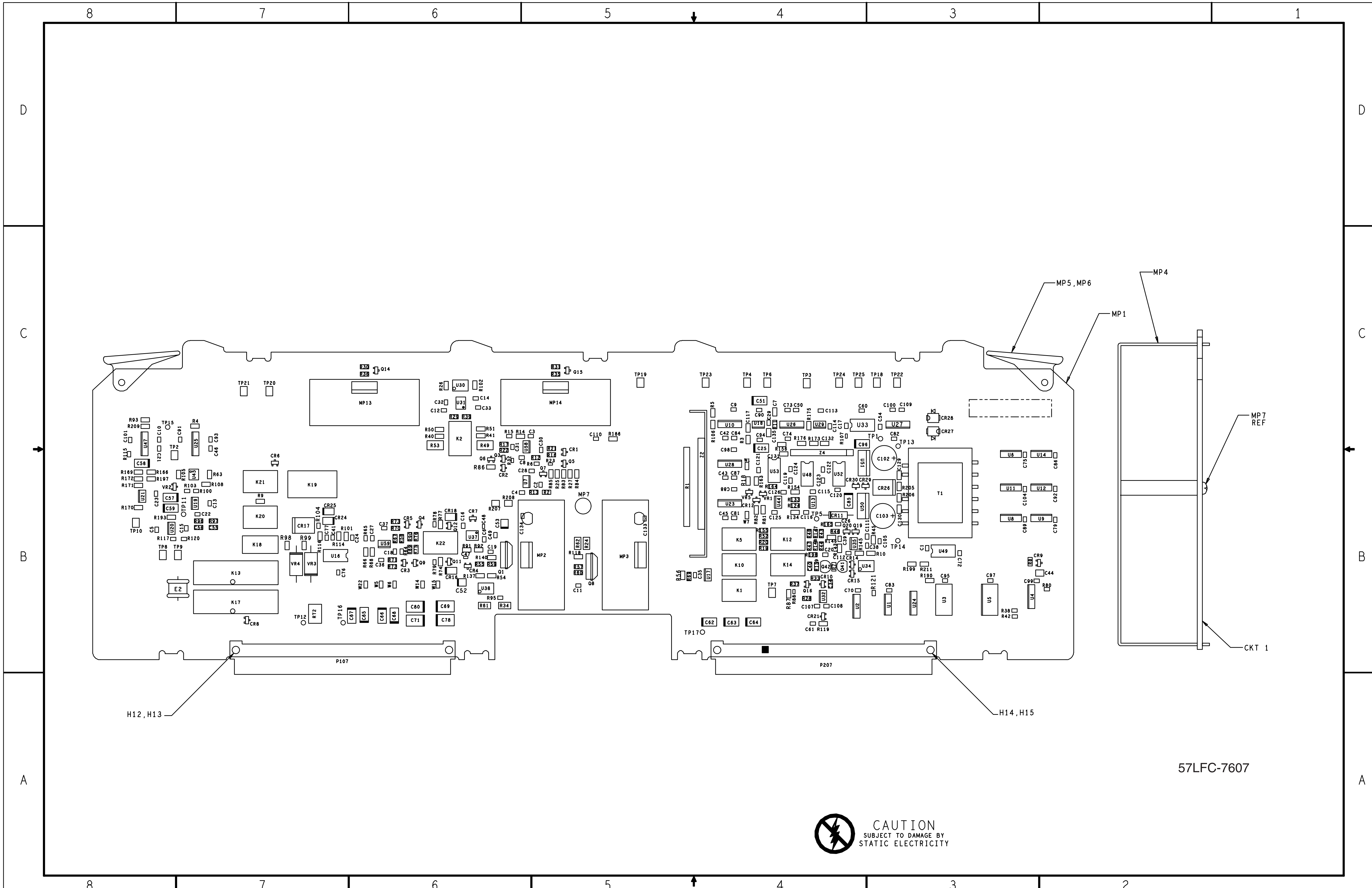

Figure 6-5. A7 Current PCA

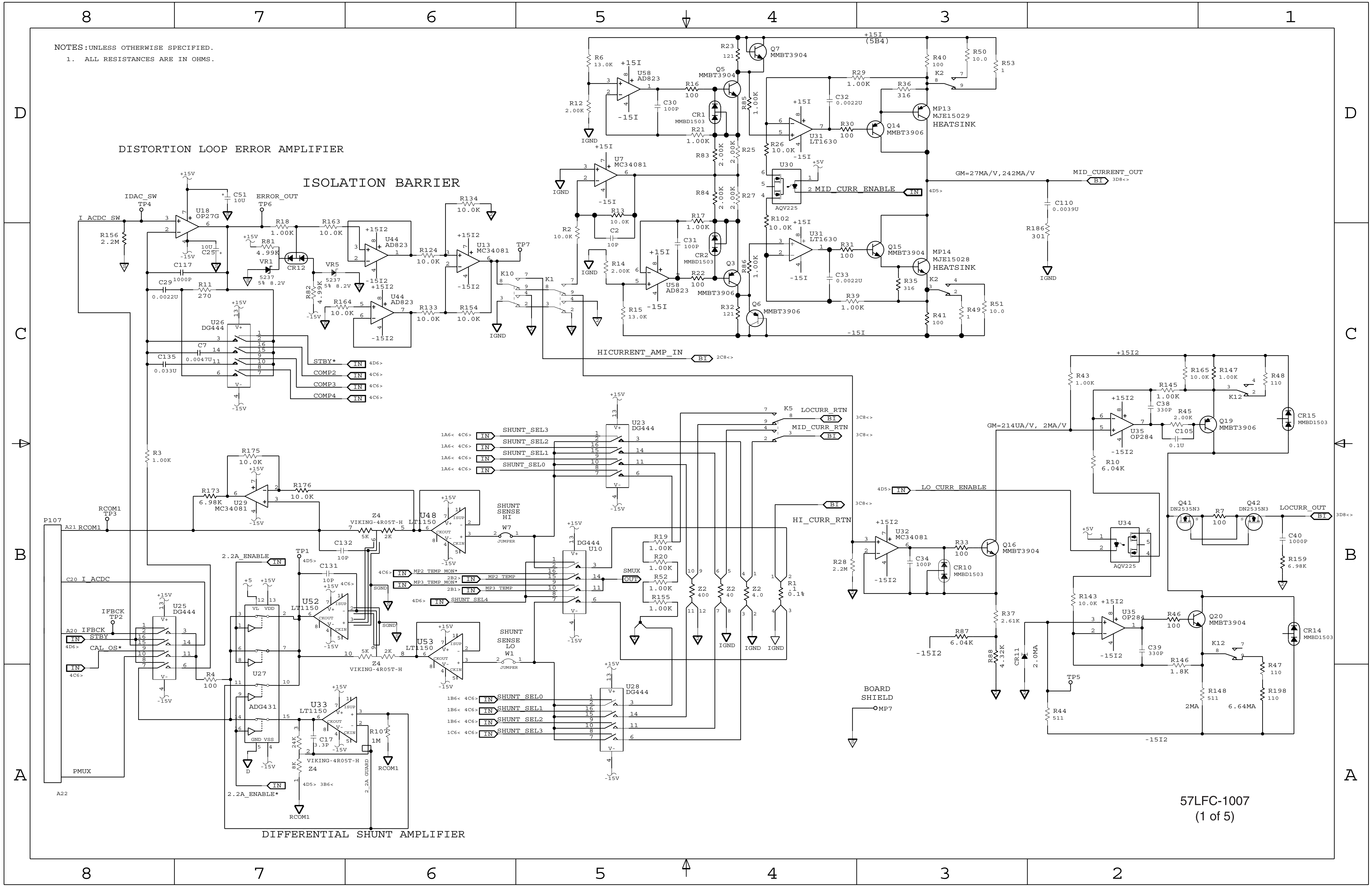

Figure 6-5. A7 Current PCA (cont)

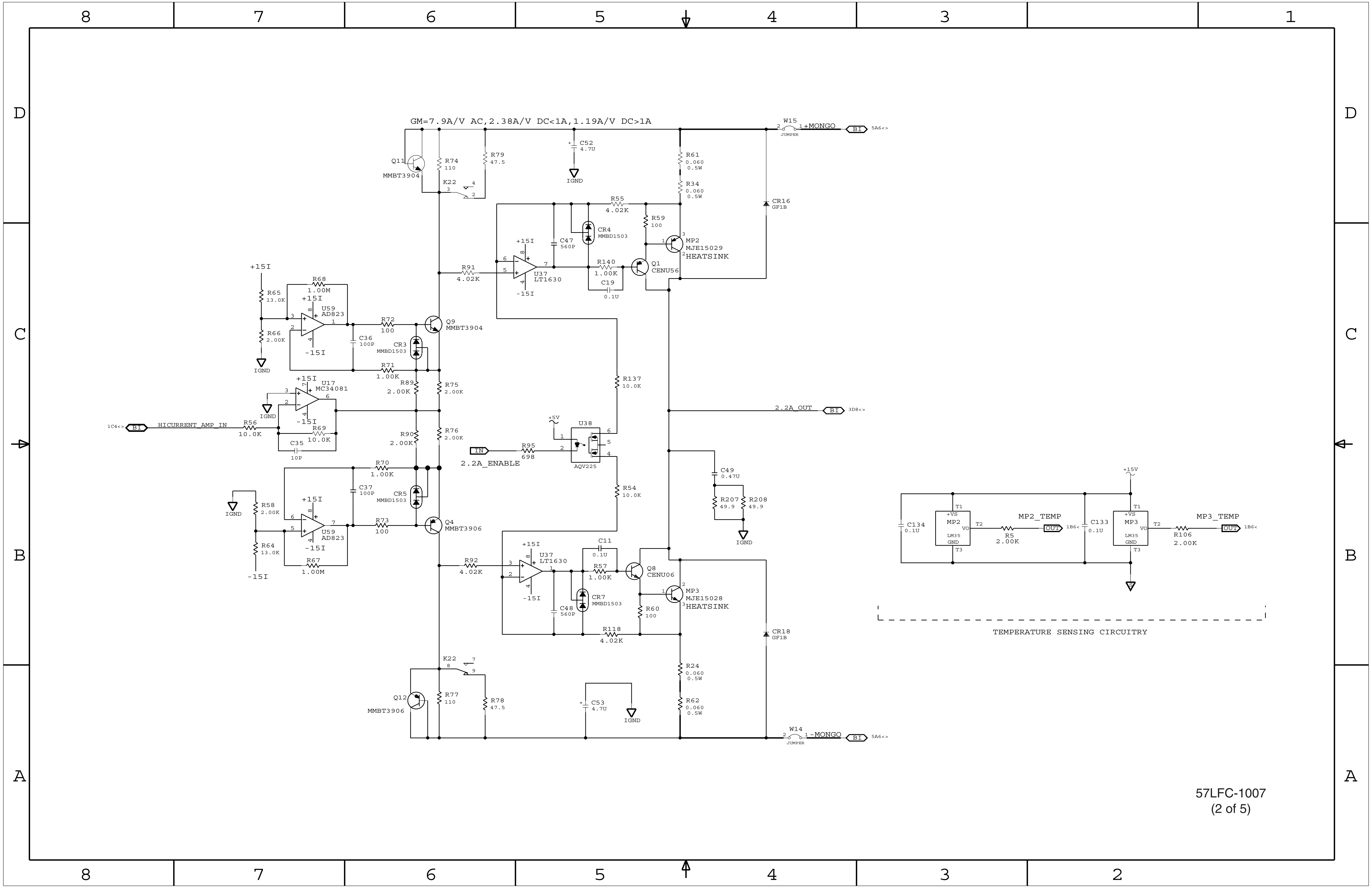

Figure 6-5. A7 Current PCA (cont)

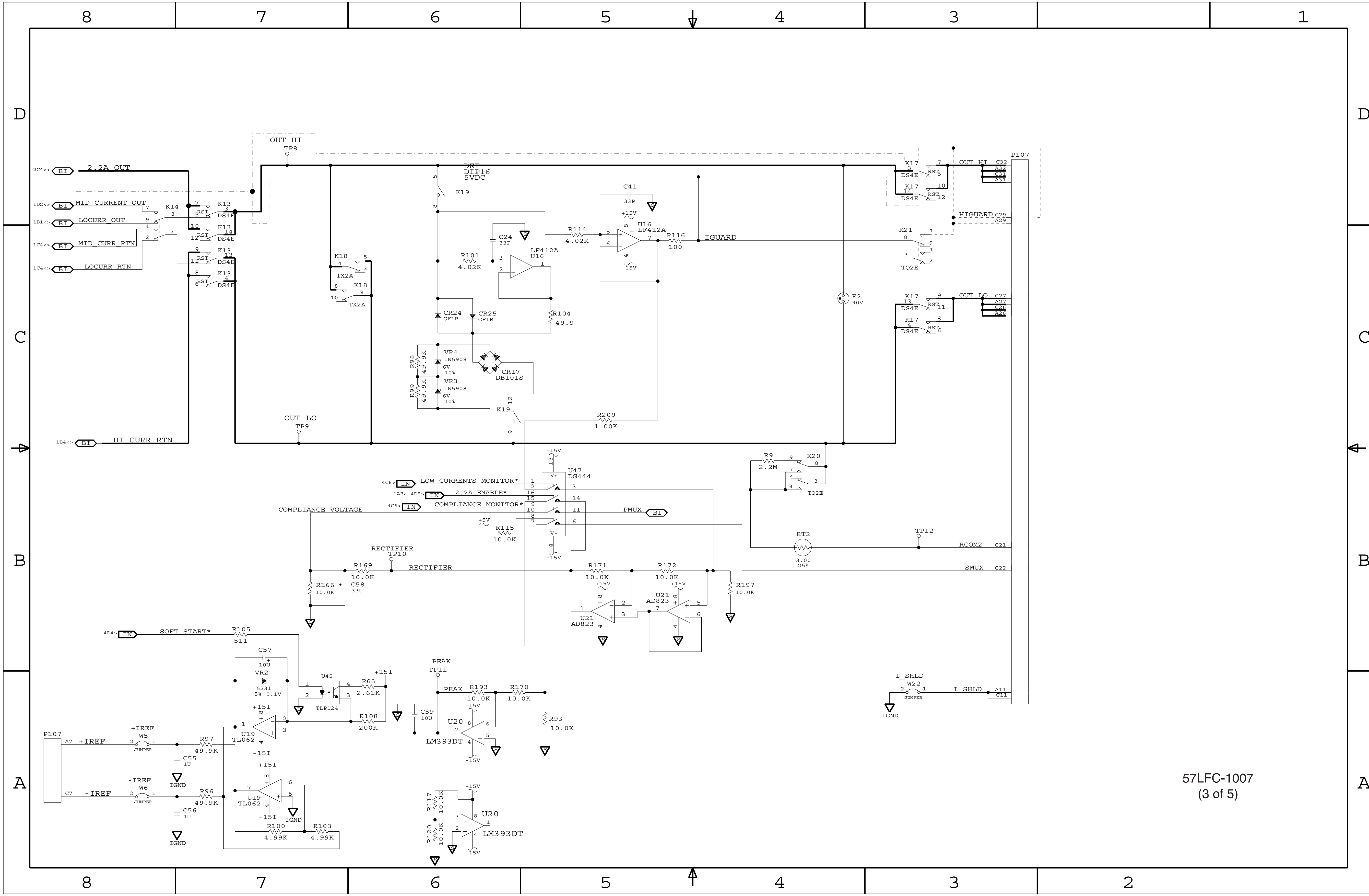

Figure 6-5. A7 Current PCA (cont)

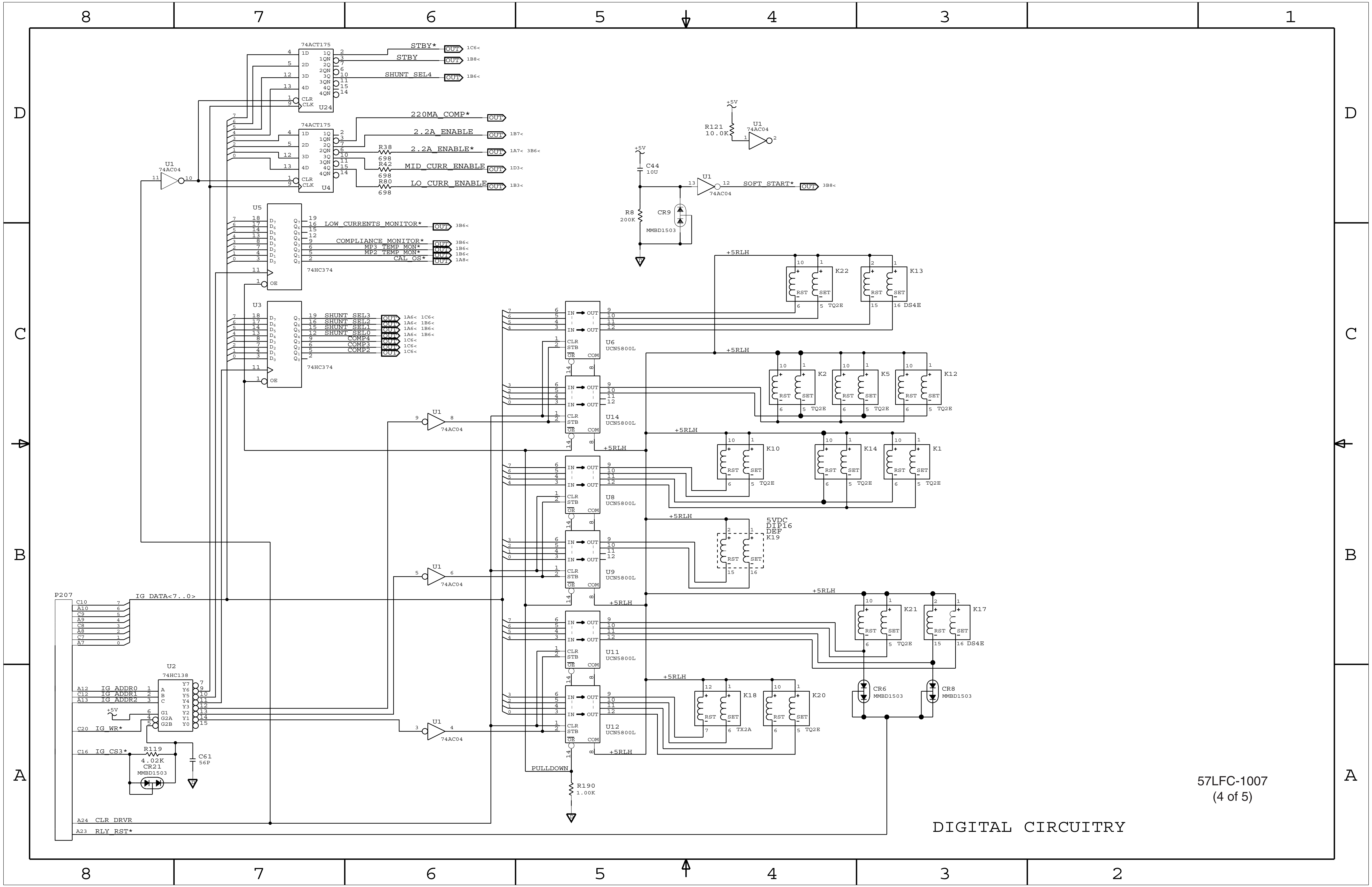

Figure 6-5. A7 Current PCA (cont)

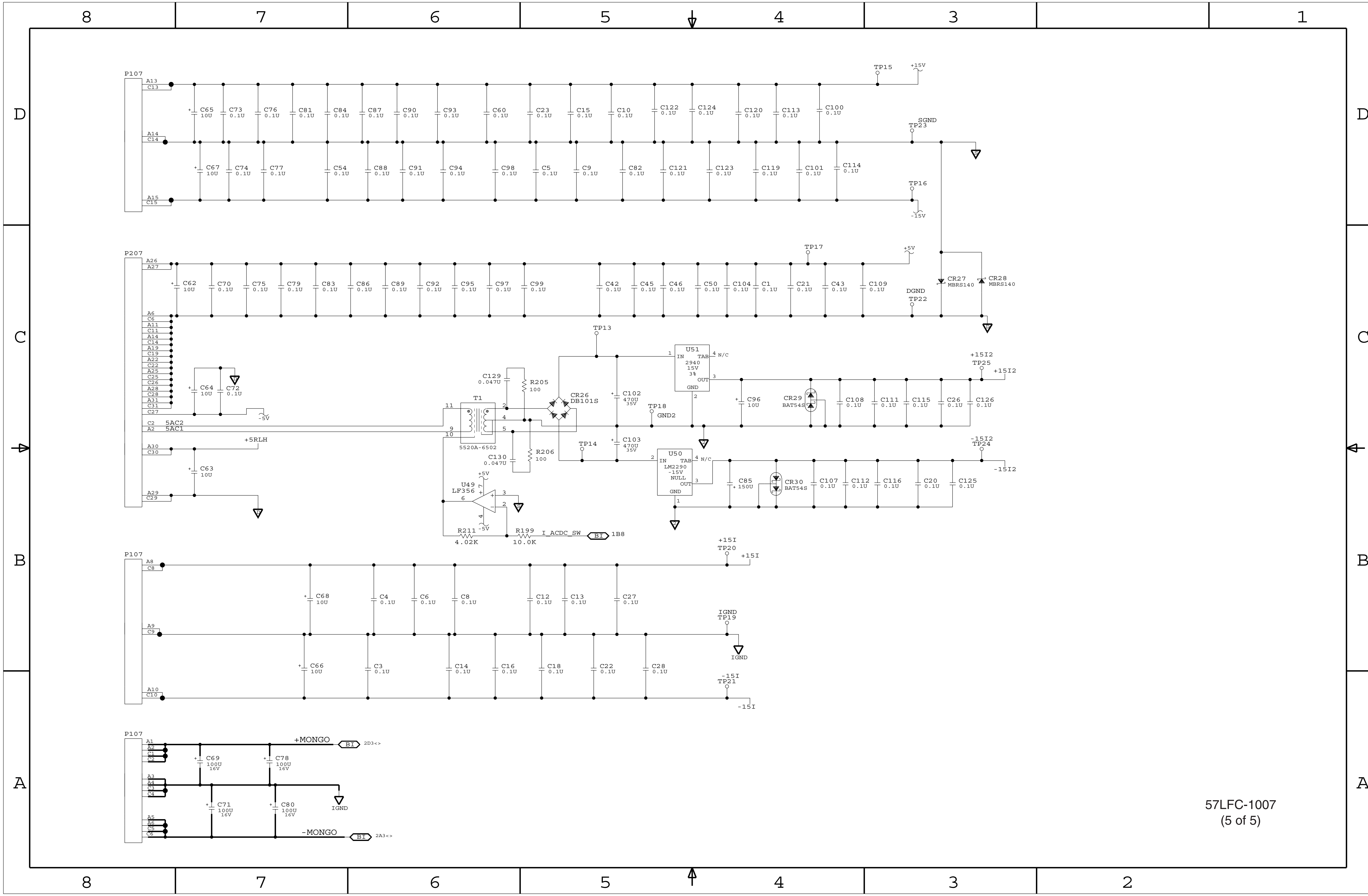

Figure 6-5. A7 Current PCA (cont)

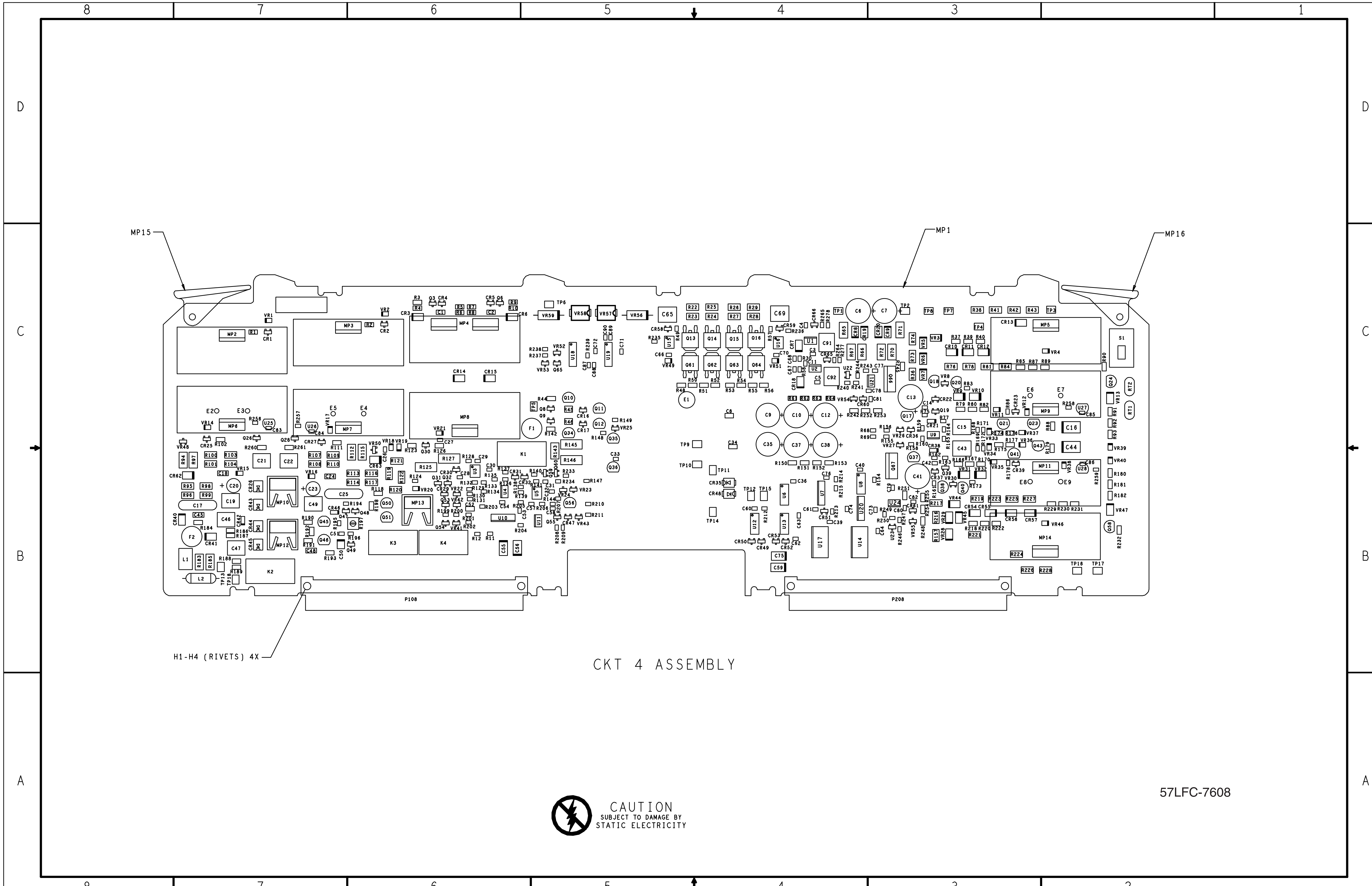

Figure 6-6. A8 High Voltage PCA

NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL RESISTANCES ARE IN OHMS.
2. ALL CAPACITANCES ARE IN FARADS.
3. ALL RELAYS ARE SHOWN IN THE RESET POSITION.

REFERENCE DESIGNATON	
LAST USED	NOT USED
C92	
CR66	CR24,28,33,34,64
E9	
F2	
K4	
L2	
M1	
MP14	MP1
P208	P1-107,109-207
Q67	Q1,2,4,5,7,22,25 Q27,29,33,42,44,52 Q57
R278	R13-21,31-35,47,59 R60,105,106,262 R263,266-276
RT2	
S1	
TP18	
U28	
VR59	

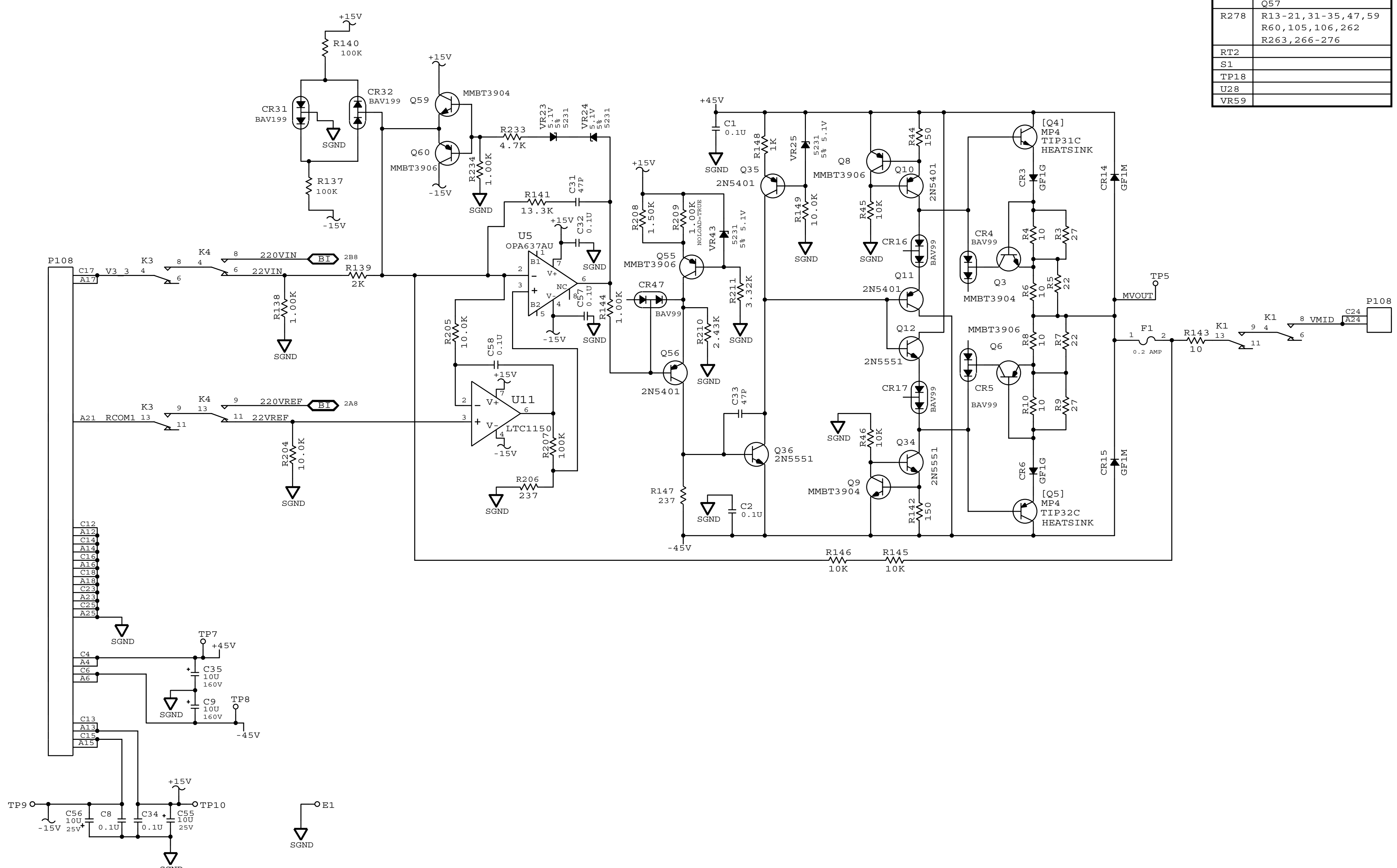

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Figure 6-6. A8 High Voltage PCA (cont)

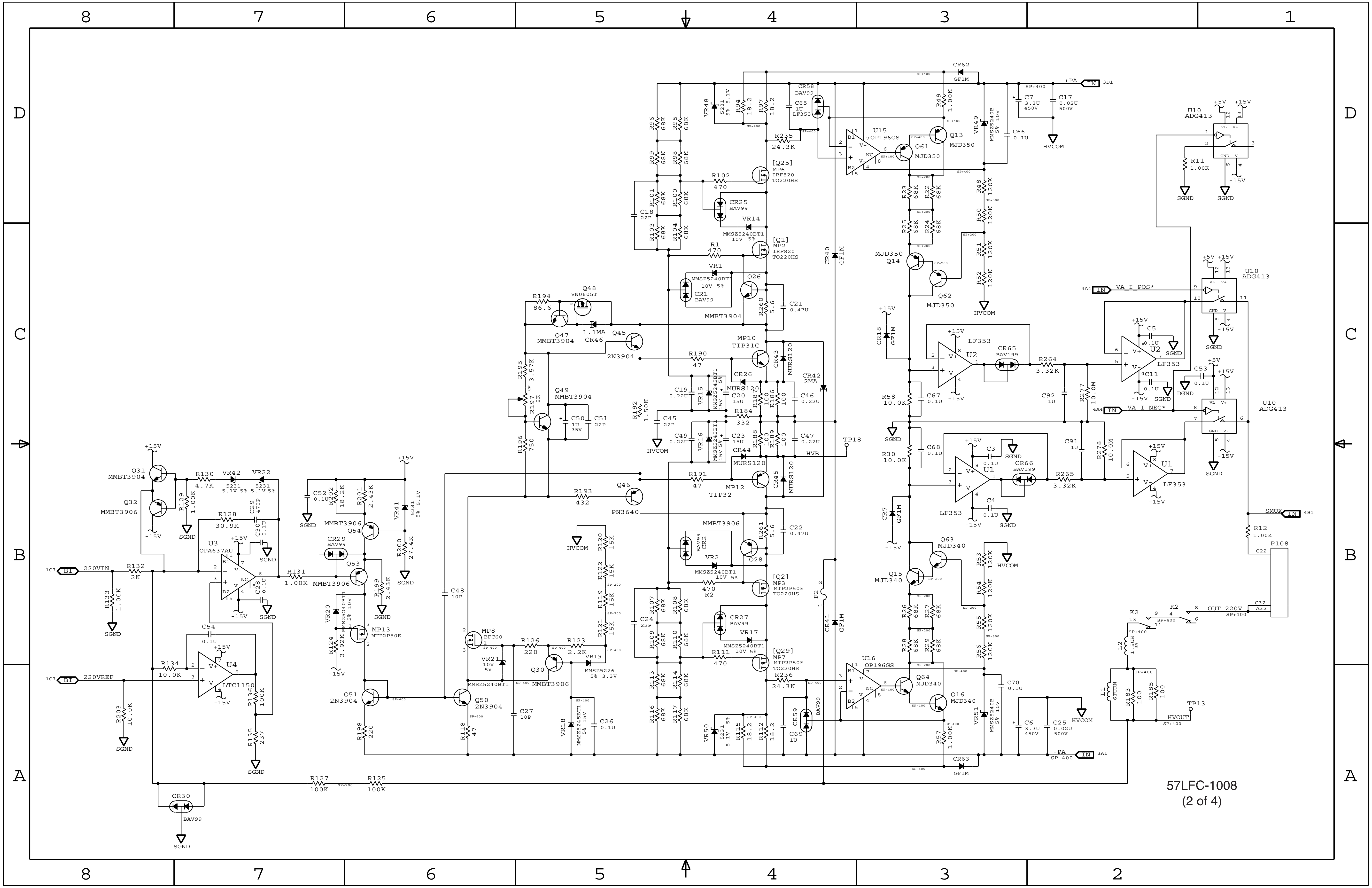


Figure 6-6. A8 High Voltage PCA (cont)

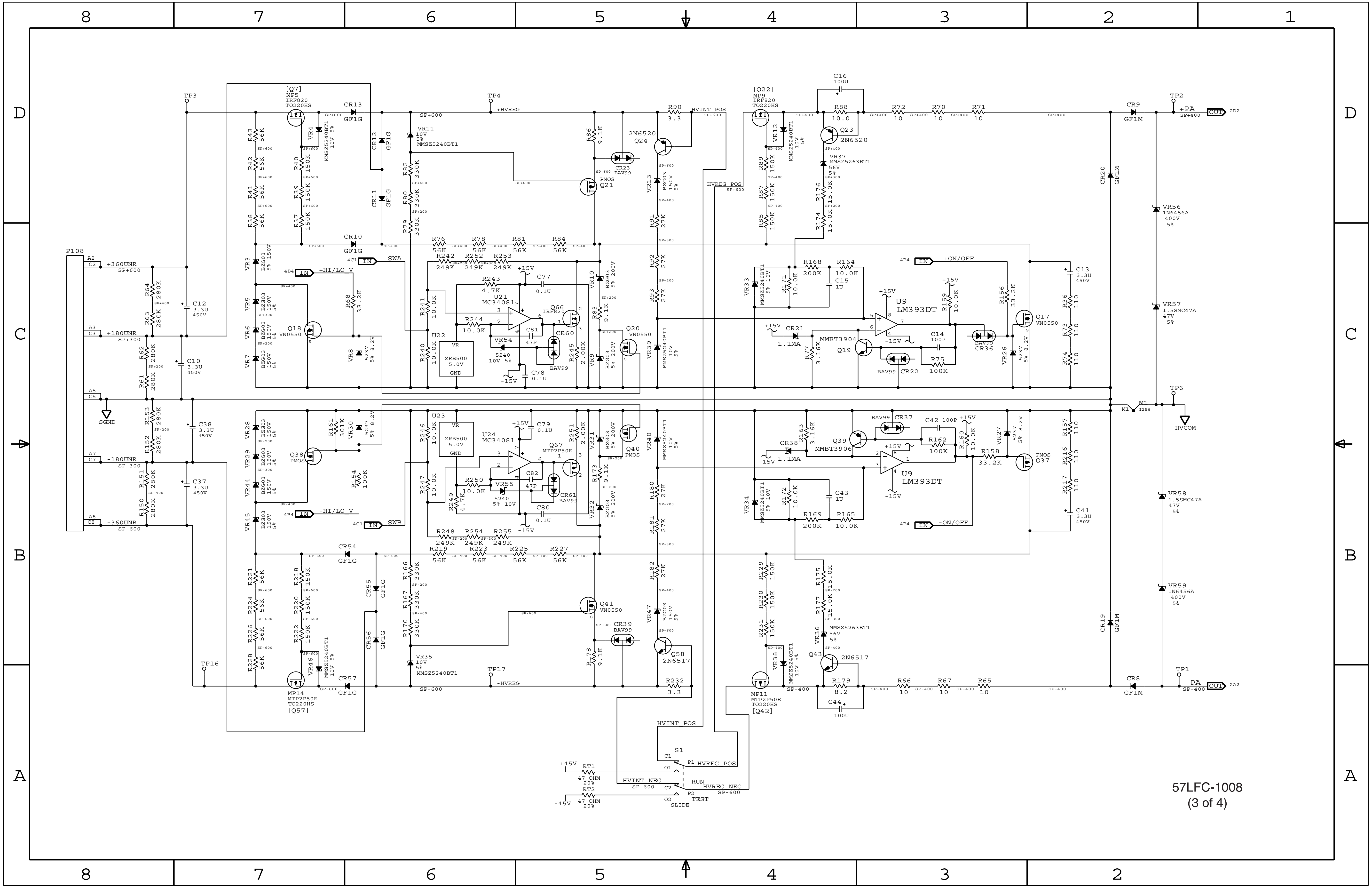


Figure 6-6. A8 High Voltage PCA (cont)

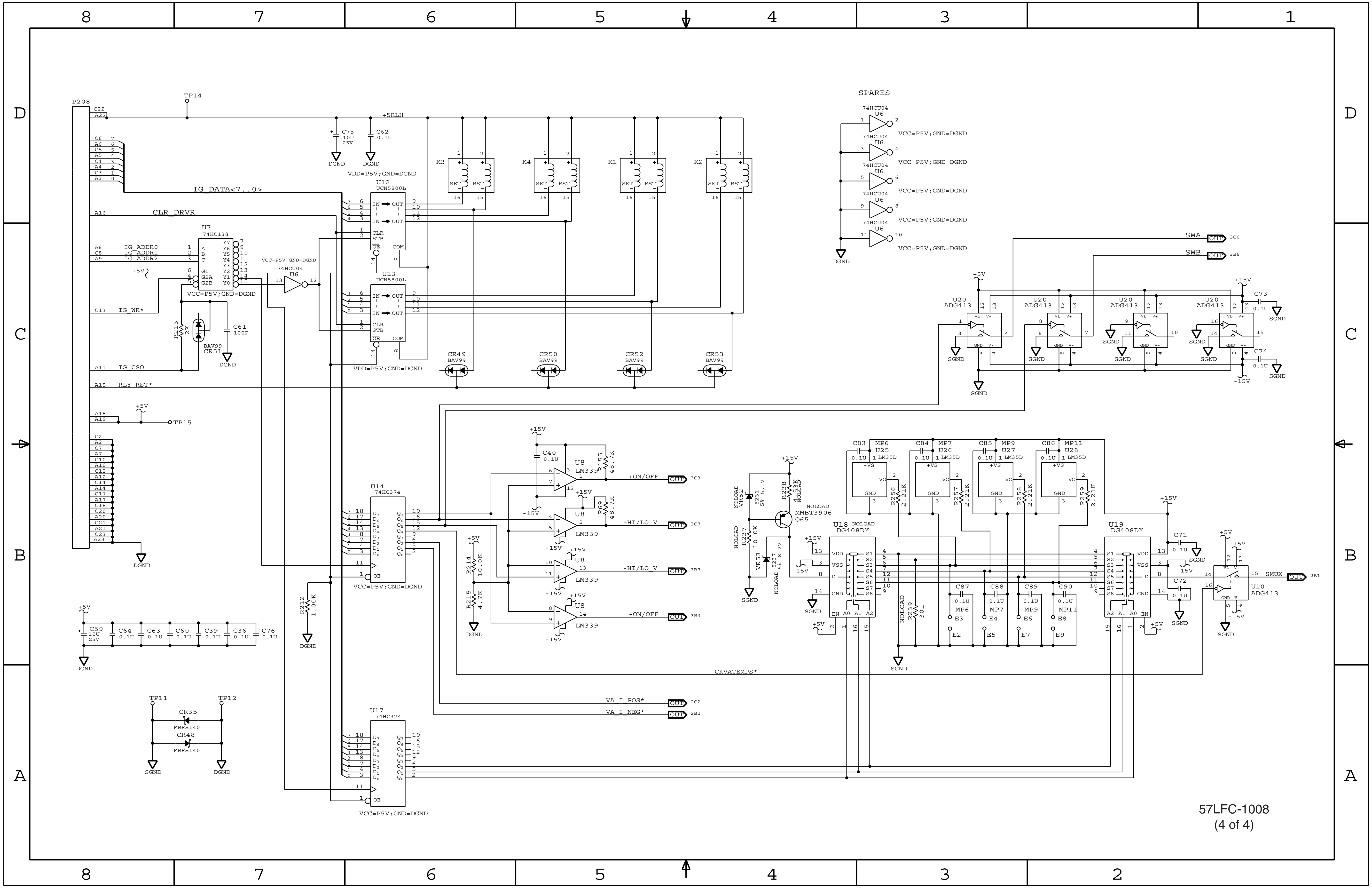


Figure 6-6. A8 High Voltage PCA (cont)

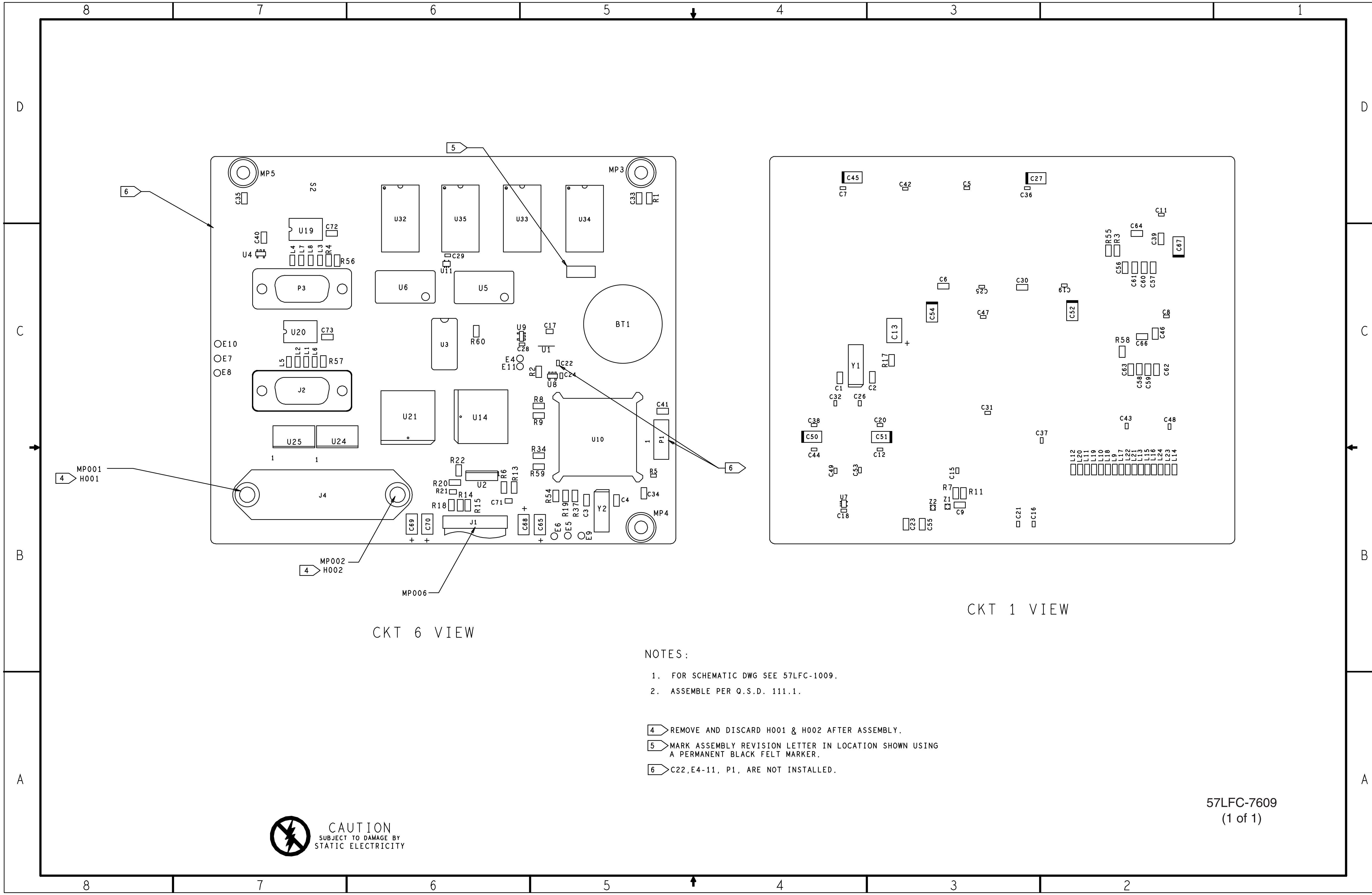
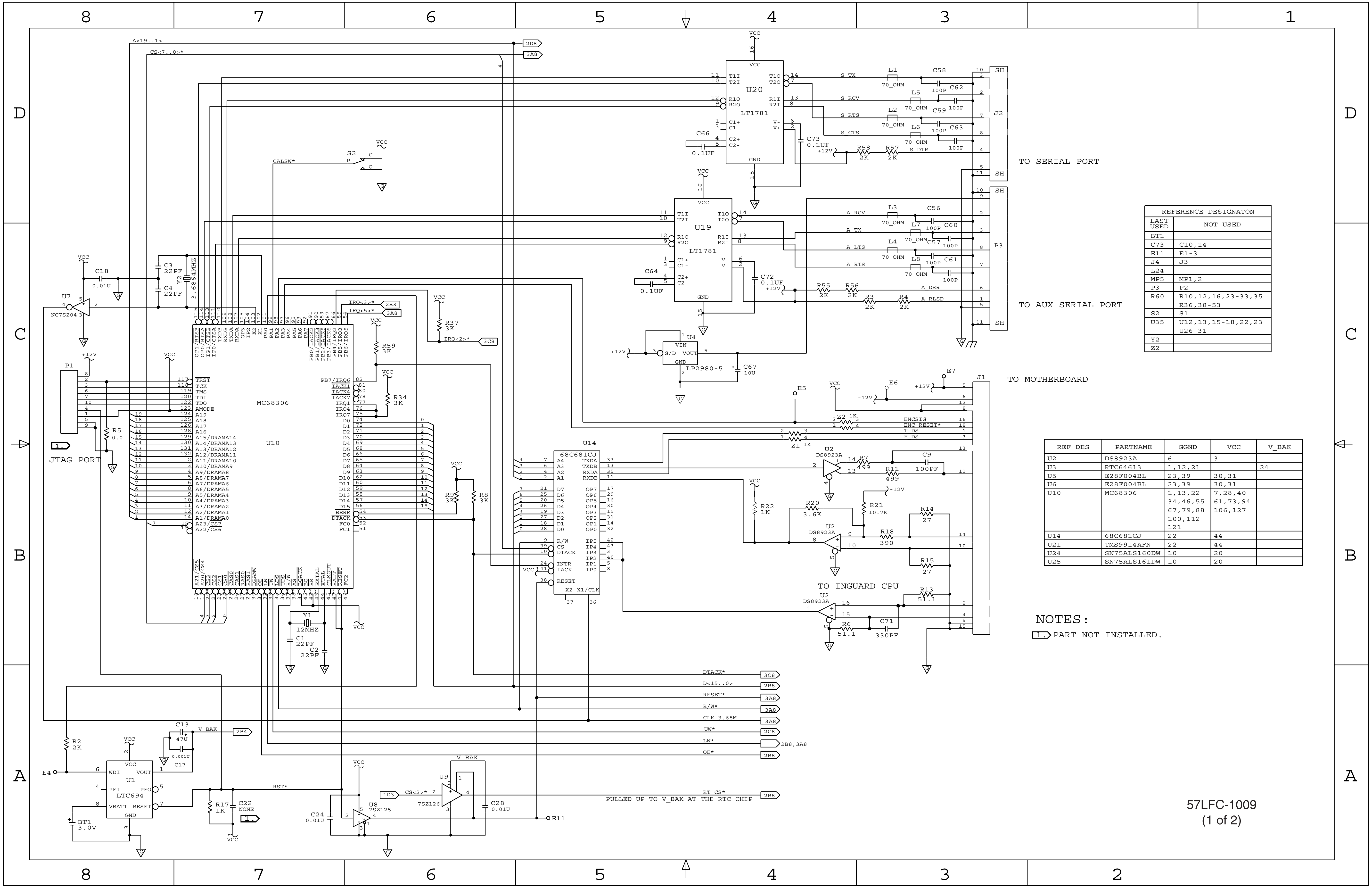


Figure 6-7. A9 Out-Guard CPU PCA



REFERENCE DESIGNATON	
LAST USED	NOT USED
BT1	
C73	C10,14
E11	E1-3
J4	J3
L24	
MP5	MP1,2
P3	P2
R60	R10,12,16,23-33,35 R36,38-53
S2	S1
U35	U12,13,15-18,22,23 U26-31
Y2	
Z2	

REF DES	PARTNAME	GGND	VCC	V_BAK
U2	DS8923A	6	3	
U3	RTC64613	1,12,21		24
U5	E28F004BL	23,39	30,31	
U6	E28F004BL	23,39	30,31	
U10	MC68306	1,13,22 34,46,55 67,79,88 100,112 121	7,28,40 61,73,94 106,127	
U14	68C681CJ	22	44	
U21	TMS9914AFN	22	44	
U24	SN75ALS160DW	10	20	
U25	SN75ALS161DW	10	20	

NOTES:
1. PART NOT INSTALLED.

Figure 6-7. A9 Out-Guard CPU PCA (cont)

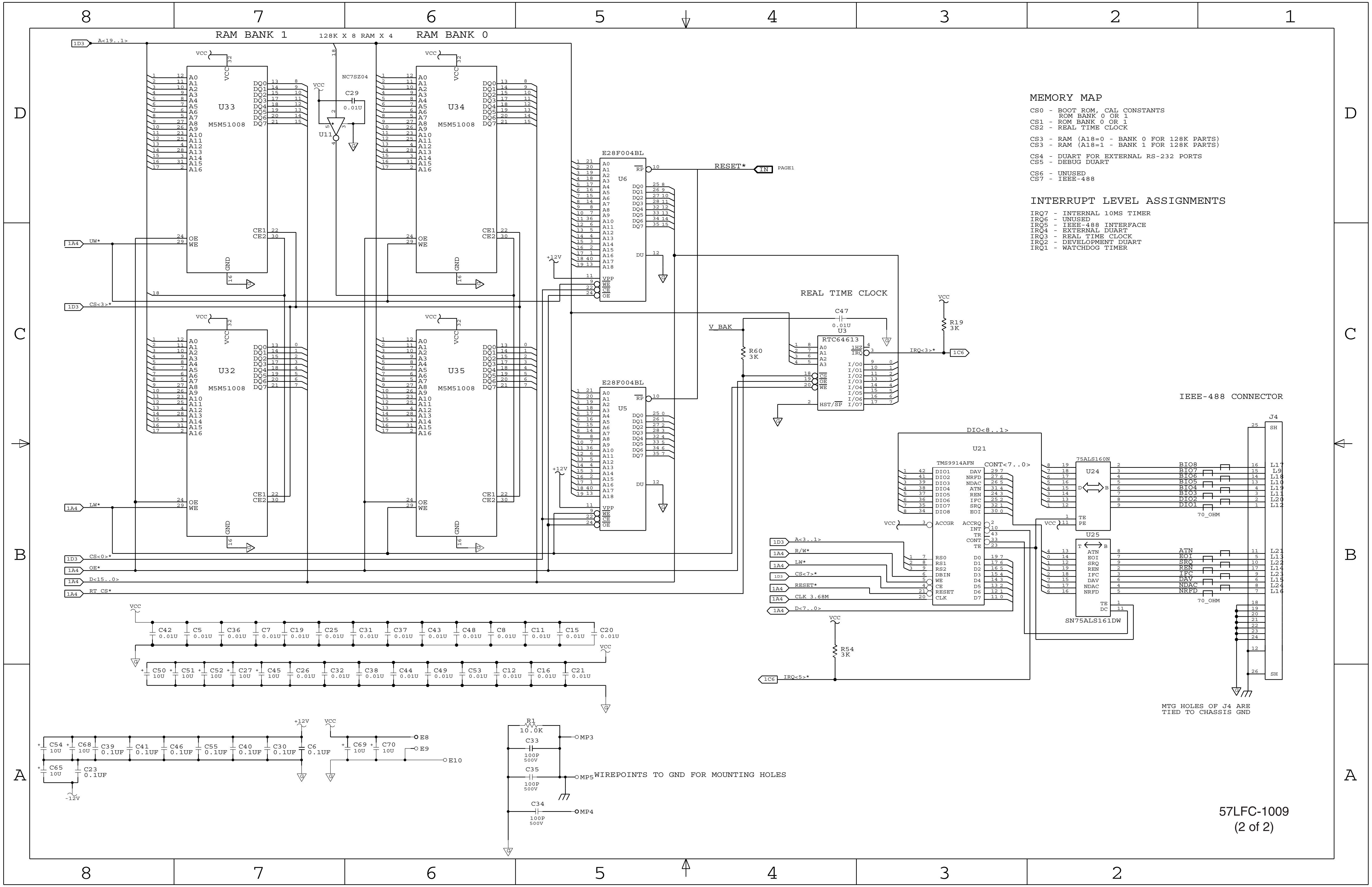


Figure 6-7. A9 Out-Guard CPU PCA (cont)