PUBLICATION NO. 980547

5001
DIGITAL MULTIMETER

RACAL-DANA

RACAL-DANA INSTRUMENTS INC.
4 Goodyear Street, P.O. Box C-19541, Irvine, CA 92713
Telephone: 714/859-8999, TWX: 910-595-1136, TLX: 67-8341

RACAL-DANA INSTRUMENTS LTD.
Duke Street, Windsor, Berkshire SL4 1SB, United Kingdom
Telephone: Windsor (07535) 68101, TLX: 847013

RACAL-DANA INSTRUMENTS S.A.
18 Avenue Dutartre, 78150 Le Chesnay, France
Telephone: (3) 955-8888, TLX: 697 215

RACAL-DANA INSTRUMENTS GmbH.
Hermannstrasse 29, D-6078 Neu Isenburg, Federal Republic of Germany
Telephone: 06102-2861/2, TLX: 412896

RACAL-DANA INSTRUMENTS ITALIA srl.
Via Mecenate 84/A, 20138 Milano MI, Italy
Telephone: (02) 5062767, (02) 5052686, (02) 503444; TLX: 315697

RACAL

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WARRANTY

Within one year of purchase, Racal-Dana will repair or replace your instrument, at our option, if in any way it is defective in material or workmanship. The instrument must be returned to the country of purchase, unless prior arrangement has been made, and Racal-Dana Instruments will pay all parts and labor charges. Just call Racal-Dana Product Service at (714) 859-8999 in U.S.A., Windsor (07535) 69811 in England, (3) 955-8888 in France, 06102-2861/2 in Germany or (02) 6459558/6468189 in Italy for assistance. We will advise you of the proper shipping address for your prepaid shipment. Your instrument will be returned to you freight prepaid.

PROPRIETARY NOTICE

FOR YOUR SAFETY

Before undertaking any maintenance procedure, whether it be a specific troubleshooting or maintenance procedure described herein or an exploratory procedure aimed at determining whether there has been a malfunction, read the applicable section of this manual and note carefully the WARNING and CAUTION notices contained therein.

The equipment described in this manual contains voltage hazardous to human life and safety and which is capable of inflicting personal injury. The cautionary and warning notes are included in this manual to alert operator and maintenance personnel to the electrical hazards and thus prevent personal injury and damage to equipment.

If this instrument is to be powered from the AC line (mains) through an autotransformer (such as a Variac or equivalent) ensure that the common connector is connected to the neutral (earthed pole) of the power supply.

Before operating the unit ensure that the protective conductor (green wire) is connected to the ground (earth) protective conductor of the power outlet. Do not defeat the protective feature of the third protective conductor in the power cord by using a two conductor extension cord or a three-prong/two-prong adaptor.

Maintenance and calibration procedures contained in this manual sometimes call for operation of the unit with power applied and protective covers removed. Read the procedures carefully and heed Warnings to avoid "live" circuit points to ensure your personal safety.

Before operating this instrument:

1. Ensure that the instrument is configured to operate on the voltage available at the power source. See Installation Section.

2. Ensure that the proper fuse is in place in the instrument for the power source on which the instrument is to be operated.

3. Ensure that all other devices connected to or in proximity to this instrument are properly grounded or connected to the protective third-wire earth ground.

If at any time the instrument:

- Fails to operate satisfactorily
- Shows visible damage
- Has been stored under unfavorable conditions
- Has sustained stress

It should not be used until its performance has been checked by qualified personnel.

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1.1 PURPOSE

1.1.1 This instruction Manual was prepared by Racal-Dana for the Model 5001 Digital Multimeter. For convenience, the Model 5001 will be called simply the "5001" throughout this manual. Refer to the published Specifications at the end of this section, whenever necessary, so that maximum performance for the 5001 can be achieved during any necessary calibration and maintenance procedures. It is recommended that all operators and technicians read this manual before using the instrument.

NOTE

Throughout this manual, the pin numbers for an Integrated Circuit will be expressed using the format U13p1. For example, "U13p1" simply refers to pin #1 of integrated circuit U13.

1.2 SCOPE

1.2.1 The Model 5001 Instruction Manual combines the information required for the Operator's Manual and the Maintenance Manual. For information on the GPIB Option 55T, designed for use with the 5001, refer to this option's separate Instruction Manual (P/N 980568). Operation Sections One through Three include General Description, Installation, and Operation of the 5001. Maintenance Sections Four through Seven provide Theory of Operation, Maintenance, Drawings (including Schematics) and Parts List.

1.3 PRODUCT SUPPORT GROUP

1.3.1 The Racal-Dana Irvine complex maintains a complete engineering laboratory, field engineers, service department and parts department to support the product commitment. Further support is provided by a network of field representatives and service centers by area. A complete list appears on the last two pages of the manual. The warranty program declaration is presented in the front matter of this manual; also, service personnel are available for consultation and assistance.

1.4 ELECTRICAL DESCRIPTION

1.4.1 General Performance Description

1.4.1.1 The following extraction from the published Specifications provides basic electrical and performance information concerning the 5001.

a) The 5001 is designed as a 5-1/2 digit meter with manual or automatic ranging on all functions.

b) The DC voltage function provides 0.1, 1, 10, 100 and 1000 V ranges.

c) The AC voltage function provides 1, 10, 100 and 750 V TRUE RMS ranges.

d) The kΩ function provides 0.1, 1, 10, 100, 1000 and 10,000 kΩ ranges. The 10,000 kΩ range provides measurement capability to 99 MΩ with 4-1/2 digit resolution above 22 MΩ.

e) The mA function for AC or DC provides 1, 10, 100, and 1000 mA ranges.

f) The 7-segment LED readout will display the value of the input signal with an appropriate decimal point, and will exhibit OL (overload) if the capacity of the 5001 is exceeded.

g) The 5001 provides the following software features:

1. PERCENT: Calculates and displays the percent deviation of the reading from a previously stored percent constant.

2. NULL: Calculates and displays the difference between the reading and a previously stored NULL constant.

3. LAH: Low-Average-High: Determines the lowest and highest readings over a series of measurements. It can also be used to average up to 10,000 readings.

1.4.2 Option 55T Interface

1.4.2.1 The Option 55T GPIB provides a systems interface for the transfer of data on the IEEE-Standard 488-1978 bus (GPIB). The GPIB is a digital interface system that maintains asynchronous data transactions between all devices residing on the bus. For further information on this GPIB option, refer to the Instruction Manual for the 55T (Racal-Dana Publication No. 980568).

1.4.2.2 The 5001 can be remotely instructed to transmit the data to another device on the bus.

1.4.3 5001 Block Diagram

1.4.3.1 The 5001 block diagram is shown in Figure 1.1. The three major sections that condition the measurement signal through the 5001 are described in the next three paragraphs.

a) The Signal Conditioning section switches, scales, attenuates and filters the input signal under microprocessor control.

b) The Analog-to-Digital converter employs a charge-balance/single-slope digitizer to change the DC voltage into a representative digital signal.

c) The μP-based digital section translates the converter's output to a numerical value for display that represents the value of the input signal. The digital section of the 5001 also provides range control, decimal placement and programming.

1.5 MECHANICAL DESCRIPTION

1.5.1 Refer to Figure 1.2 which shows a dimensional outline for the 5001.

1.6 POWER REQUIREMENTS

1.6.1 The 5001 is designed to operate from a wide range of AC line voltages and frequencies with 120 VAC standard setup. The selectable multi-tapped transformer will accommodate line voltages of 100, 120, 220 and 240 VAC ± 10%, 47 to 450 Hz. Section (2) presents the AC primary voltage selection instructions and the AC line cord requirements.

1.7 SPECIFICATIONS

1.7.1 The published Specifications for the Racal-Dana Model 5001 are provided at the end of this section of the manual.

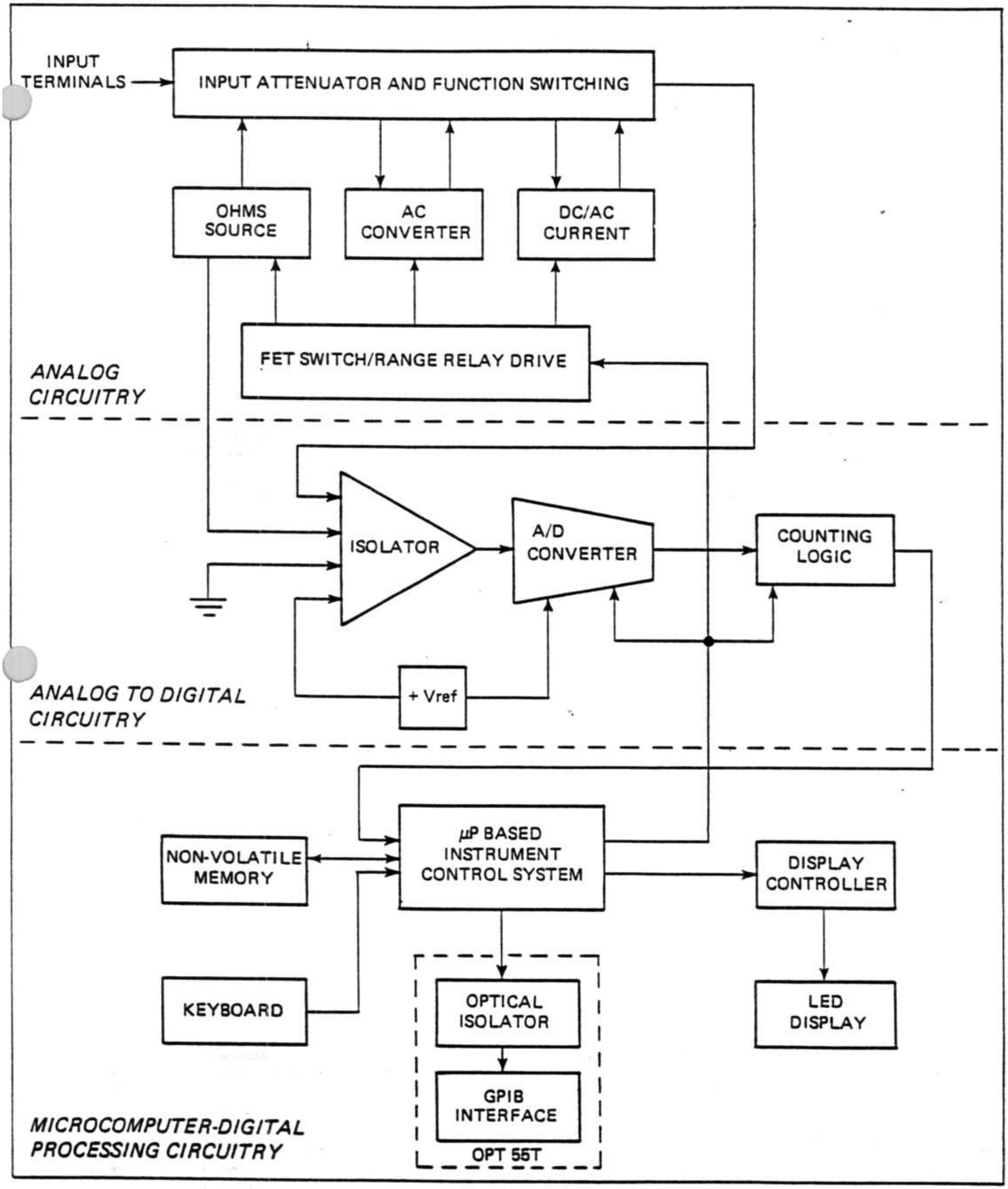


Figure 1.1 - 5001 Block Diagram

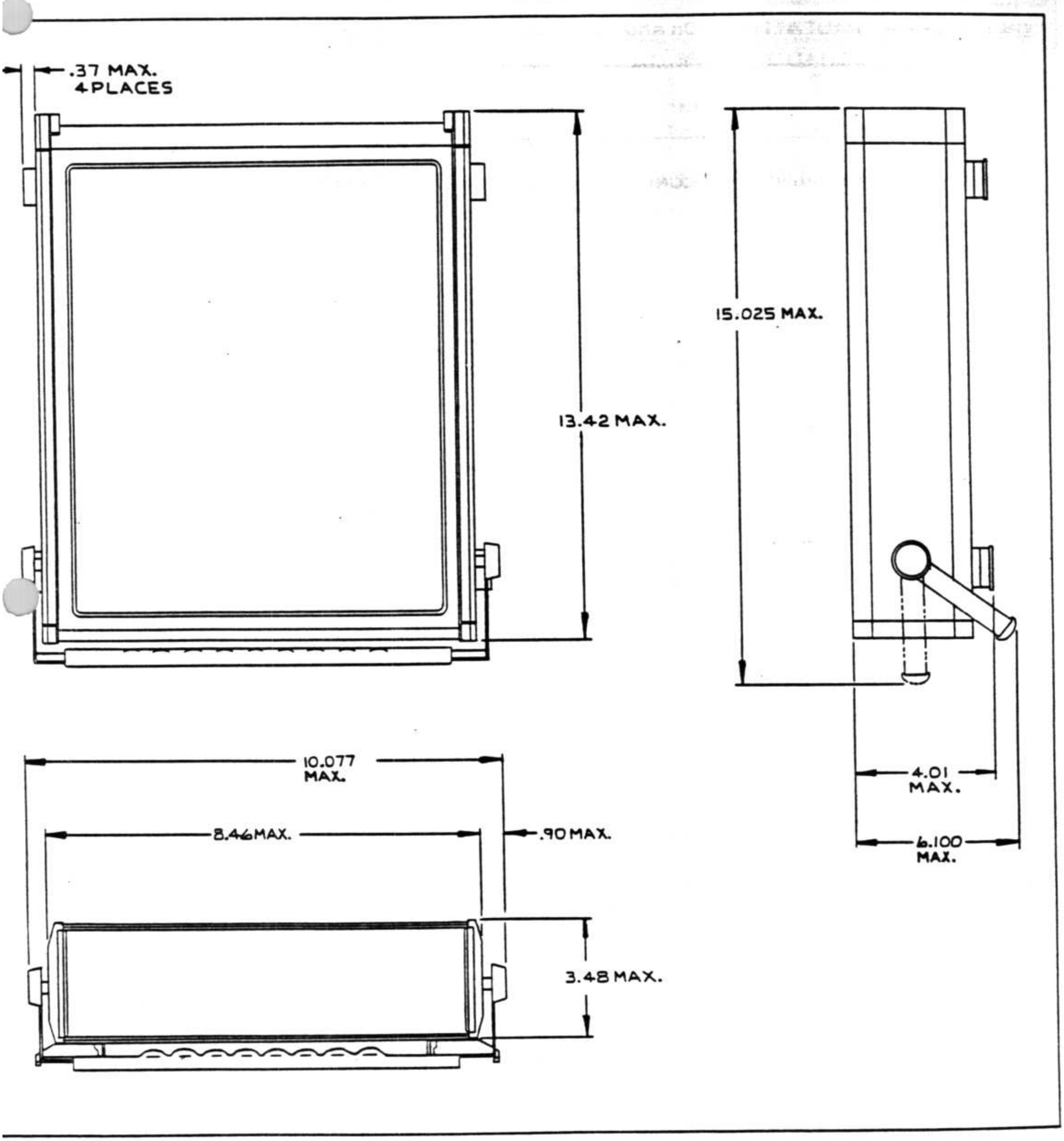


Figure 1.2 - 5001 Dimensional Outline

GENERAL SPECIFICATIONS	
Power Requirements	100, 120, 220 or 240 ± 10% VAC 20 watts maximum 47 to 450 Hz
Weight	10 lbs.
Dimensions	Height 3.5" (88.9 mm) Width 8.3" (209.8 mm) Deep 13" (330.2 mm)
Rack Mounting: Fixed Mount	 Option 60-1/2 Rack Standard 19" Rack
Warranty	1 Year
Environmental Requirements	
Temperature Range Operating Storage	 0.0 to 50°C -40°C to + 70°C
Humidity Operating Storage	 <75% RH, 0 to 40°C <50% RH, 40°C to 50°C <80% RH
Fuse 100-120 Volts AC 220-240 Volts AC	 0.25 Amp SLO-BLO 0.125 Amp SLO-BLO
Battery Type Life (Not Rechargeable)	 3 Volt Lithium Battery 3 Years minimum at 50°C ambient temperature
Display Data Decimal Point Function Overload Indicator	 5-1/2 digits, 0.43 inch, 7-segment red LED Automatic Decimal Point Selected via Pushbutton Switches Display Reads OL
Warmup Time	
Warmup time to 24 Hour Specifications	2 Hours
Warmup time to 90 Day Specifications	1 Hour
Maximum Common Mode Voltage	1000V Peak or DC: Guard to case. 250V Peak or DC: Analog common to Guard.
Overrange	100% overrange with full accuracy on all ranges and functions, except 1000 VDC and 750 VAC Ranges.
Ranging	Auto-Range, upranges at approximately 225% of range and Downranges at approximately 20% of range.
Read Rate	4 Readings/Sec in DC, AC, DC-ma, AC-ma 3 Readings/Sec in Ohms or when Filter is enabled.
Filter (analog) Frequency Response Application Settling Time	 ≥20dB rejection at 55 Hz All ranges except 1 VAC and 10 kΩ DC: 400 ms Ohms: 0.1 - 100 kΩ Range 400 ms 1000 kΩ Range 700 ms 10,000 kΩ Range 3 sec

GENERAL SPECIFICATIONS continued	
Math Capability Low/Avg/High Percent Null	 The voltmeter stores the LOW, AVERAGE, and HIGH values of the input during a series of measurements. The voltmeter will display the percent deviation of input during a series of measurements. The voltmeter will display only the difference between the reading taken and reference readings.
Digital Averaging	Previous 4 or 6 readings are averaged prior to display update. Averaging is momentarily aborted if input signal changes by more than approximately .005% FS, or .1% FS when FILTER is enabled.

DC VOLTS	
Range	0.1, 1, 10, 100, 1000 Volts
Resolution	0.001% of range 1 Microvolt on 0.1V Range
Maximum Input Voltage	1000 VDC or Peak AC (one minute maximum in 0.1 V or 1 V ranges, 700 V continuous)
Accuracy	
Accuracy, Short Term 24 hrs: 23°C ± 1°C (Requires NULL in .1 VDC Range)	0.1 V Range: ± (0.007% Rdg. + 3 digits) 1V Range: ± (0.007% Rdg. + 3 digits) Other Ranges: ± (0.007% Rdg. + 3 digits)
Accuracy. 90 Days 23°C ± 5°C (Requires NULL in .1 VDC Range)	0.1 V Range: ± (0.015% Rdg. + 4 digits) 1V Range: ± (0.012% Rdg. + 4 digits) Other Ranges: ± (0.015% Rdg. + 4 digits)
Accuracy, 1 Year 23°C ± 5°C (Requires NULL in .1 VDC Range)	0.1 V Range: ± (0.02% Rdg. + 6 digits) 1V Range: ± (0.015% Rdg. + 6 digits) Other Ranges: ± (0.02% Rdg. + 6 digits)
Temperature Coefficient	0.1 V: ± (0.0008% of Rdg. + 3 digits)/°C 1 V: ± (0.0008% of Rdg. + 0.5 digits)/°C 10 V-1 kV: ± (0.0013% of Rdg. + 0.5 digits)/°C
Input Impedance	0.1, 1 V Ranges: 1,000 MΩ 10, 100, 1000 V Ranges: 10 MΩ ± 0.5%
Normal Mode Rejection	
Normal Mode Rejection, Unfiltered	Notch of ≥60 dB at 50 Hz and 60 Hz ± 0.1%
Normal Mode Rejection, Filtered	Notch of ≥75 dB at 50 and 60 Hz ± 0.1%

Specifications (Continued)

DC VOLTS continued	
Common Mode Rejection Ratio (CMRR)	
Effective CMRR, 1 kΩ Unbalance	≥120 dB at 50 and 60 Hz
CMRR, 1000 VDC, 1 kΩ Unbalance	≥140 dB at DC
Input Bias	
Input Bias Current	≤50 pA at ≤25°C
Input Bias Current Temperature Coefficient:	Doubles every 10°C above 25°C

OHMS	
Ranges	0.1, 1, 10, 100, 1000, 10,000 kΩ
Resolution 10,000 kΩ Range: Other Ranges:	0.001% of range to 22 MΩ decreasing to 0.01% of range to 99 MΩ 0.001% of range (1 mΩ in .1 kΩ Range)
Measurement Scheme	Modified 4-Wire
Voltage Across Unknown	.5 Volts maximum on .1kΩ range, 5 Volts maximum on other ranges
Voltage Protection (Without Damage)	260 V RMS Maximum 360 V Peak
Accuracy	
Accuracy, Short Term 24 Hrs., 23°C ± 1°C (Requires NULL in .1 kΩ Range)	.1 kΩ Range: ± (0.02% Rdg. + 4 digits) 1 k-1000 kΩ Ranges: ± (0.02% Rdg. + 5 digits) 10,000 kΩ Range: ± 0.06% Rdg. + 5 digits); Rx≤20 MΩ ± (0.3% Rdg.); Rx>20 MΩ
Accuracy, 90 Days 23°C ± 5°C (Requires NULL in .1 kΩ Range)	.1 kΩ Range: ± (0.03% Rdg. + 5 digits) 1 k-1000 kΩ Ranges: ± (0.035% Rdg. + 5 digits) 10,000 kΩ Range: ± (0.08% Rdg. + 5 digits); Rx≤20 MΩ ± (0.8% Rdg.); Rx>20 MΩ
Accuracy, 1 Year 23°C ± 5°C (Requires NULL in .1 kΩ Range)	0.1 kΩ Range: ± (0.04% Rdg. + 6 digits) 1 k-1000 kΩ Ranges: ± (0.047% Rdg. + 6 digits) 10,000 kΩ Range: ± (0.1% Rdg. + 6 digits); Rx≤20 MΩ ± (1.0% Rdg.); Rx>20MΩ
Settling Time (Filtered) .1 kΩ Range 1 k-100 kΩ Ranges 1000 kΩ Range 10,000 kΩ Range	400 ms to within 20 digits 400 ms to within 10 digits 1s to within 10 digits 3s to within 40 digits
Temperature Coefficient	0.1 kΩ: ± (.0035% Rdg. + 3 digits)/°C 1, 10, 100, 1000 kΩ: ± (.004% Rdg. + .5 digits)/°C 10,000 kΩ: ± (0.01% Rdg. + .5 digits)/°C

OHMS continued		
Current through Unknown (at full scale)	RANGE	CURRENT
	.1 kΩ	2 mA
	1 kΩ	2 mA
	10 kΩ	.2 mA
	100 kΩ	20µA
	1000 kΩ	2µA
	10,000 kΩ	.2µA

AC VOLTS (TRUE RMS)	
Range	1, 10, 100, 750 Volts RMS
Maximum Input Voltage	750 RMS (6 x 10^6 volt-hertz maximum) 1100 V Peak
Resolution	.001% of Range (10µVAC on 1 VAC Range)
CMRR, 1 k Unbalance DC to 60 Hz	≥60 dB
Accuracy	
Accuracy, Short Term Sinewave Input, V_{IN} ≥0.1% FS, 24 Hours 23°C ± 1°C	45 Hz - 10 kHz: ±(0.4% Rdg. + 120 digits) 10 kHz - 20 kHz: ± (0.6% Rdg. + 150 digits) Add 0.1% Rdg. if V_{in} ≥500 V
Accuracy, 90 Days Sinewave Input, V_{IN} ≥ 0.1% FS, 23°C ± 5°C	45 Hz - 10 kHz: ±(0.5% Rdg. + 150 digits) 10 kHz - 20 kHz: ± (0.7% Rdg. + 180 digits) Add 0.1% Rdg. if V_{in} ≥500 V
Accuracy, 1 Year Sinewave Input V_{IN} ≥ 0.1% FS 23°C ± 5°C	45 Hz - 10 kHz: ±(0.6% Rdg. + 170 digits) 10 kHz - 20 kHz: ± (0.8% Rdg. + 200 digits) Add 0.1% Rdg. if V_{in} ≥500 V
Temperature Coefficient	± (.02% Rdg. + 10 digits)/°C
Crest Factor	At 200% of Scale: 4:1 Below 200% of Scale: $4\sqrt{\frac{V\ Range}{V\ Input}}$
Input Impedance	1MΩ in series with .22 µF, shunted with less than 100 pF.

DC CURRENT	
Ranges	1, 10, 100, 1000 mA
Display	4-1/2 Digits
Resolution	.01% of Range (100 nA in 1 mA range)

DC CURRENT continued	
Accuracy	
Accuracy, Short Term 24 Hours, 23°C ± 1°C	1, 10, 100 mA Ranges: ± (0.1% Rdg. + 2 digits) 1000 mA Range: ± (0.25% Rdg. + 2 digits)
Accuracy, 90 Days 23°C ± 5°C	1, 10, 100 mA Ranges: ± (0.15% Rdg. + 2 digits) 1000 mA Range: ± (0.35% Rdg. + 3 digits)
Accuracy, 1 Year 23°C ± 5°C	1, 10, 100 mA Ranges: ± (0.2% Rdg. + 2 digits) 1000 mA Range: ± (0.4% Rdg. + 3 digits)
Input Resistance	Range / Resistance: 1 mA 100Ω; 10 mA 10Ω; 100 mA 1Ω; 1000 mA .1Ω
Temperature Coefficient	± (0.01% of Rdg. + 0.3 digits)/°C
Voltage Burden	≤0.3 volts
Maximum Current	2A (fuse protected)

AC CURRENT	
Ranges	1, 10, 100, 1000 mA
Display	4-1/2 Digits
Resolution	.01% of Range (100 nA in 1 mA range)
Accuracy	
Accuracy, Short Term Sinewave Input, 45 Hz - 1 kHz, $V_{in.}$ ≥0.1% FS, 24 Hour 23°C ± 1°C	1, 10, 100 mA Ranges: ± (0.5% Rdg. + 12 digits) 1000 mA Range: ± (0.8% Rdg. + 12 digits)
Accuracy, 90 Days 45 Hz - 1 kHz $V_{in.}$ ≥0.1% FS, 23° C ± 1°C	1, 10, 100 mA Ranges: ± (0.65% Rdg. + 14 digits) 1000 mA Range: ± (0.8% Rdg. + 14 digits)
Accuracy, 1 Year 45 Hz - 1 kHz $V_{in.}$ ≥.1% FS, 23° C ± 1° C	1, 10, 100 mA Ranges: ± (0.7% Rdg. + 15 digits) 1000 mA Range: ± (1% Rdg. + 15 digits)
Temperature Coefficient	± (0.03% of Rdg. + 1 digit)/°C
Voltage Burden	≤0.3 Volts
Maximum Current	2A (Fuse Protected)
Input Resistance	Range / Resistance: 1 mA 100Ω; 10 mA 10Ω; 100 mA 1Ω; 1000 mA .1Ω

GPIB INTERFACE (OPTION 55T)

Subset Capability

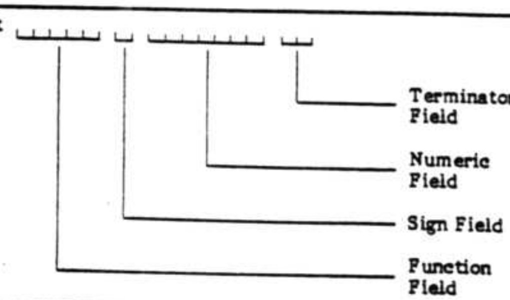
IEEE-488-1978 Standard Interface Subset Capability

GPIB Subset	Description/Applicable Capability
SH1	Source Handshake: Complete Capability
AH1	Acceptor Handshake: Complete Capability
T7	Talker: Complete Capability Except Serial Poll 1) Basic Talker 2) Talk-Only Mode 3) Unaddress if MLA
L4	Listener: Complete Capability except Listen Only 1) Basic Listener 2) Unaddress if MTA
SR0	Service Request: No Capability
RL0	Remote/Local: No Capability
PP0	Parallel Poll: No Capability
DC1	Device Clear: Complete Capability 1) DCL - Device Clear 2) SDC - Selected Device Clear
DT1	Device Trigger: Complete Capability GET - Group Execute Trigger
C0	Controller: No Capability
E1	Open Collector Bus Drivers

NOTE: Although Option 55T provides Listener Capability, only the trigger mode may be programmed. Function and Range are not programmable.

Output Format

Standard Output



Function Field

1) "VDC--"
2) "VAC--"
3) "kohm-"
4) "DCmA-"
5) "ACmA-"
6) "%----"
7) "rdgs-"
8) "-----" 5 spaces - see "F0" command

Note: "-" represents space

Sign Field

1) space represents positive
2) "-" represents negative

GPIB INTERFACE continued

Numeric Field	Range	Field Contents
	.1	. D D D D D D
	1	D . D D D D D
	10	D D . D D D D
	100	D D D . D D D
	1,000	D D D D . D D
	10,000	D D D D D . D
	.1 mA	. D D D D D -
	1 mA	D . D D D D -
	10 mA	D D . D D D -
	100 mA	D D D . D D -
	1000 mA	D D D D . D -
	22M	D D D D D . -
	Note: "-" represents space	

Terminator Field	Conditions	Term.
	1) Talk-only Mode with address previously set to 30	LF
	2) All other conditions	CR LF
	Note: "-" represents space	
Overload Output	9999999 in numeric field	
Programming Requirements	1) Character Code: 7 bit ASCII, upper or lower case. 2) All Program Strings transmitted to the 5001 should end in a terminating character. Acceptable terminators are: CR Carriage Return LF Line Feed At least one of the above terminators is required at the end of every program string.	

GPIB Program Codes

Trigger Commands

NOTE: The 5001 will continue to trigger internally and display readings even when programmed to the HOLD mode over the bus. Also, bus outputs will cease if the 5001 is placed in the STORE or RECALL mode from the keyboard, or if an error message is on the 5001 display.

Operation	Program Code	Special Notes
Trigger Immediate	T0	Used in conjunction with T2, T3, T4, T5
Internal Trigger	T1	Causes continuous readings
Hold	T2	Hold Mode with No Delay
Hold	T3	Hold Mode with 4 Rdg. Delay
Hold	T4	Hold Mode with 6 Rdg. Delay
Hold	T5	Hold Mode with 8 Rdg. Delay

Format Commands

Operation	Program Code	Special Notes
Disable Function Output	F0	Output 5 - spaces preceding each reading
Enable Function Output	F1	Output 5 - character function code preceding each reading

GPIB INTERFACE continued

Command String Terminator (Optional)

Operation	Code	Special Notes
Terminator	X	Use is required only when the 5001 is being programmed from a controller which does not terminate the program string with a CR or LF.

NOTE: Opt 55T will terminate on any unrecognized character. Program code "X" is preferred in order to maintain compatibility with other R-D products.

General Specifications

Programming GPIB Address/Talk Only	During power-up, the GPIB address is read from Non Vol by the 5001 and transmitted across guard to Option 55T. If the user wishes to temporarily modify the GPIB address, the following procedure is used: a) Power-on the 5001. b) To enter the "address select mode", press the STORE key while "AddrXX" or "ton" is displayed on the 5001's 7-segment display. c) Press any key other than STORE, 1k or 10k to toggle from addressed mode to "Talk-Only" mode. The 7-segment LEDs will display "ton" or "AddrXX" to indicate which mode is presently selected. d) If the addressed mode is selected, press the 1k and 10k buttons to increment the MSD and LSD of the displayed address. e) Exit the address select mode by pressing the STORE key once again. If the user wishes to permanently modify the address or Talk-Only setting, hold the CAL switch depressed while performing Step (e). This will store the new setting into Non Vol.
Terminator control when in Talk-Only mode	To eliminate a CR from the output string while operating in the Talk-Only mode the following procedure is used: a) Power-on the 5001. b) Set the GPIB address to 30. c) Toggle "ADR 30" to "ton". d) Press the STORE key to send the "ton" message across guard.

Specifications (Continued)

GPIB INTERFACE continued	
Skill level required by Installer	The installation of Option 55T should only be performed by qualified service personnel.
Handshake Times (typical) a) Interface Messages b) Device Commands c) Output Reading (15 bytes)	 4 ms .6 ms/byte .3 ms/byte
Testability	
Microcomputer Self-Test	Upon power-on, the 8748 uP performs the following self-tests: a) RAM test b) ROM checksum If both RAM and ROM tests show no errors, the uP drives test point #3 low and continues execution.
Signature Analysis	70% of the circuitry can be tested using SA. For further details, see the Instruction Manual, P/N 980568.

2.1 PURPOSE

2.1.1 This section describes 5001 installation for bench or rack mounting and optional package installation as may be required.

2.2 5001 UNPACKING AND INSPECTION

2.2.1 Instructions

2.2.1.1 Prior to unpacking the 5001, examine the exterior of the shipping carton for any signs of damage (all irregularities should be noted on the shipping bill). Carefully remove the instrument from the carton's plastic-foam packaging and inspect the instrument for any signs of damage. Notify the carrier immediately if damage is apparent.

2.2.1.2 A qualified person should check the operation of the 5001 for safety when damage is suspected.

2.3 5001 INSTALLATIONS

2.3.1 General

2.3.1.1 The 5001 can be operated in three installation environments to meet the specific application need. Figure 1.2 provides the major dimensions for the 5001, which can be set up in one of the three following installations:

a) Bench Operation, for which the 5001 is equipped with four bench-feet and a tilt-bail/handle.

b) Fixed-Mount Rack (Option 60), for installing the 5001 in the standard 19-inch rack.

c) Custom Installations

2.3.2 Bench Operation

2.3.2.1 Each instrument is equipped with a tilt-bail/handle to elevate the front of the instrument for easy operation. The tilt-bail becomes a handle that locks in three positions upon depressing the mounting knobs on both sides of the instrument. The tilt-bail/handle can be rotated over the top of the instrument when the instrument rests on the four bench-feet.

2.3.3 Fixed-Mount Rack Installation - Option 60

2.3.3.1 The Fixed-Mount Installation Package includes a pair of angle brackets and 4 flat-head #8-32 x 1/2 screws. To install the angle brackets, refer to Figure 2.1 and proceed as described in the next five paragraphs.

2.3.3.2 The preparation of the 5001 for rack-mount is started by removing the tilt-bail/handle. First, pry off the decorative disks on the mounting knobs marked "Push-to-Unlock". This exposes the Phillips-head screws that retain the tilt-bail/handle to the case. Remove the two screws, one in each knob, to free the tilt-bail/handle from the case.

2.3.3.3 Next, to disassemble the bench feet and side panels, remove the rear corner-feet as follows:

a) Unscrew the two Phillips-head retaining screws from each rear corner-foot. This frees the corner-feet, covers and side panels. Remove the rear corner-feet from the case.

b) With the instrument bottom-up, slide the bottom cover one-half inch towards the rear, then lift off. (The top covers slides off in the same fashion.)

c) The four bench-feet can be removed from the cover by unscrewing the Phillips-head retaining screws in each foot.

2.3.3.4 With the rear corner-feet detached from the instrument, remove the side panels by sliding them in their retaining tracks towards the rear panel.

2.3.3.5 To install the custom-mount angle-brackets, proceed as follows:

a) With the side panels removed, the retaining screws for the front-cover inserts are visible. Remove the screws, but leave the corner inserts in place.

b) The angle bracket is placed over the corner inserts with the mounting holes aligned over the retaining screw-holes.

c) Insert the two flat-head #8-32 x 1/2 screws (supplied with the kit) through both the angle bracket and corner insert, then screw to the case.

2.3.3.6 To reassemble the instrument, reinstall the top and bottom covers, fitting the front edge of each cover under the front panel, then screw the rear corner-feet to the case. The side panels, tilt-bail/handle and hardware should be stored in a convenient location.

2.4 AC POWER CONNECTIONS

2.4.1 General

2.4.1.1 Standard units operate on either 100, 120, 220 or 240 volts, 45 to 450 Hz. Power consumption is less than 20 W. Operation on any one of the four line voltages is selected by the placement of a small printed circuit card (P4), located in J4 receptacle on the main PCB. Selection of a specific line voltage is accomplished as follows:

a) Disconnect the power cord from the AC power source.

WARNING

Removal of covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while the unit is connected to the AC power source.

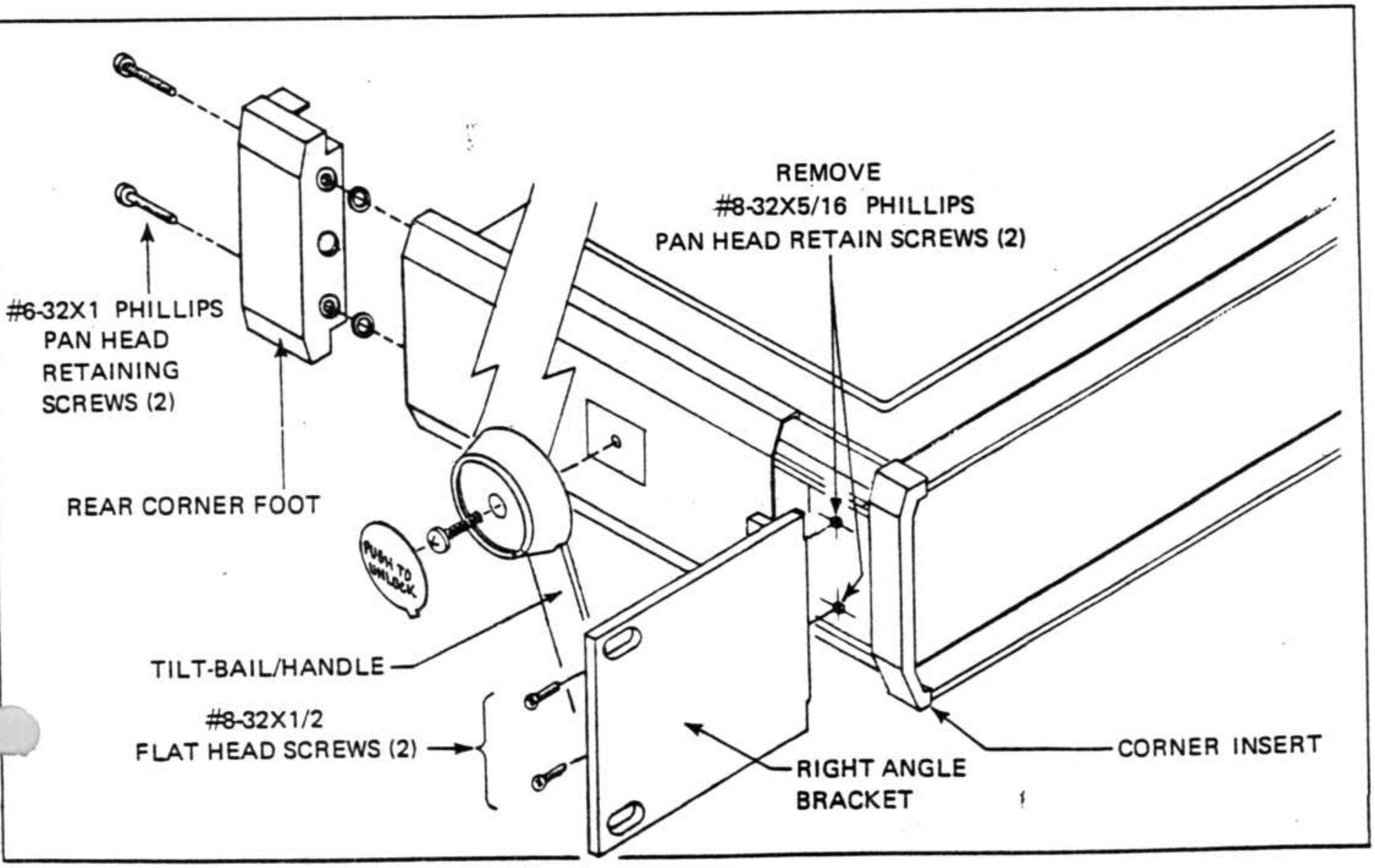


Figure 2.1 - 5001 Rack-Mounting Diagram

b) Remove the 5001's top cover by loosening each corner-foot as described in paragraph 2.3.3.3. Next, slide the top cover toward the rear panel approximately one-half inch, then lift the cover from the frame.

c) Remove the screw which holds the plastic protective cover over the transformer box.

d) Remove the voltage card-selector P4 from the J4 receptacle, then re-insert it permitting the desired line voltage number to be visible through the small view window on the rear panel of the instrument (needle-nose pliers will simplify this step).

NOTE

Ensure that the rating for the AC line fuse corresponds to the voltage setting by checking the POWER FUSE chart on the rear panel of the 5001.

e) To reassemble the instrument, place the top cover on the frame with the side flanges fitting correctly in the frame grooves and the front edge of the cover approximately one inch from the front panel. When correctly seated on the frame, slide the cover forward until the front edge slides under the front panel. Replace the rear corner-feet to complete the assembly.

2.5 GROUNDING REQUIREMENTS

2.5.1 The front panel and cabinet of the instrument are grounded in accordance with MIL-T-28800C to protect the user from possible injury due to shorted circuits. The three-conductor AC power cable supplied with the instrument maintains a low impedance path to ground when connected to a three-wire single-phase AC receptacle. This device and other devices connected to or in proximity to this instrument must maintain the third-wire earth ground intact as stated in current regulations.

2.6 RESHIPMENT PACKAGING

2.6.1 During shipment of the instrument, the original shipping carton with the foam packaging-forms and plastic dust-cover provide the necessary protection. This carton should be preserved if possible.

2.6.2 When the original shipping carton is not available, reconstruct the packaging using a can of plastic spray-foam to surround the plastic-wrapped unit in the carton.

2.7 INPUT-OUTPUT CABLES

2.7.1 The input terminals used on the front panel are standard banana jacks. The spacing among the banana jacks permits a molded dual banana-plug to be connected directly between connectors. The dual banana plug-cables are available under Racal-Dana P/N 402190.

2.8 FUSE LOCATION AND REPLACEMENT

2.8.1 AC Line Fuse

2.8.1.1 AC LINE FUSE (F2) is located next to the voltage card-selector (P4) in the transformer box. The procedure to replace the AC fuse is the same as the voltage card-selector instructions listed in paragraph 2.4.1.1, steps b) - e).

2.8.1.2 The clip fuse-holder is located next to the power transformer. The rating of the SLO-BLO fuse varies with the AC primary voltage selected:

100-120 volts AC: use 0.25 A rating.
220-240 volts AC: use 0.125 A rating.

2.8.2 mA Protector Fuse

2.8.2.1 The mA current-limiting protector fuse (F1) is located at center-front on the main PCB. Access to the fuse is gained by removing the cover. Follow the cover removal instructions outlined in Subsections 2.3.3.3 and 2.3.3.4.

2.8.2.2 The mA current limiting fuse is rated at 2.5 A, 250 V. This rating must not be exceeded.

2.9 BT1 LITHIUM CELL REPLACEMENT

2.9.1 The life of the lithium cell varies between three and eight years. Therefore, the cell is not classified as a routine service or installation component. Refer to Subsection 5.4.16 of this manual for complete replacement information.

2.9.2 When reviewing the Maintenance Section, remember the critical importance of the lithium cell. Exercise caution to avoid losing data stored in memory.

3.1 INTRODUCTION

3.1.1 This section contains operating information for the 5001. The information contains illustrations of all front panel controls, indicators and connectors along with a tabular listing of their function and purpose. Operating instructions for manual or bench operation are presented in two ways; a description of each operating feature followed, when necessary, with a step-by-step operating example. Some operating features or functions are simple one or two-step operations and, thus, no operating examples are included.

3.2 OPERATION

3.2.1 Before operating the 5001, it is strongly recommended that the operator read this entire section in order to avoid damage to the unit. After reading the operating instructions, refer to the Installation Section; then check the position of the line voltage selector through the viewing window on the rear panel.

CAUTION

This 5001 may be damaged if operated on a line voltage other than that specified on the line voltage selector card P4 which can be seen through a rectangular opening on the rear panel.

WARNING

Removal of covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while the unit is connected to an AC power source.

3.2.2 After ensuring that the line voltage selector is in the proper position and, if removed, the cover on the 5001 replaced, connect the power cord to the AC outlet and depress the POWER switch to power-on the 5001. The 5001 will momentarily light all LEDs followed by the model number (5001) upon applying power.

3.3 FRONT AND REAR PANELS

3.3.1 Refer to Figure 3.1 which shows the 5001 front and rear panels, illustrating the panel designations, keyboard switches (called keys also) and locations for all controls, indicators, and connectors. The description for each is provided in Table 3.1.

3.3.2 The front panel switches execute all the 5001 functions and operating modes. The front panel itself provides five input signal connectors (color-coded banana plugs) and three interlocking function switches, excluding the mA and filter switches. The keyboard provides twelve range selection and software function keys with 6-LED status annunciators. The LED display generates six digits, decimal point, sign indicator and read-rate indicator.

3.3.3 The rear panel provides access to the power plug and voltage selection window.

3.4 BASIC MEASUREMENTS

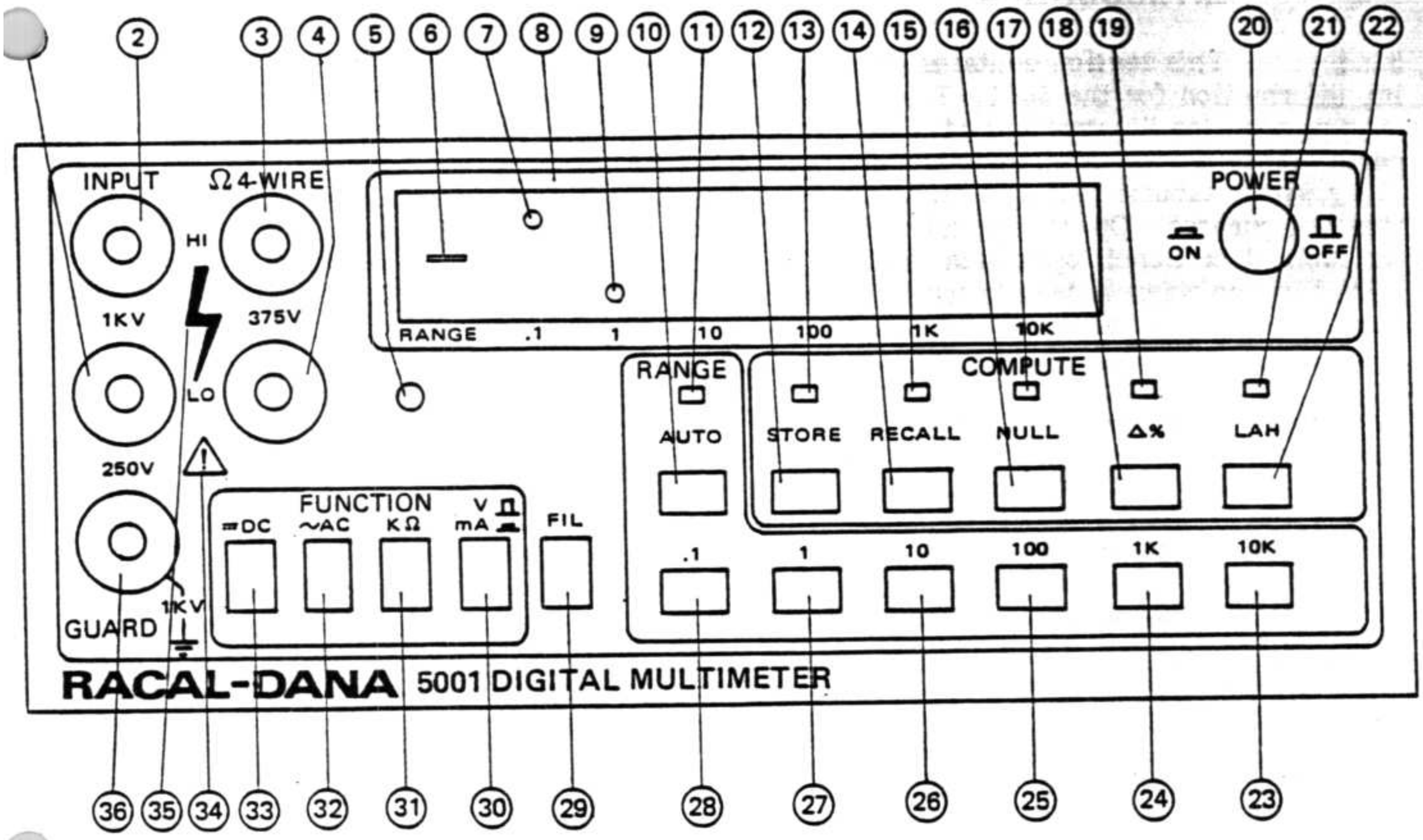
3.4.1 Zero Correction

3.4.1.1 The Null function eliminates potentiometer zeroing, offsets, lead resistance in resistance measurements, and cancels out thermal EMFs in low level DC measurements.

3.4.1.2 These procedures should be performed at power-on and from time to time, if the user requires high accuracy in the .1 VDC or .1 kΩ range. By performing these procedures, the 5001 will meet published specifications in these two ranges. The zero correction procedures for DC and Ohms are described in paragraphs 3.4.3.6 and 3.4.6.2, respectively.

3.4.2 Power-On

3.4.2.1 Upon initialization, the 5001 goes to its home state: autorange and continuous readings. With the VDC



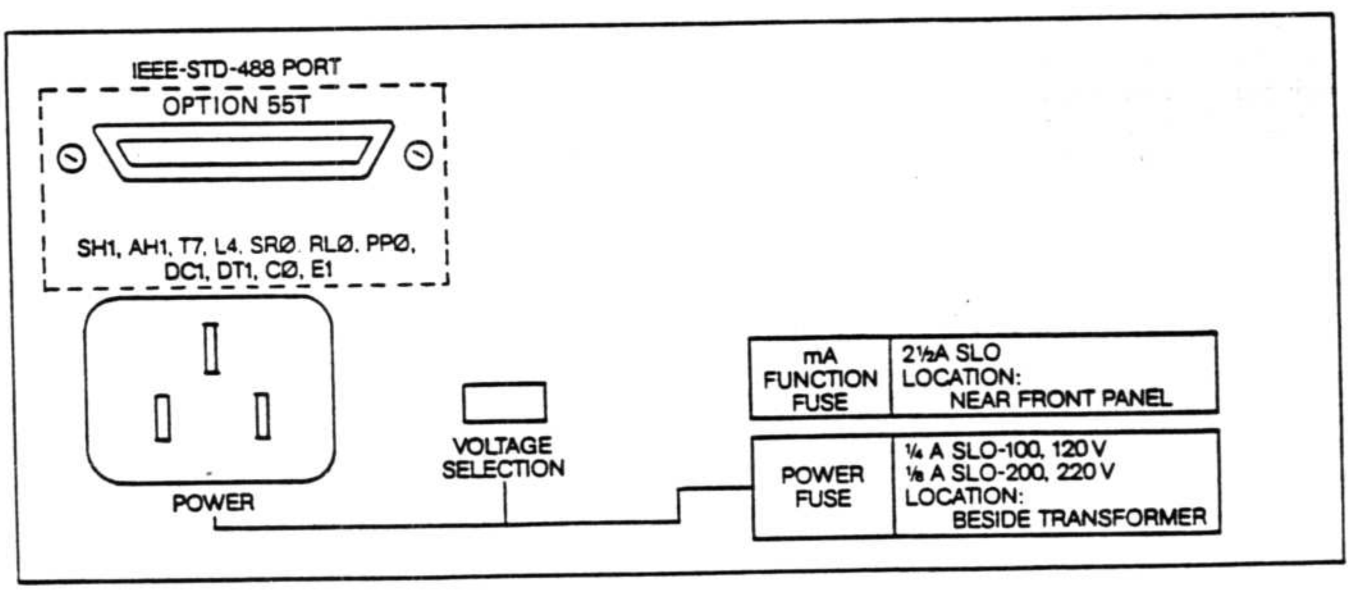


Figure 3.1 – 5001 Front and Rear Panels

Table 3.1 – Description of 5001 Controls, Connectors and LEDs

REFERENCE	DESIGNATOR/LABEL		DESCRIPTION
1	INPUT Lo	Banana Connector	- Signal Input (J101) connector.
2	INPUT High	Banana Connector	+ Signal Input (J103) connector.
3	Ω(4-WIRE) High	Banana Connector	High-Potential Ohms-Sense (J104) connector for 4-WIRE measurements.
4	Ω(4-WIRE) Lo	Banana Connector	Low-Potential Ohms Sense (J102) connector for 4-WIRE measurements.
5	○	Calibration Port	This accesses the CAL switch which is held depressed while entering software calibration constants into non-volatile memory. Refer to calibration instructions in Subsection 5.3.
6	LED —	Polarity Indicator	This LED illuminates the negative sign when the display reading is negative.
7	LED ○	Read-Rate Indicator	This LED illuminates when the 5001 takes a reading.
8	Display LEDs	7-Segment Red LEDs	These LEDs display the value of the input signal with the appropriate decimal point.
9	LEDs ○	Decimal Red LEDs	Automatic Decimal Point. The position indicates which range is selected except when STORE, RECALL, NULL, Δ% or LAH are in effect.
10	AUTO ▭	AUTO RANGE Toggle Key	This key enables the automatic ranging mode. If AUTO ranging has been previously selected, depressing this key or any range key will return the 5001 to manual range control. If STORE is enabled, this key manually positions the decimal point. Refer to paragraph 3.4.8.3(B) for details.

Table 3.1 - Description of 5001 Controls, Connectors and LEDs (Continued)

REFERENCE	DESIGNATOR/LABEL		DESCRIPTION
11	LED ▭	AUTO RANGE Annunciator	If illuminated, this LED advises that AUTO RANGE is enabled.
12	STORE ▭	STORE Enable Toggle Key	A push-push toggle that enables and disables the STORE mode. When enabled, readings or numerical constants can be stored using the procedure in paragraph 3.4.8.
13	LED ▭	STORE Annunciator	If illuminated, this LED advises that the STORE function is enabled. Refer to paragraph 3.4.8.3(B) for details.
14	RECALL ▭	RECALL Enable Toggle Key	A push-push toggle that enables and disables the RECALL mode. While enabled, constants associated with NULL,△% and LAH can be recalled to the display. Refer to paragraph 3.4.8.4 for details.
15	LED ▭	RECALL Annunciator	If illuminated, this LED advises that the RECALL function is enabled. Refer to paragraph 3.4.8.4 for details.
16	NULL ▭	NULL Function Selection Key	Selects Null function. When selected, the Null constant is subtracted from all future readings until the Null function is disabled by depressing the Null key again. The Null constant can be either the measurement value at the time NULL is selected or a value entered via the keyboard.
17	LED ▭	NULL Annunciator	If illuminated, this LED advises that the Null function is enabled.
18	△% ▭	Percent Function Selector Key	Calculate and displays: $\frac{\text{Reading}-(\text{Percent Constant})}{\text{Percent Constant}} \times 100$ which is the percentage deviation of the input reading from a reference value called "Percent Constant" (a stored reading or constant entered via keyboard). Refer to paragraph 3.4.10 for details.

Table 3.1 - Description of 5001 Controls, Connectors and LEDs (Continued)

REFERENCE	DESIGNATOR/LABEL		DESCRIPTION
19	LED ▭	Percent Annunciator	If illuminated, this LED advises that the Percent function is enabled.
20	POWER ○	AC POWER Selector Switch	A 2-position switch whose shaft position (extended or retracted) indicates the ON-OFF position.
21	LED ▭	LAH Annunciator	If illuminated, this LED advises that the LAH function is enabled.
22	LAH ▭	LOW-AVERAGE-HIGH Function Selector Key	Selects the function that compares the present reading with previously determined Low (most negative) or High (most positive) readings. Stores the present reading in place of one of these if it is found to be lower or higher. Also calculates and stores the average value of a selected number of readings. The Low, Average, High or number of readings averaged can be selected for continuous display or recalled from memory and displayed. The number of readings to be averaged can be entered prior to selection of LAH operation, and this number can be recalled from memory and displayed. Refer to Subsection 3.4.11 for details.
23	10 K ▭	10 K Range Selector Key	Selects the manual (AUTO RANGE LED off) 10 kΩ resistance range for kΩ readings up to 99 MΩ. In STORE mode, this key performs the numerical entries.
24	1 K ▭	1 K Range Selector Key	Selects the manual (AUTO RANGE LED off) 1 K range mode for DC, AC, kΩ and mA functions. In STORE mode, this key performs the numerical entries.
25	100 ▭	100 Range Selector Key	Selects the manual (AUTO RANGE LED off) 100 range mode for DC, AC, kΩ and mA functions. In STORE mode, this key performs the numerical entries.

Table 3.1 - Description of 5001 Controls, Connectors and LEDs (Continued)

REFERENCE	DESIGNATOR/LABEL		DESCRIPTION
26	10	10 Range Selector Key	Selects the manual (AUTO RANGE LED off) 10 range mode for DC, AC, kΩ and mA functions. In STORE mode, this key performs the numerical entries.
27	1	1 Range Selector Key	Selects the manual (AUTO RANGE LED off) 1 range mode for DC, AC, kΩ and mA functions. In STORE mode, this key performs the numerical entries.
28	.1	.1 Range Selector Key	Selects the manual (AUTO RANGE LED off) 0.1 range mode for DC and K Ohms functions. In STORE mode, this key performs the numerical entries.
29	FIL	FILter Selector Switch	It is a 2-position push-button switch. When depressed, the single-pole analog filter and/or the µP's digital routine is activated.
30	mA	Milliampere	The mA function is selected when switch mA is depressed to the ON position, and the AC or DC function switch (as required) is also depressed.
31	KΩ	Resistance Measurement Selector Switch	The Resistance Measurement Function is selected if the kΩ switch is depressed to the ON position.
32	~AC	AC Voltage Selector Switch	The AC Voltage switch serves two functions: a) Configures the 5001's switching circuitry to process AC voltage signals. b) Enables AC-mA readings if the mA switch is also depressed.

Table 3.1 - Description of 5001 Controls, Connectors and LEDs (Continued)

REFERENCE	DESIGNATOR/LABEL		DESCRIPTION
33	⎓ DC	DC Voltage Selector Switch	The DC Voltage switch serves two functions: a) Configures the 5001 switching circuitry to process DC voltage signals. b) Enables DC-mA readings if the mA switch is also depressed.
34	⚠	Caution Symbol	Refer to the manual for complete instructions. This is a precaution to protect the 5001 against damage.
35	ϟ	High Voltage Symbol	High voltage signals may be applied to the 5001's front panel. Alerts user to a possible shock hazard.
36	GUARD	Banana Connector	Banana connector that connects J100 on the front panel to the internal guard shield.
Rear Panel	POWER	AC Receptacle On Rear Panel	This 2-wire and ground AC receptacle accepts Racal-Dana cord P/N 600200 and European standard cord P/N 600858.
AC Transformer Section	AC LINE Fuse	Mounted Inside Transformer Shield	Clip-mounted SLO-BLO fuse: a) 100-120 Volts AC, use 0.25 A rating. b) 220-240 Volts, AC, use 0.125 A rating. Refer to 5001 Installation in Section Two, Subsection 2.8 for replacement instructions.
Rear Panel	PORT	Line Voltage Selection Window	The AC primary voltage selected by P4 voltage card can be viewed through this port.

switch selected, and a signal applied to the INPUT HI-LO terminals, AUTO RANGE will set the range to match whatever signal the 5001 sees at the input terminals. For example, if a 6-volt battery is connected to the input terminals and the 5001 is initialized by power turn-on, the 5001 will select the 10 V range automatically.

3.4.2.2 To manually disable autorange, depress the AUTO key or one of the range keys. This action extinguishes the autorange annunciator and the 5001 will now respond to the selected range.

3.4.3 DC Volts Measurements

3.4.3.1 The basic instrument is capable of measuring DC volts in 5 ranges; 0.1 V, 1 V, 10 V, 100 V, and 1000 V. To measure DC voltage proceed as follows.

3.4.3.2 Complete the 5001 power-on procedure described in Subsection 3.2.2.

3.4.3.3 Select the DC function by pressing the — DC switch.

3.4.3.4 Connect the DC voltage to the INPUT HI-LO terminals, refer to Figures 3.2 and 3.3.

3.4.3.5 For the top four ranges, merely observe the displayed digits, polarity sign and decimal point locations.

3.4.3.6 For the .1 V range, zero must be set with the Null function to obtain rated accuracy. Zeroing is necessary to compensate for thermal EMFs generated by the connections to the circuit to be measured. These voltages may be only a few microvolts or several tens of microvolts. Set zero as follows:

a) Select the .1 VDC range.

b) Short the test leads at the point of measurement.

c) If NULL LED is lit, depress the NULL key to disable the Null function.

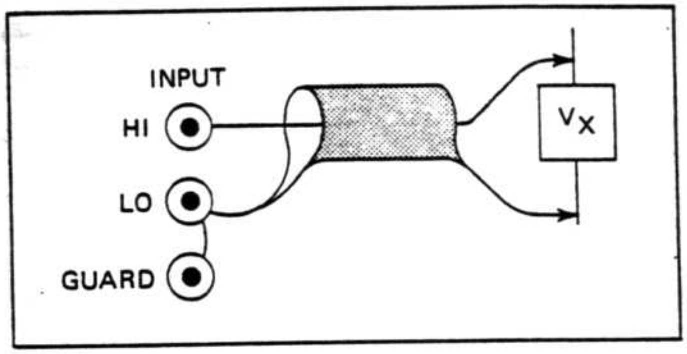


Figure 3.2 - DC, AC Measurement Connections Using Coaxial Cable

d) Depress the NULL key.

e) The displayed reading will be .000000 V ± .000001 V.

3.4.4 AC Volts Measurements

3.4.4.1 The 5001 is capable of measuring AC volts in four ranges: 1 V, 10 V, 100 V, 750 V. To measure AC voltage, proceed as follows:

a) Complete the 5001 turn-on procedure as described in Subsection 3.2.2.

b) Select the AC volts function by pressing the AC function switch.

c) Connect the AC voltage to the INPUT HI-LO terminals; refer to Figures 3.2 and 3.3 and read the value from the display, noting the decimal point.

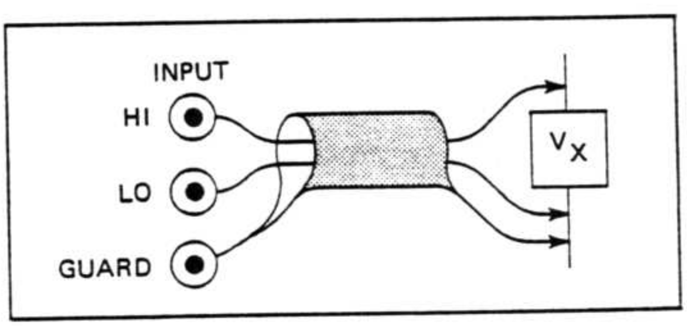


Figure 3.3 - DC, AC Measurement Connections Using 2-Conductor Shielded Cable

3.4.5 Milliampere Measurements

CAUTION

The current function is protected by a fuse of 250 V rating. To avoid damage to the 5001, current sources having open circuit voltages greater than 250 V (DC or RMS AC) must not be connected to the Input terminals if the mA function is selected.

3.4.5.1 The 5001 is capable of measuring DC or AC-mA in four ranges: 1, 10, 100 and 1000 mA.

3.4.5.2 To measure DC-mA, proceed as follows:

a) Complete the 5001 power-on procedure as described in Subsection 3.2.2; then check the zero accuracy of the instrument as described in Subsection 3.4.1.

b) Depress the DC volt switch and the mA switch as required.

c) Connect the mA source to be measured to the INPUT HI-LO terminals; refer to Figures 3.4 and 3.5 and read the value from the display.

3.4.5.3 To measure AC-mA, follow the instructions in paragraph 3.4.5.2, but change "b)" to read: "b). Depress the AC volt switch and mA switch as required."

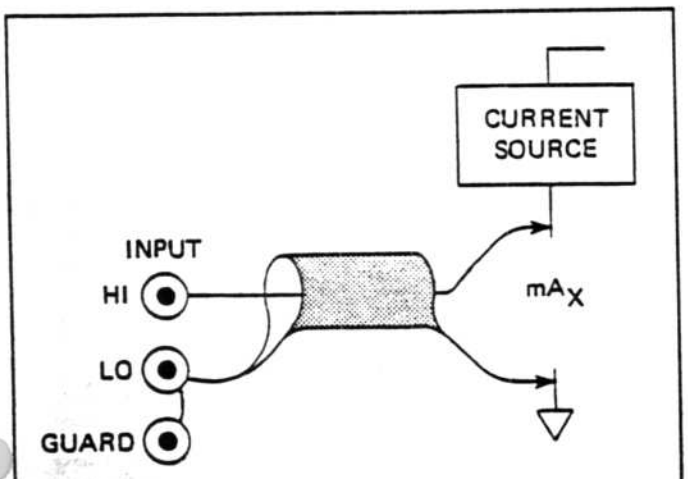


Figure 3.4 - mA Connection Using Coaxial Cable

3.4.6 Resistance Measurements kΩ

3.4.6.1 The 5001 is capable of measuring values in six ranges starting at 100 ohms full scale to 10,000,000 ohms (10 M ohms) full scale. The correlation between the front-panel keyboard and resistance selection is best described by the chart that compares range designators and resistance scales. In Table 3.2 when the kΩ function is selected, the range keys carry a scaled factor of 1000 or range key "1" equals 1,000 ohms full-scale.

Table 3.2 - Resistance Ranges

RANGE KEY KΩ	MAX. OUTPUTS*		4-WIRE MAXΩ**
	I (Shorted)	V (Open)	
.1***	-5 mA	-.5 V	7Ω
1	-5 mA	-5 V	22Ω
10	-500 µA	-5 V	70Ω
100	-50 µA	-5 V	220Ω
1 K	-5 µA	-5 V	700Ω
10K****	-.5 µA	-5 V	2200Ω

* HI binding post (white) is negative.

** Maximum resistance per lead for additional 1-digit error.

*** Zero must be set by NULL to obtain rated accuracy.

**** 10 K range provides 1000% overrange. Inputs up to 99 MΩ can be measured with a resolution of 4-1/2 digits above 22 MΩ.

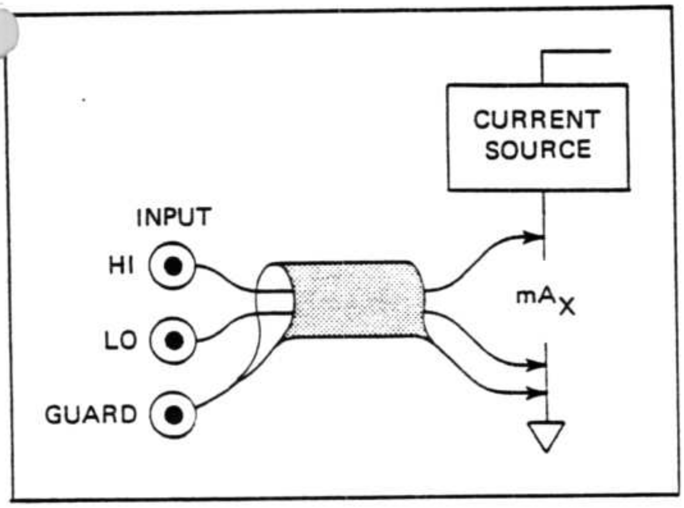


Figure 3.5 - mA Connections Using 2-Conductor Shielded Cable

3.4.6.2 The 5001 provides automatic 2-wire or 4-wire ohms operation (refer to Figures 3.6 and 3.7). This means that if the unknown resistance is connected only to the two INPUT terminals, the measurement will be in 2-wire. If an additional set of leads are used to connect the unknown resistance to the 4-wire terminals as well as INPUT terminals, the measurement will be made in a 4-wire configuration. For 4-wire measurements, rated accuracy (+ 1 digit) can be obtained on the top five ranges as long as the maximum lead resistances given in Table 3.2 are not exceeded. For 2-wire or 4-wire measurements on the .1 kΩ range, zero must be set by the Null function to obtain rated accuracy. Use the 5001 to measure resistance as follows:

CAUTION

MAXIMUM ALLOWABLE INPUT VOLTAGE (all ranges): 360 V peak, 250 V RMS. Do not exceed maximum voltage. Instrument damage may occur.

a) Power-on the 5001 and depress kΩ function switch.

b) Connect the circuit to be measured to the INPUT terminals (2-wire) and select AUTO RANGE or the desired range from the six ranges available. The decimal point is positioned automatically.

c) For a 4-wire measurement, connect the sense leads to the circuit to be measured and to the Ω4-wire terminals on the 5001. This arrangement eliminates the error due to the voltage drop across the INPUT leads.

d) The NULL push button should be out (LED off) unless measurements will be made as deviations from a preset value.

e) For the top five ranges of 2-wire or 4-wire measurements, merely observe the displayed digits and decimal point to make the measurement.

f) For a 2-wire or a 4-wire measurement on the .1 range, zero must be set with the Null function to obtain the rated accuracy. Zeroing is necessary to compensate for test lead resistance on 2-wire and thermal EMFs on 2 or 4-wire setups. Set zero as follows:

1. Disconnect the test leads at the circuit to be measured, and short at the point of measurement.

2. Depress NULL push-button.

3. Reconnect the test leads and make the measurement.

g) Diode Test. The 1 kΩ range is recommended for diode testing. On this range the forward on-resistance of a silicon diode will read approximately 190Ω. (INPUT HI terminal is negative).

3.4.6.3 Two-wire measurements are connected as shown in Figures 3.6A and

3.6B using a Teflon-shielded cable as shown. As you perform polarity-sensitive resistance measurements, (semiconductor junctions) note the polarity of the voltage across 4-wire terminals, (upper terminal is negative with respect to the lower terminal).

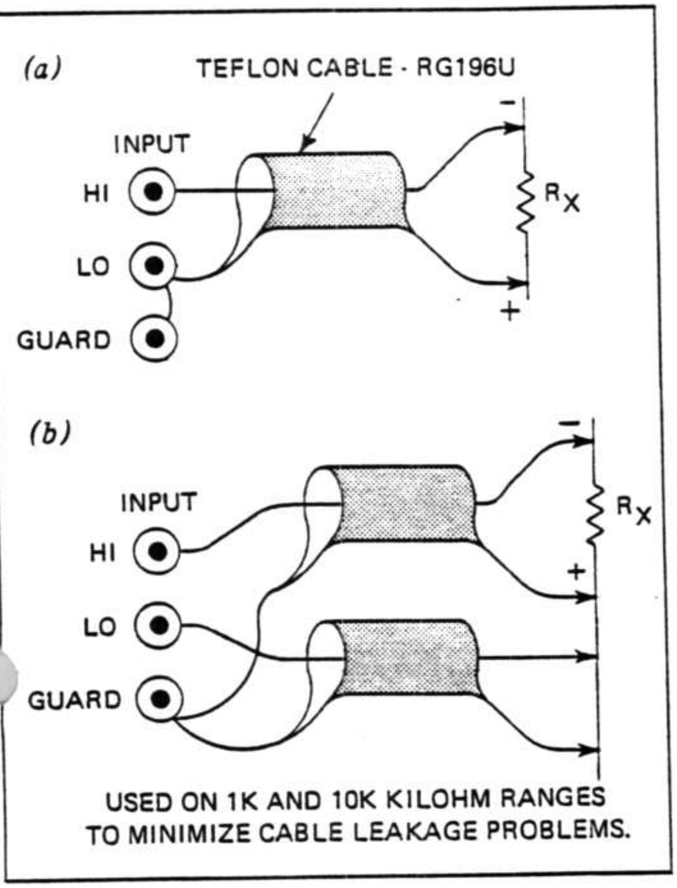


Figure 3.6 - 2-Wire Ohms Measurement

3.4.6.4 When measuring resistances in the above 100 kΩ, cable leakage may cause measurement errors if the connections of Figure 3.6A are used. The amount of inaccuracy will depend on the cable insulation and environmental conditions, (e.g., high relative humidity, etc.). For this reason, Teflon insulation is recommended to minimize cable leakage. If Teflon cable is not used, then the 2-wire cable wiring diagram in Figure 3.6B is recommended.

3.4.6.5 A 4-wire measurement system is used in most systems applications, particularly where the device to be measured is at a remote location requiring interconnection by cables from several feet to hundreds of feet in length. When measuring low resistance values over long cables, most resistance problems can be resolved by the use of the 4-wire measurement configuration.

3.4.6.6 The 4-wire resistance measurement diagrams are shown in Figures 3.7A and 3.7B. If Teflon-insulated coaxial cable is used, accurate measurements can be made on all ranges and under severe environmental conditions. Figure 3.7B shows the recommended connections when using 2-conductor shielded cable. This wiring system eliminates most problems of cable leakage when high resistances are measured with relatively high leakage cables.

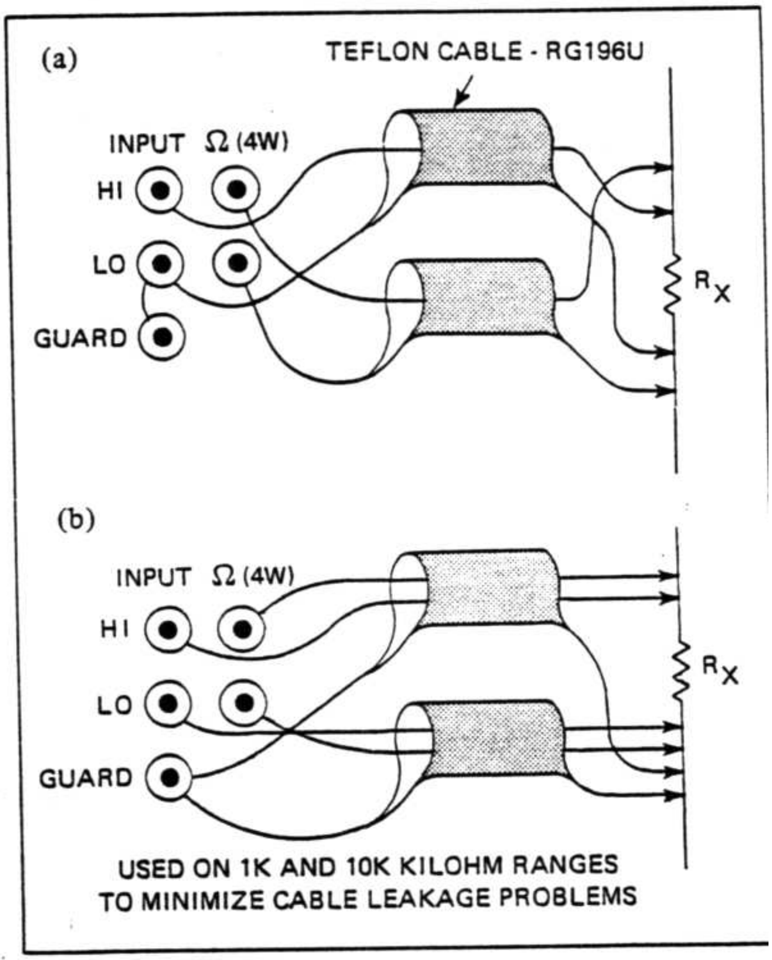


Figure 3.7 - 4-Wire Ohms Measurement

3.4.7 Software Capability

3.4.7.1 The software capability increases the versatility of the 5001. The software includes NULL, Δ%, LAH, STORE and RECALL. The software descriptions were presented in Section 3.3. Additional information for each feature continues in this subsection.

3.4.7.2 The 5001's software programs can be operated either separately or in various combinations. For instance, the Δ% and LAH function can be used together to determine the average and worst-case percentage variations. In general, when two or more software features are enabled, they will take place in the order shown in the flowchart, Figure 3.8.

3.4.7.3 Keyboard operation which makes use of the STORE or RECALL keys causes the 5001 to stop taking readings, and instead, respond only to the keyboard input. When finished with keyboard operations, the operator can return to the flowchart sequence by noting whether the STORE or RECALL LED is illuminated and then press the key associated with the illuminated LED.

3.4.8 Store and Recall Procedures

3.4.8.1 The STORE key is used in conjunction with other keys to store readings and numerical constants. Refer to Table 3.3 for the chart of STORE operations.

3.4.8.2 The procedure for storing display readings is as follows:

a) If presently in the STORE or RECALL mode, depress either key as required to exit the mode so that readings will appear on the display.

b) Depress the STORE key. (STORE LED indicator is ON).

c) Depress the required software function key, (NULL, Δ%, or LAH), as shown in Table 3.3.

d) The STORE LED will automatically toggle to OFF and the 5001 will resume taking readings.

NOTE

If any software capability is enabled with the exception of Δ%, NULL, LAH, the number stored will not match the number displayed. The Software Capability Flowchart presented in Figure 3.8 can be used as an aid to understand this phenomenon because the flowchart indicates that the Input Buffer contains the unprocessed reading rather than the output of Δ% or LAH.

3.4.8.3 The following procedure should be used to store numerical constants:

a) Depress the STORE key, (STORE LED indicator is on). This shifts the range keys to numerical data entry keys.

b) Depress the AUTO or any range key once, to return the display to all zeros. Continue to depress the AUTO key and it manually positions the decimal point between digits. Each closure of the AUTO key will move the decimal point one digit to the right, down to the LSD, then cycles back to the MSD. If the AUTO key is held depressed, the decimal point will move between digits, from left to right and repeat until the AUTO key is released.

c) Continuing with the range keys: depressing the .1-range key sets the MSD. Holding the .1-range key depressed, the MSD will increment from 0 to 5 in a positive direction, return to zero, then decrement from 0 to 5 in a negative direction. This limits the maximum numerical entry to ±59, 999.9.

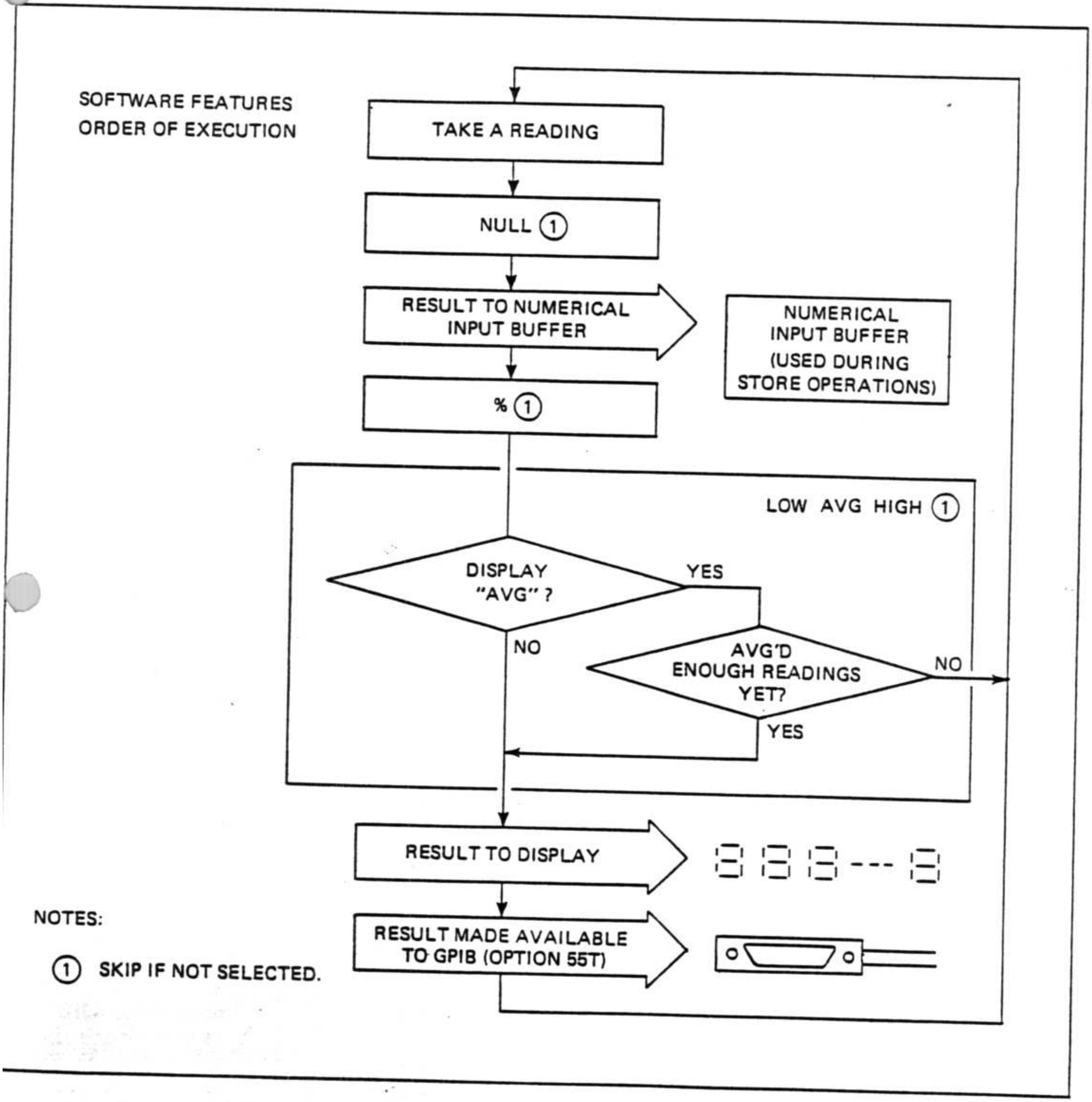


Figure 3.8 - 5001 Software Capability Feature Flowchart

Table 3.3 – Store Key Operations for Storing Displayed Readings

Key Sequence	Storage Location	Power-On Value	Units	Notes
STORE □ NULL □	Null Constant	0.00	Volts, Milliamps or Kohms	Null Function should be enabled before the Null constant is stored.
STORE □ Δ% □	Percent Constant	0.00	Volts or Milliamps or Kohms	
STORE □ LAH □	LAH Average Cycle Count, C	4	Dimensionless	C, the LAH Average cycle constant should be between 1 and 10,000. If C=10,000, A and N will not periodically reset.

Table 3.4 – Recall Key Operations

Key Sequence	Recall Location	Power-On Value	Units	Notes
RECALL □ NULL □	Null Constant	0.00	Volts or Milliamps or Kohms	
RECALL □ Δ% □	Percent Constant	0.00	Volts or Milliamps or Kohms	
RECALL □ LAH □ L	Lowest Reading	Blank Display	Volts or Milliamps or Kohms	① ③
LAH □ A	Average Reading	Blank Display	Volts or Milliamps or Kohms	① ② ③
LAH □ H	Highest Reading	Blank Display	Volts or Milliamps or Kohms	① ③
LAH □ n	Number of Readings	0	Dimensionless	② ③
LAH □ C	Average Cycle Constant	4	Dimensionless	③

① A blank display indicates that no answer is presently available (answer is "the empty set");

② Automatically initialized every C readings.

③ The Recall Letter associated with each LAH location will remain on the display until the key is released.

d) The descending digits to LSD will respond to RANGE keys 1 through 10 K. When a RANGE key is depressed, the related digit will increment from zero to nine, then return to zero to repeat the cycle.

e) To enter 1.23456 as a numerical constant, execute the following sequence:

1. Depress STORE key (STORE LED on).

2. Depress .1-key to obtain a MSD of one.

3. Depress 1-key to obtain next descending digit-two.

4. Depress 10-key to obtain the next descending digit-three.

5. Depress 100-key to obtain the descending digit-four.

6. Depress 1 K-key to obtain the descending digit-five.

7. Depress 10 K-key to obtain the LSD digit-six.

8. Depress AUTO key to position the decimal point.

9. Depress the required software key (NULL, △%, or LAH) as shown in Table 3.3

3.4.8.4 The RECALL key is used in conjunction with other keys to examine data which is stored in the 5001's memory.

3.4.8.4.1 The procedure for recalling data is listed below:

a) Depress the RECALL key, this also illuminates the Recall LED.

b) Select the appropriate data location from Table 3.4, and press the appropriate key. Note that access to all LAH data is gained by pressing the RECALL key only once, followed by depressing the LAH key multiple times.

c) To exit the Recall mode, depress the RECALL key once again.

3.4.9 Null Function

3.4.9.1 The Null function calculates and displays the difference between each measurement value and a Null constant. When Null is enabled, the reading before LAH, and △%, is stored as a Null constant and subtracted from all future readings until changed or the Null function is disabled by depressing the NULL key again. The Null constant can be either the measurement value at the time Null functioning is enabled or a numerical value entered via the keyboard.

3.4.9.2 To subtract a constant entered via the keyboard from each reading, execute the following keystrokes:

a) Enable the Null function by depressing the NULL key as required.

b) Use the procedure in paragraph 3.4.8.3 to enter the Null constant.

3.4.9.3 The Null constant stored in memory can be recalled to the display anytime by entering the Recall mode and depressing NULL. The Null Function Applications are numerous but a few are listed as examples:

a) The measurement of line or load regulation of a DC power supply. The nominal DC output from the supply is subtracted from its output under modified line or load conditions and the deviation displayed directly.

b) Cancellation of lead resistance

in the measurement of low resistance values with a 2-wire connection to the unknown resistance.

c) Addition or subtraction of a constant from the measured value. Addition is accomplished by entering the Null constant with a minus sign.

3.4.10 Percent Function

3.4.10.1 The Percent Function calculates and displays the percentage deviations of each measurement from a reference value (Percent Constant). The deviation calculation formula is:

$$\text{PERCENT DEVIATION} = \frac{\text{Measurement Value} - \text{Percent Constant}}{\text{Percent Constant}} \text{X100}$$

The Percent Function is enabled or disabled by pressing the Percent △% key. The △% annunciator indicates if the function is enabled.

3.4.10.2 The Percent Constant can be either a measurement reading or a numerical value entered via the keyboard. The Percent entry procedure is identical to the instructions in paragraph 3.4.8.2 (storing display readings) and paragraph 3.4.8.3 (storing entered constants). Note that the "ERROR 0" message is displayed when enabling the percent function with a percent constant set to zero. The operator can check the percent constant in memory by recalling it to the display, following the instructions listed in Section 3.4.8.4.

3.4.10.3 Percent deviations too large to display will cause "OL" (overload) to be displayed instead.

3.4.11 Low-Average-High Function

3.4.11.1 The 5001 provides a Low-Average-High (LAH) measurement capability. When used in this mode, the instrument performs the following operations:

a) Stores the least positive (or most negative) value measured during LAH operation.

b) Stores the value of the most positive (or least negative) measurement made during LAH operation.

c) Calculates the average value of all measurements taken during the LAH average cycle.

d) Counts the number of measurements taken during the LAH cycle.

NOTE

Because the 5001 employs a digital nonrecursive filter to average measurements, the LAH function may not be useful for recording small instantaneous changes in the input that fall within the averaging band of the filter. Depending on the present function and range, the input is averaged within the digit band defined in Section Four.

3.4.11.2 [redacted] number entered will equal the number of readings the operator wants to average in each LAH average cycle up to a maximum of 10,000. If selected for display, a new average is displayed at the end of each LAH average cycle. However, the low and high values are derived from all readings taken since the LAH function was selected.

NOTE

The LAH function will update the minimum and maximum readings indefinitely, but will not update the average or the number of measurements readings beyond the first 10,000 examples.

3.4.11.3 The operator may select the lowest (most negative) measurement (L), average measurement (A), highest (most positive) measurement (H), number of measurements (n) or the present reading (r) to be displayed while the LAH function is selected. The desired display selection is described in the following procedure.

a) Depress and hold the LAH key. As long as the key is depressed, the display will repeat the sequence r, L, A, H, n, in the least significant digit location.

b) To display the most negative reading, release the LAH key while the "L" is displayed.

c) To display the average reading, release the LAH key while the "A" is displayed.

d) To display the most positive reading, release the LAH key while the "H" is displayed.

e) To display the number of measurements taken during each LAH Average cycle, release the LAH key while the "n" is displayed.

f) To display the present measurement reading, release the LAH key while the "r" is displayed.

3.4.11.4 The desired number of measurements to be averaged (C) during each LAH average cycle is programmed prior to entering the LAH function as follows:

a) Press the STORE Key, (LED indicator on).

b) Key in the number of measurements to be averaged. Refer to paragraph 3.4.8.3 for sequence.

c) Press the LAH key. The number of measurements constant (c) will remain in memory until it is changed or until power is removed from the instrument.

d) Select the desired display by following the procedure in the preceding paragraph. If the average reading is selected for display, the display will be updated each time the selected number of measurements is completed (e.g., every 58 measurements).

e) If the operator is not interested in using the averaging capabilities of the LAH function, the LAH average cycle constant need not be initialized.

3.4.11.5 The operator, when using the RECALL key, has access to the data stored during LAH operation. Press the RECALL key, then LAH and a letter will appear in the least significant digit location. Upon release of the LAH key, the letter will be replaced with the following corresponding data:

a) C: Number of readings averaged in LAH average cycle, operator entered as described in 3.4.8.4.

b) L: The least positive (most negative) reading that has occurred since the LAH function was selected.

c) A: The average computed over N readings (see N below).

d) H: The most positive (least negative) reading that has occurred since the LAH function was selected.

e) n: The number of readings taken during the present LAH average cycle.

NOTE

If the number of measurements to be averaged (C) is entered as zero, then the average will be taken over one reading (i.e., zero defaults to one). (C) will default to 10,000 if entered greater than 10,000. The "number of measurements" constant is initialized to four (C=4) at power-on.

3.4.12 Overload Indicator

3.4.12.1 The Overload (OL) indicator appears on the display if the 5001 measurement range is exceeded. If this occurs, the overload is indicated by two digits on the display, the least significant digit (LSD) and the next to LSD which exhibits the letters "OL". The remaining digits are blanked.

3.4.12.2 The OL indicator is activated by two separate conditions:

a) The input exceeds 215% ± 15% of full scale for all ranges except the 10 MΩ RANGE where overloads are 1000% of full scale.

b) With software functions selected, trying to display a number greater than ± 99999.9.

3.4.13 Error Messages

3.4.13.1 Error messages result from the 5001 self-test instructions which are designed into the program to alert the user that a malfunction or an operator error has occurred.

3.4.13.2 There are six error messages that will identify a specific problem for the user. This error message group excludes the power-on display messages of "all eights" LED lamp test followed by the model number (5001). If the model number fails to appear, an error message will follow.

3.4.13.3 The six messages are described and listed in Table 3.5.

Table 3.5 - 5001 Error Messages

DISPLAYED ERROR MESSAGE	DESCRIPTION
Error 0	Percent Constant (Reference Value): set to zero during percent calculations.
Error 2	The mA key and the kΩ key are depressed simultaneously.
Error 3	6802 RAM TEST failed (U10).
Error 4	Non-Vol Memory Checksum failed (U27).
Error 7	6810 RAM TEST failed (U9).
Error 8	An attempt to store an overload to a register inside the 5001.

4.1 INTRODUCTION

4.1.1 This section provides the circuit description for the Model 5001 Digital Multimeter. Information includes a brief description of general 5001 operation followed by separate coverage of individual circuit blocks. Simplified block diagrams, schematics, and tabulations are provided to facilitate the user's understanding of the operating theory. Detailed schematics for the 5001 are provided in Section 6 of this manual.

4.2 OVERALL 5001 OPERATION

4.2.1 Figure 4.1 provides a simplified block diagram of the 5001 showing the three major sections of the digital multimeter and their interconnections. Figure 4.2 shows a current 5001 motherboard assembly drawing numbered by functional subsections as listed in the legend.

4.2.2 The 5001 is a dedicated microcomputer (μC)-based digital multimeter which uses the processing capabilities of its microprocessor (μP) in conjunction with input keyboard and output control devices to perform user-selected measurements. Also, Option 55T is available for use with the 5001, permitting it to be interfaced within instrument systems. Refer to Racal-Dana Publication No. 980568 for details on this option.

4.2.3 Model 5001 digital control centers around U10, a 6802 μP, which executes the program stored in ROMs U3 and U4, reads data from various locations in the unit and, finally, stores data to RAM and various hardware locations in the instrument. The μP executes the ROM program based on this data, performs calculations, and makes logic decisions to control and time all 5001 functions described in Section 3 of this manual.

4.2.4 Software instructions executed by the 5001's μP establish the settings for the (1) function, (2) range, (3) filter, (4) CAL (ibration) sequence and (5) digitizer clock and hardware control of the digital multimeter.

4.2.5 Digital operation of the 5001 is organized around the function of the digitizer. The digitizer is designed to handle input measurement signals in a range of -2 to +2 VDC. The 5001's μC provides the required switching of four important signals input to the digitizer at different times (termed time-division multiplexing). These four signals are designated VSIG, CAL 1, CAL 2, and CAL 3. VSIG is the output voltage generated by the analog signal conditioning circuitry. CAL 1, CAL 2, and CAL 3 are the ground (zero), +2V reference, and ohms reference voltages, respectively. Proper μC-controlled switching of these four signals involves both their correct timing and sequencing prior to isolator and digitizer application.

4.2.6 Timing in the 5001 includes a precise 100 μSec integration period for the charge balance (CB) phase of digitization; up to 1 μSec for single-slope (SS) conversion; and the required delays. These delays allow an input measurement signal to "settle" along with permitting the uP to perform the necessary arithmetic calculations and "housekeeping" tasks.

4.2.7 Function and range for the 5001 are controlled by front-panel keyboard inputs. These input signals are sent to the μC which, in turn, routes the proper data pattern to the control shift-registers for the selected function and range. These registers then enable the proper FET and relay switching circuits for the selected function and range.

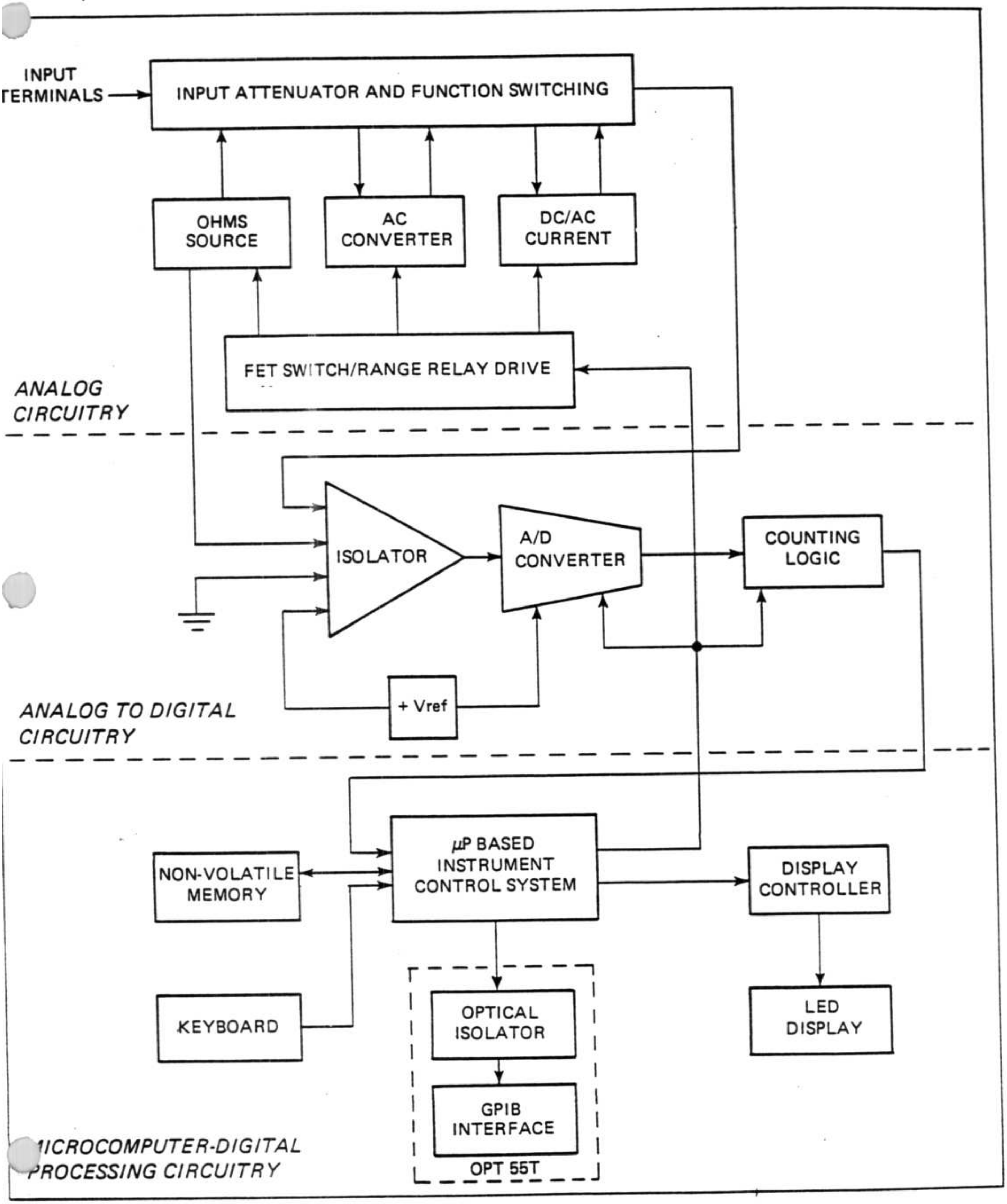
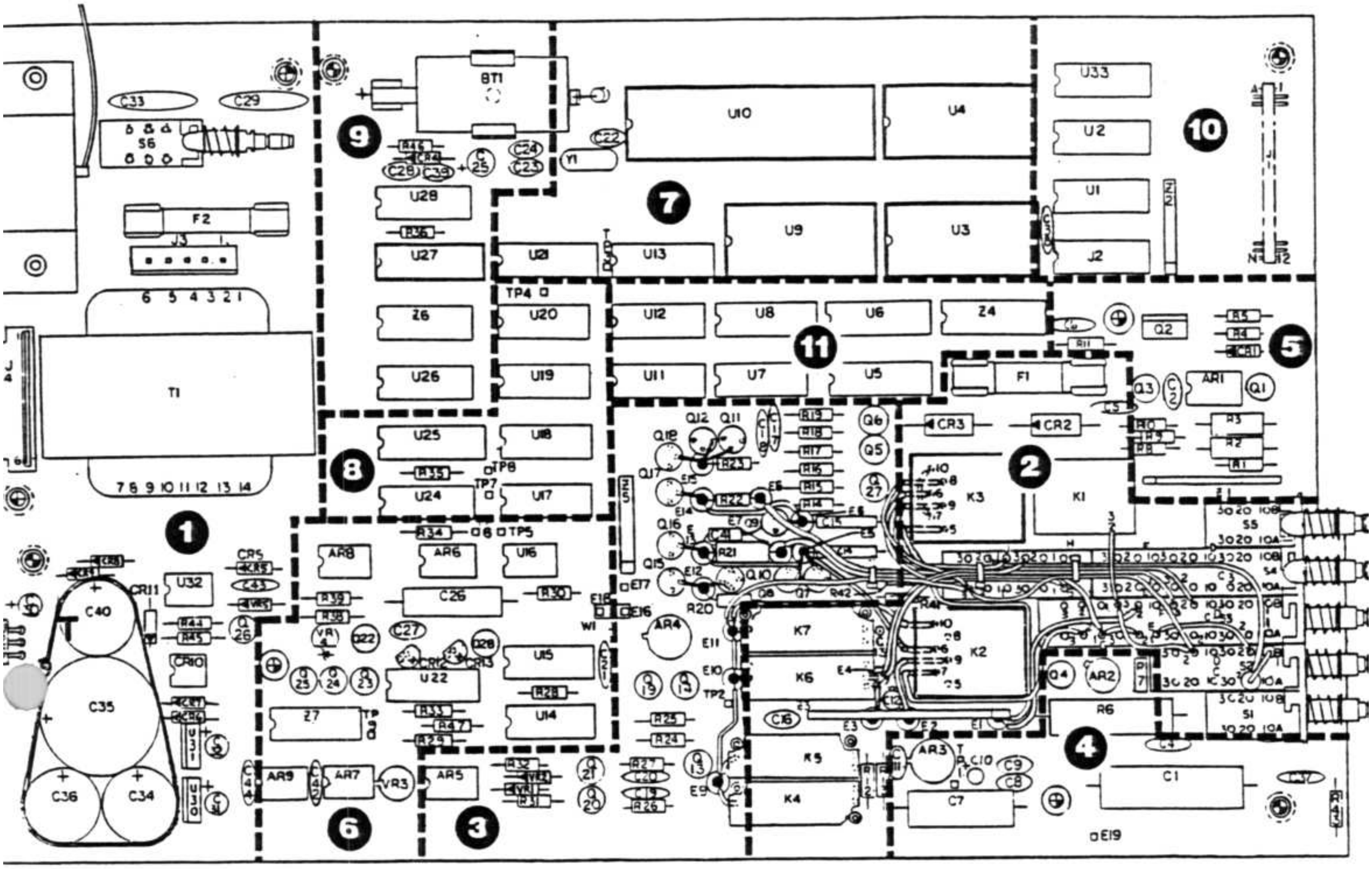


Figure 4.1 - 5001 Block Diagram



LEGEND - 5001 PCB Assy. Section

1. POWER SUPPLY
2. FUNCTION and RANGE SWITCHING
3. ISOLATOR
4. AC CONVERTER
5. OHMS VOLTAGE SOURCE
6. DIGITIZER
7. MICROPROCESSOR and MEMORY
8. CLOCK CIRCUITRY
9. NON-VOLATILE MEMORY
10. DISPLAY and KEYBOARD DRIVE
11. RELAY and FET SWITCH DRIVE

Figure 4.2 - 5001 Sectionalized PCB Assembly

4.2.8 The 5001's isolator functions as a buffer circuit providing both high input and low output resistances. Therefore, it minimizes loading from the FET and relay switching circuits, and also produces an isolator output signal that is linear. To ensure a high degree of linearity and common mode rejection, a bootstrap amplifier is incorporated into the isolator's circuitry.

4.2.9 The isolator receives the required input function signals (VSIG and the calibration signals) from their four respective FET switching circuits. VSIG, CAL 1 and CAL 2 voltages are required for all measurement functions except ohms when CAL 3, the ohms reference voltage, is also needed.

4.2.10 Automatic elimination of zero (ground) and gain errors from the input measurement signal requires digitization of not only VSIG, but also the calibration input signals required for the selected function. Under µC control, all function signals needed for final measurement and display are applied serially to the digitizer for conversion. The digitizer uses a combination of charge balance (CB) and single-slope (SS) cycles to perform digitization of each input signal. During the CB cycle, the digitizer generates a series of current pulses which are precisely balanced to the integrator's analog input. These pulses are counted for a fixed period, the final count representing the CB component of the digitized value. The µC then executes a SS measurement cycle to resolve the residual signal in the digitizer after the CB cycle.

4.2.11 After conversion, each digitized value of VSIG and the required calibration signals is stored. The uC then combines these stored values arithmetically to compute the digital reading for the input measurement signal, sending the calculated measurement reading for display. For a detailed description of the equations used by the µC for each selected function, refer to their corresponding Subsections 4.4.2 to 4.4.6.

4.3 POWER SUPPLIES

4.3.1 The 5001 is designed to operate from a wide range of AC line voltages and frequencies with 120 VAC and 60 Hz considered standard. The transformer design incorporates selectable, multi-tapped, dual primary windings to accommodate line voltages of 100, 120, 220 and 240 VAC ±10%, 47 to 450 Hz. The center-tapped, dual secondary windings generate low VDC supplies to power the main circuitry sections of the 5001.

4.3.2 The designations for voltage levels and grounds shown on the power supply schematic, page 6-15, are used on all schematics, providing reliable assistance for 5001 troubleshooting.

4.4 5001 FUNCTIONAL DESCRIPTION

4.4.1 Signal Conditioning

4.4.1.1 Since the 5001 is a DC multimeter, signal conditioning for all functions except DC Volts is completed by circuitry sections designed to convert AC Volts or resistance values to a DC signal. A DC signal is required for input to the isolator which, in turn, scales the analog signal before applying it to the digitizer.

4.4.1.2 Refer to Figure 4.3 showing the 5001's analog signal conditioning circuitry. Observe that three of the 5001's five measurement functions (DC Volts, AC Volts and Ohms) use a common decade resistor divider and relay network to generate the correct range for each selected function. A +7 reference voltage (+7V REF in Fig. 4.3) provides the +2 volts and +0.2 volts for DC, AC and mA functions. A -7 reference voltage (-7V REF in Fig. 4.3) provides both -4 volts and -0.4 volts for the ohms source.

4.4.1.3 The five measurement functions of the 5001 are described in the following subsections (4.4.2 to 4.4.6). Each description is prefaced by (1) a sim-

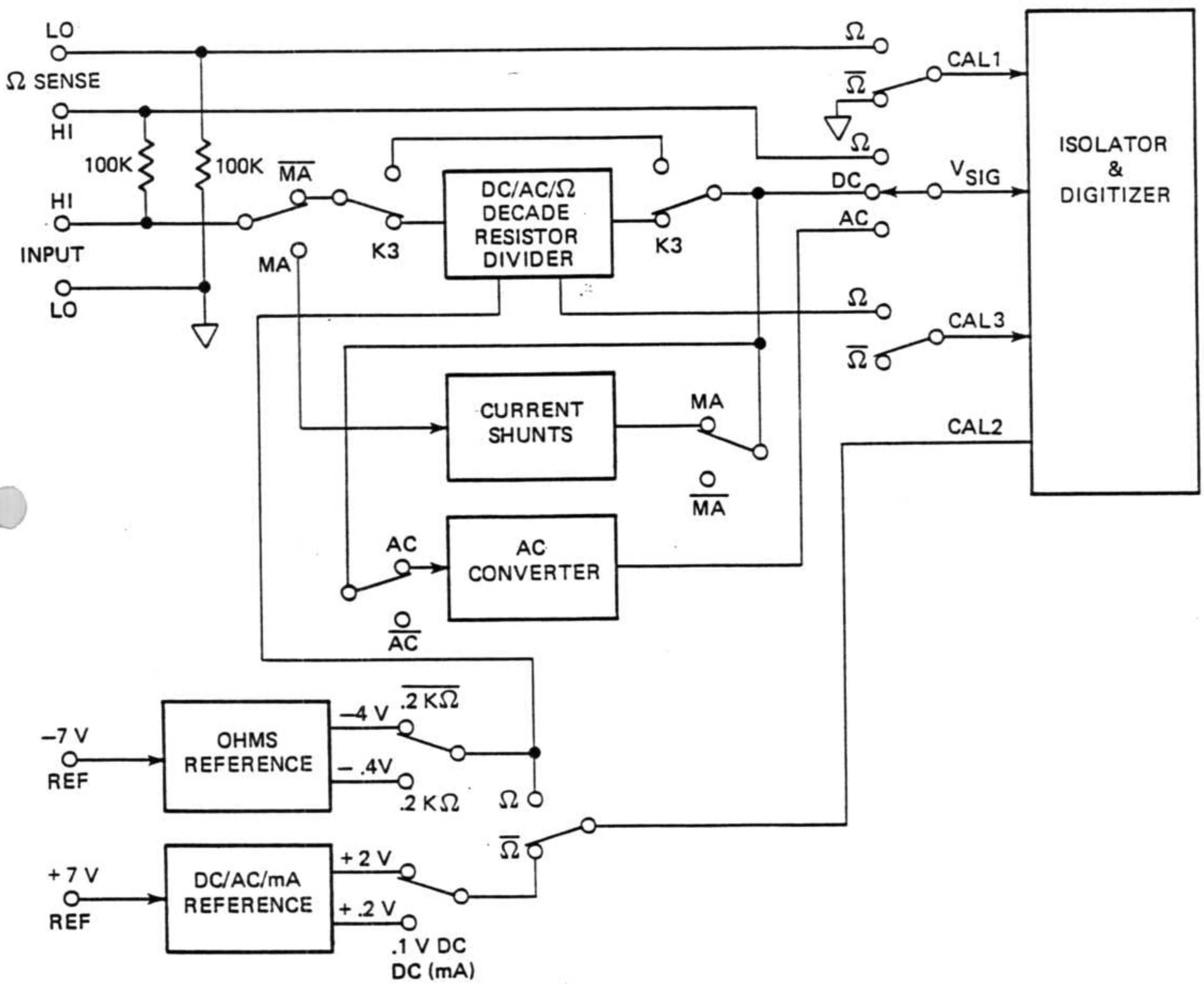


Figure 4.3 - 5001 Analog Signal Conditioning Block Diagram

plified signal path diagram using the corresponding schematic and (2) a corresponding front-end diagram. Also, note that the 5001's analog section is situated within the guard area of the main PCB assembly. This section includes subsections 2, 4, and 5 of the assembly as shown in Figure 4.2.

4.4.2 DC Volts Function

4.4.2.1 DC signal conditioning is performed by the input attenuator and function switching circuitry. Signal conditioning for DC Volts measurement includes the following functions:

a) Attenuating the input measurement signal in the 10, 100 and 1000 VDC ranges to two volts maximum for isolator application.

b) Filtering the analog signal to reduce unwanted noise.

c) Isolating (buffering) the voltage source to minimize loading effects on it.

4.4.2.2 Refer to Figure 4.4 which shows a simplified VDC input signal path with schematic and Figure 4.5 which provides a VDC front-end diagram. When the DC Volts function is selected, the signal applied to the HI and LO INPUT terminals is routed through Switch MA-G to relay K3.

4.4.2.3 If either the 0.1 or 1 VDC range is selected, relay K3 is energized. The measurement signal is then routed through K3 as VSIG, the conditioned analog signal output to the isolator. If the 10, 100, or 1K VDC range is selected, K3 remains deenergized. In this situation, the input measurement signal is routed through the decade resistor divider Z3. Here one of the relays is energized according to input voltage range as follows: relays K2, K6 and K7 divide the input voltage by 10:1, 100:1 and 1000:1, respectively. This decade division attenuates the input measurement signal prior to isolator application.

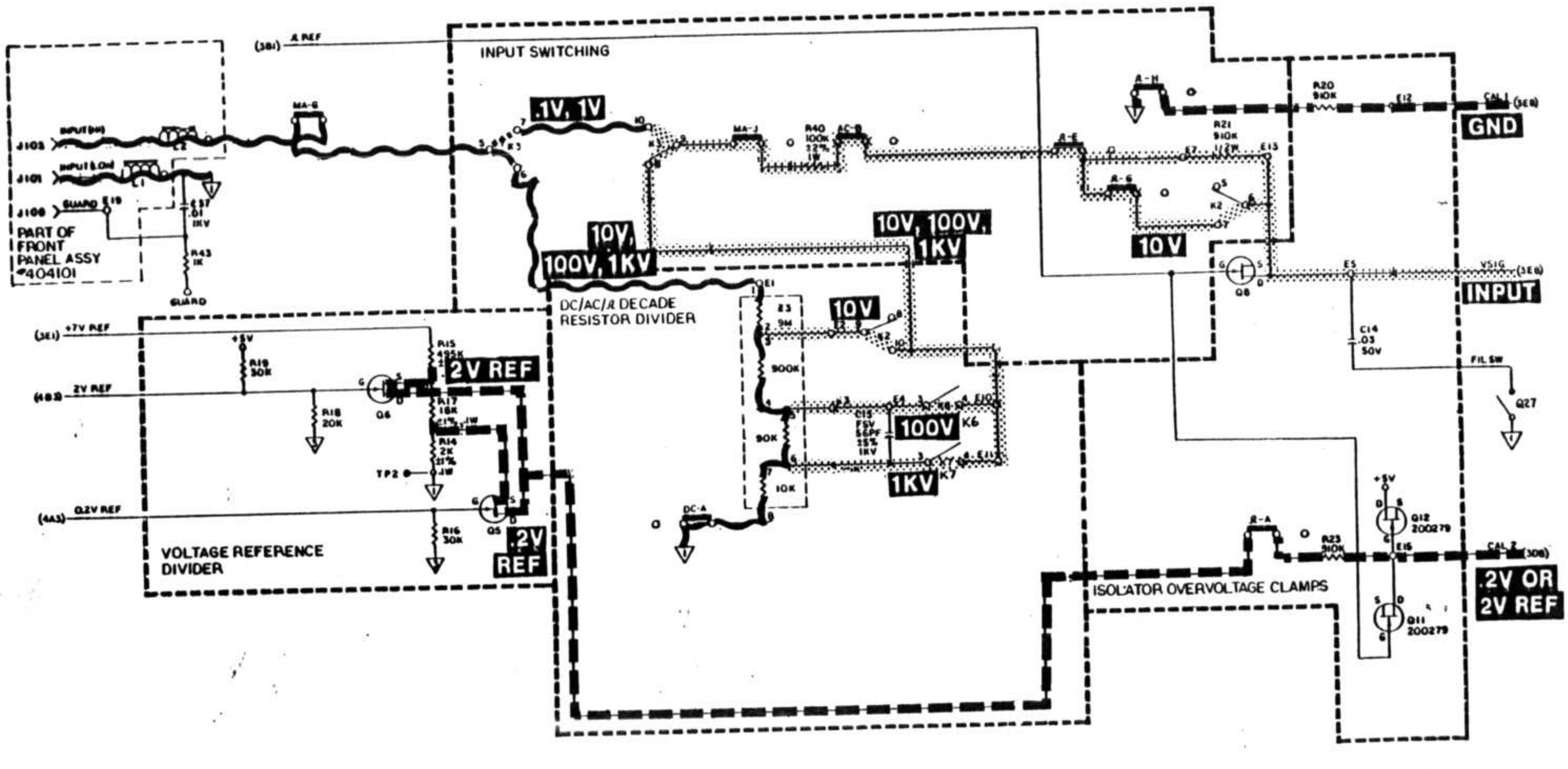
NOTE

The user is referred to Subsections 4.4.8.1 and 4.4.8.4 as required where the isolator input and gain switching are described. This reference applies to all five measurement functions as described in Section 4.

4.4.2.4 For the DC Volts measurement, VSIG along with CAL 1 and CAL 2 function signals are necessary. The three signals are buffered by the isolator after input attenuation and range switching and before digitization and storage. Upon storage, the measurement reading for display is computed by the µP using the following equation:

$$V_{OUT} = \frac{2\,(VSIG - CAL\ 1)}{CAL\ 2 - CAL\ 1}$$

4.4.2.5 CAL 1 is the ground (zero) reference. CAL 2, the +2V reference, is derived from the +7 reference voltage located in the digitizer section in conjunction with resistors R14, R15 and R17 in the voltage reference divider section. CAL 2 also provides the +2 VDC level required by the isolator. The two voltages (+2 and +.2 VDC) are determined by FET switches Q5 and Q6, set by the selected measurement range. If the 0.1 voltage range is selected, CAL 2 is switched to +0.2 VDC by FET switch Q5. If, however, the 1, 10, 100 or 1K voltage range is chosen, CAL 2 is switched to +2 VDC by FET switch Q6. Both Q5 and Q6 functions are under µP control.



FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	ISO X10	.2V REF	2V REF	Z3 ATTENUATION
DC	.1			▨						▨	▨		
	1			▨					▨			▨	
	10		▨						▨			▨	÷10
	100						▨		▨			▨	÷100
	1K							▨	▨			▨	÷1000

▨ ENERGIZED

Figure 4.4 - 5001 VDC Input Path with Schematic

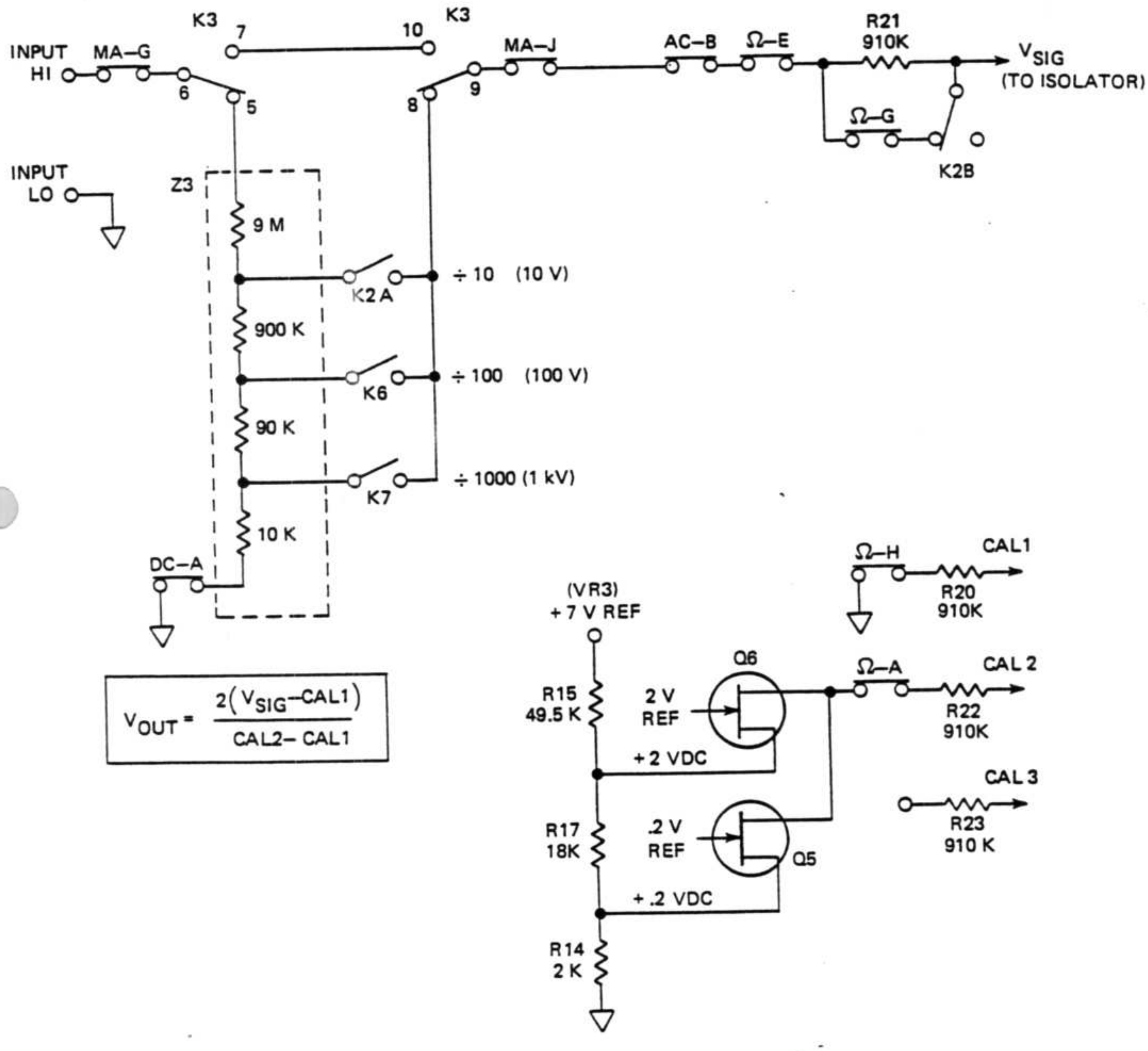


Figure 4.5 - 5001 VDC Front-End Diagram

4.4.3 AC Volts Function

4.4.3.1 AC signal conditioning is performed by the AC scaling amplifier AR2, the RMS converter, and an output filter network. Signal conditioning for AC Volts measurement includes the following operations:

a) Buffering and scaling the input measurement signal in the 1, 10, 100 and 750 VAC ranges to two volts full-scale AC for application to the RMS converter.

b) Generating two volts full-scale DC in the true RMS AC converter whose output then is applied to the isolator input.

c) Filtering the converted signal to reduce unwanted noise.

d) Isolating (buffering) the voltage source to minimize loading effects on it.

4.4.3.2 Refer to Figure 4.6 which shows a simplified VAC input signal path with schematic and Figure 4.7 which provides a VAC front-end diagram. When the AC Volts function is selected, the input measurement signal applied to the HI and LO INPUT terminals is routed through switches MA-J and AC-A to C1, the DC blocking capacitor. The measurement signal then is applied to the input of AR2, the AC scaling amplifier. AR2 delivers two volts AC full scale, for all ranges, to the RMS converter which produces a two-volt DC full-scale output. This DC output from AR2 is routed to the isolator input as VSIG through switches AC-B and Ω-E.

4.4.3.3 A feedback network for the AC scaling amplifier AR2 is provided through relay switching of the decade resistor divider. This divider is connected across pins 2 and 6 of AR2 forming the amplifier's feedback path.

4.4.3.3.1 The one volt range is activated with the closure of relay K2; the ten volt range by relay K6; the 100 volt range by relay K7; and the 750 volt range by K5. Protection of AR2 from input surge and overload is provided by R6, the input resistor for the scaling amplifier.

4.4.3.4 The RMS converter is driven by AR2's output in conjunction with DC blocking capacitor C10. The converter generates a true root-mean-square (TRMS) level of a complex AC signal, in which the equivalent VDC output equals: $\sqrt{\text{Ave.}\,(V_{I/P})^2}$

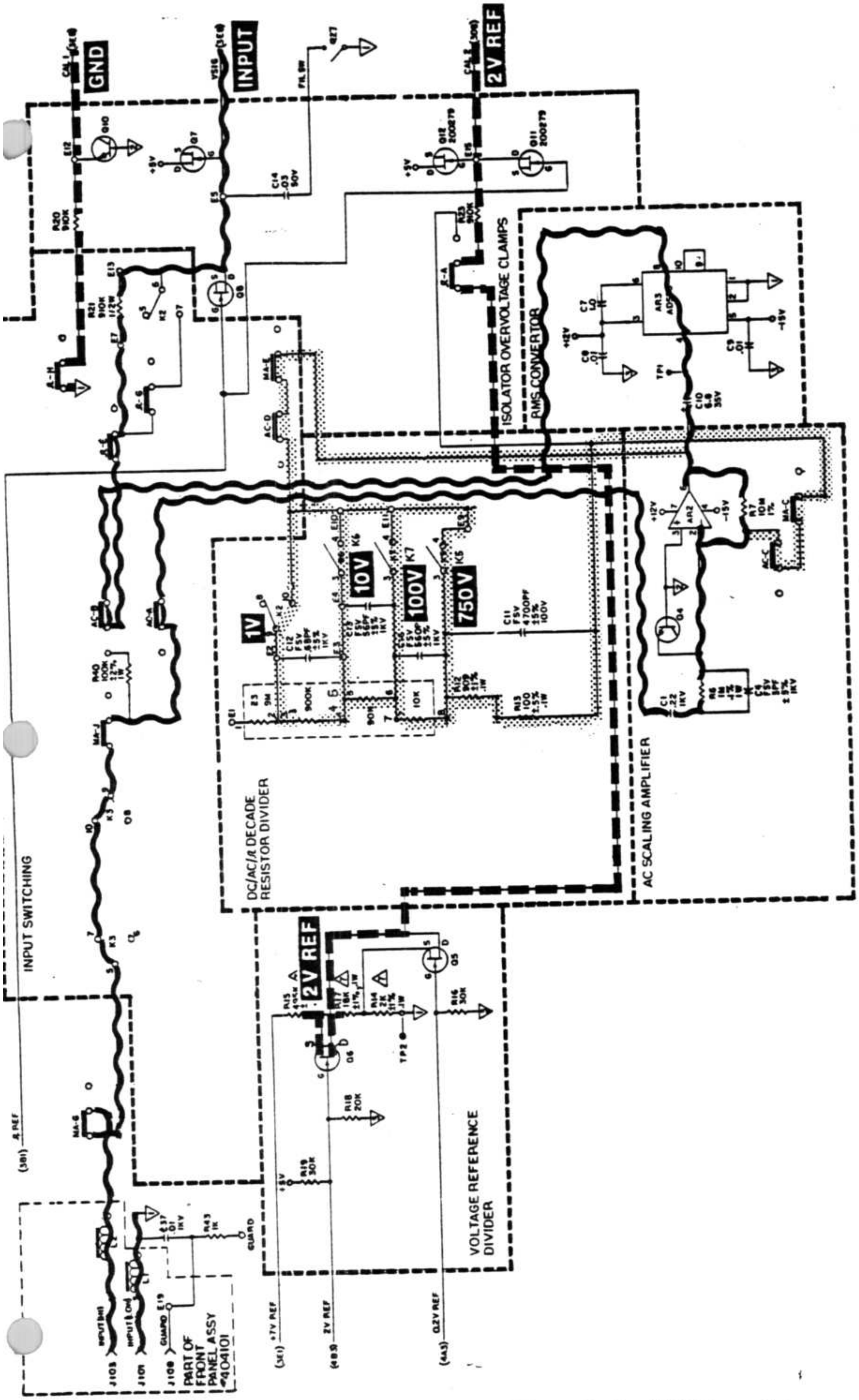
4.4.3.5 The isolator establishes its effective VDC input using VSIG (TRMS signal voltage), CAL 1 and CAL 2. After buffering by the isolator, these three signals are digitized and stored. Upon storage, the measurement reading for display is computed by the μC using the same formula as that for DC Volts:

$$V_{OUT} = \frac{2\,(VSIG - CAL1)}{CAL\,2 - CAL\,1}$$

4.4.4 DC - mA Function

4.4.4.1 DC - mA current measurement by the 5001 is achieved by routing the input measurement signal through a precision decade current-shunt and measuring the voltage developed across the resistor. The voltages for the four DC-mA ranges (1, 10, 100 and 1000 mA) are produced by the current flow through decade resistor network Z1 and R1. For example, 1mA flowing through the 100Ω precision resistor will generate 100 mV. These four range voltages, under μP control, are processed through the isolator and digitizer, appearing on display in mA units.

4.4.4.2 Refer to Figure 4.8 which shows a simplified DC-mA input signal path with schematic and Figure 4.9 which provides a DC-mA front-end diagram. When the DC-mA function is selected, the input measurement signal applied to the HI and LO INPUT terminals is routed through switches MA-G and MA-I to the decade resistor/relay network of Z1, R1 and K1, K4, K6 and K7.



FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	2V REF	FEEDBACK RESISTANCE	ATTENUATION
AC	1		■	■					■	■	1 MΩ	÷1
	10		■*	■			■		■	■	101 KΩ	÷10
	100		■*	■				■	■	■	11 KΩ	÷100
	1K		■*	■		■			■	■	1 KΩ	÷1000

■ ENERGIZED

*ONLY WITH FILTER OUT

Figure 4.6 – 5001 VAC Input Path with Schematic

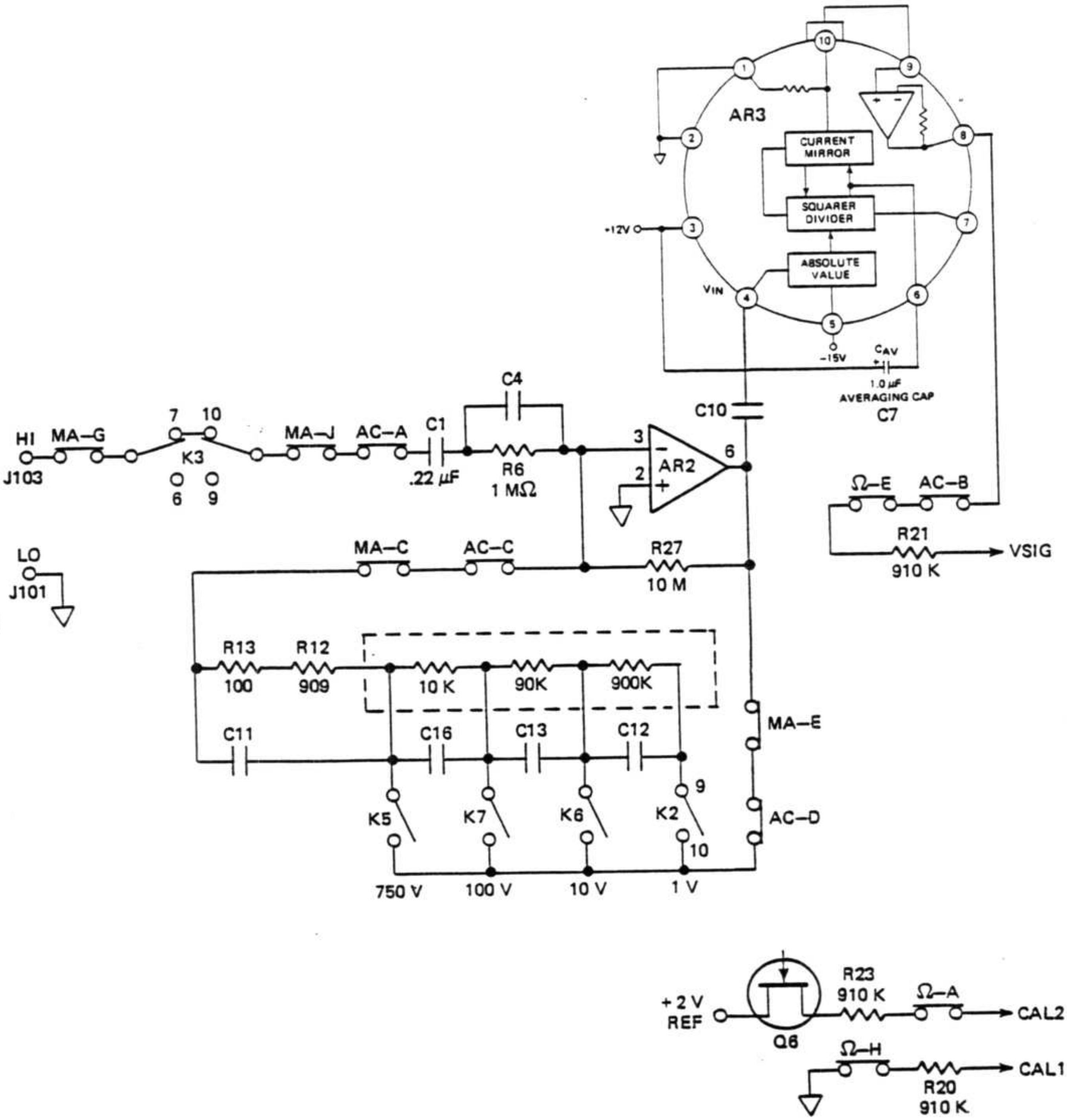
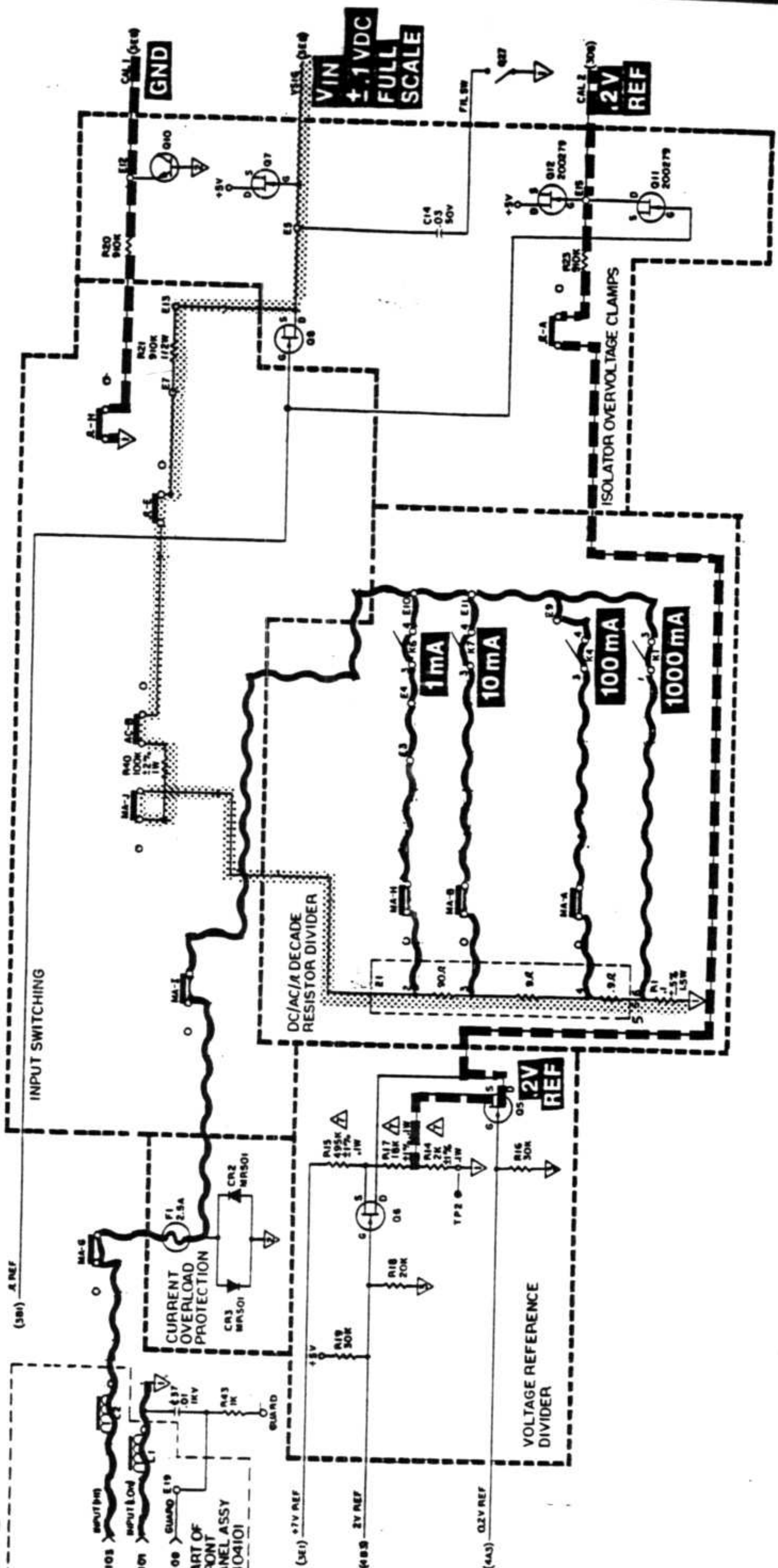


Figure 4.7 - 5001 VAC Front-End Diagram



FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	ISO X10	.2V REF	2V REF	CURRENT SHUNT
DC MA	1						■			■	■		100Ω
	10							■		■	■		10Ω
	100				■					■	■		1Ω
	1K	■								■	■		.1Ω

■ ENERGIZED

Figure 4.8 - 5001 DC-mA Input Path with Schematic

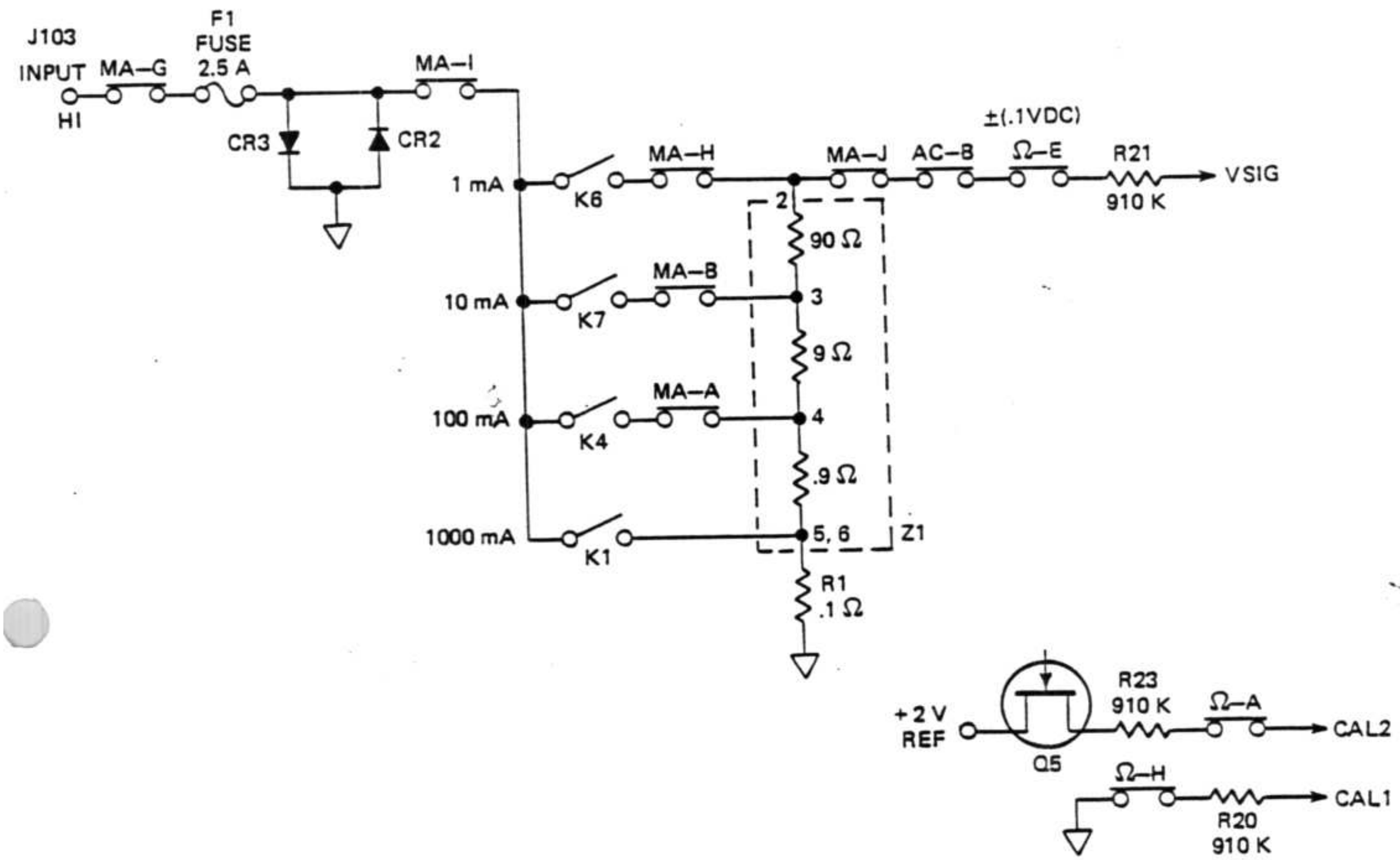


Figure 4.9 - 5001 DC-mA Front-End Diagram

Table 4.1 - DC-mA Range Relay Chart

RANGE	RELAY CLOSURE	DECADE RESISTORS	VSIG
1 mA	K6	(90)+(9)+(0.9)+(0.1) = 100Ω	.1V
10 mA	K7	(9)+(0.9)+(0.1) = 10Ω	.1V
100 mA	K4	(0.9)+(0.1) = 1Ω	.1V
1000 mA	K1	(0.1) = .1Ω	.1V

The decade resistors are connected to the network input by these four range relays as shown in Table 4.1.

4.4.4.3 The following switches are turned on by the µP when the 5001 is in the DC-mA function:

a) FET Q5, the +0.2V reference

b) FETs Q16 (VSIG), Q15 (CAL 1) and Q18 (CAL 2) for the isolator

c) FET Q19 (x10 gain switch) for the isolator

4.4.4.3.1 The full-scale DC-mA output of +0.1 VDC is applied to the isolator as VSIG along with CAL 1 and CAL 2 function signals. After buffering by the isolator, these three signals are digitized and stored. Upon storage, the measurement reading for display in mA units is computed again using the formula for DC Volts:

$$V_{OUT} = \frac{2\,(VSIG - CAL1)}{CAL\ 2 - CAL\ 1}$$

4.4.4.4 Fuse F1 and voltage clamps CR2 and CR3 provide current overload protection for the DC-mA input circuitry. This fuse limits the input current to 2.5A; the diodes CR2 and CR3 clamp at $\pm$0.6 VDC.

4.4.5 AC-mA Function

4.4.5.1 Two primary circuits are used in AC-mA current measurement by the 5001. First, the 5001's input attenuator and function switching circuitry routes the AC-mA measurement signal through the same switches and decade resistor/relay network used in the DC-mA function. This generates the 1, 10, 100 and 1000 mA ranges. Second, the .1 VAC maximum output developed across the decade resistor network Z1 + R1, is routed to the AC scaling amplifier AR2 and RMS converter (as in VAC conversion), then applied to the isolator as VSIG.

4.4.5.2 Refer to Figure 4.10 which shows a simplified AC-mA input signal path with schematic and Figure 4.11 which provides an AC-mA front-end diagram. When the AC-mA function is selected, the input measurement signal applied to the HI and LO INPUT terminals is routed through the same signal paths as those used in DC-mA measurement, up to switch AC-A. At this point, the AC-mA signal is routed to the AC scaling amplifier AR2. The AC scaling amplifier AR2 applies a X10 gain (R6 = 1MΩ, R7 = 10MΩ) before routing the scaled AC signal to the RMS converter. The AC converter generates a full-scale output of +1 VDC. This output is applied to the isolator as VSIG through switches AC-B and Ω-E. (Refer to paragraphs 4.4.3.2 to 4.4.3.4 for a description of scaling amplifier/RMS converter operation in AC Volts function.)

4.4.5.3 When the front-panel AC-mA function switches are depressed, the 5001's attenuation and switching circuitry is configured to route the mA measurement signal. This signal is processed through the same circuitry that conditions the DC-mA signal. The following

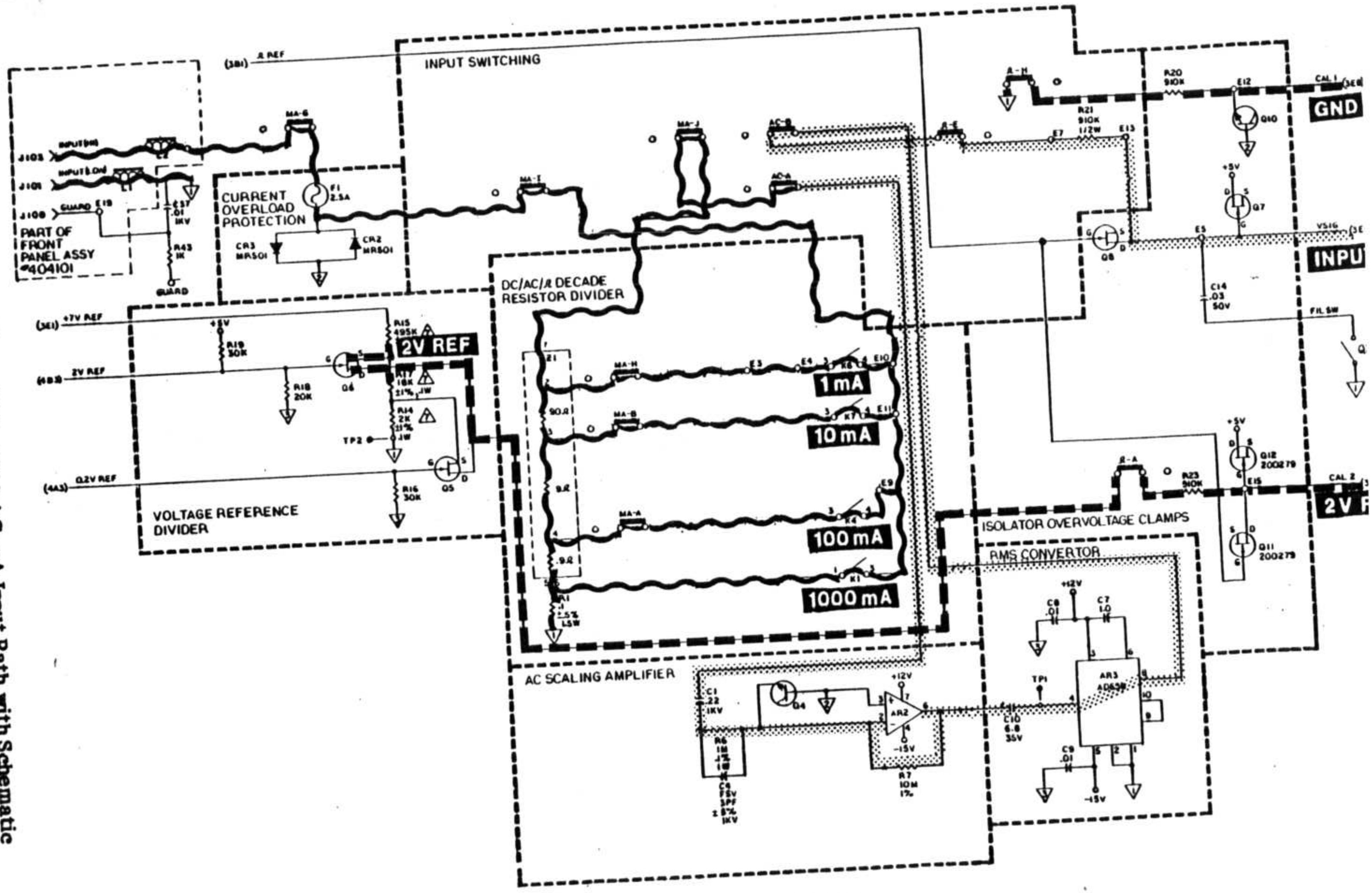


Figure 4.10 - 5001 AC-mA Input Path with Schematic

FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	ISO X10	.2V REF	2V REF	CURRENT SHUNT
AC MA	1						▨		▨			▨	100Ω
	10							▨	▨			▨	10Ω
	100				▨				▨			▨	1Ω
												▨	1Ω

▨ ENERGIZED

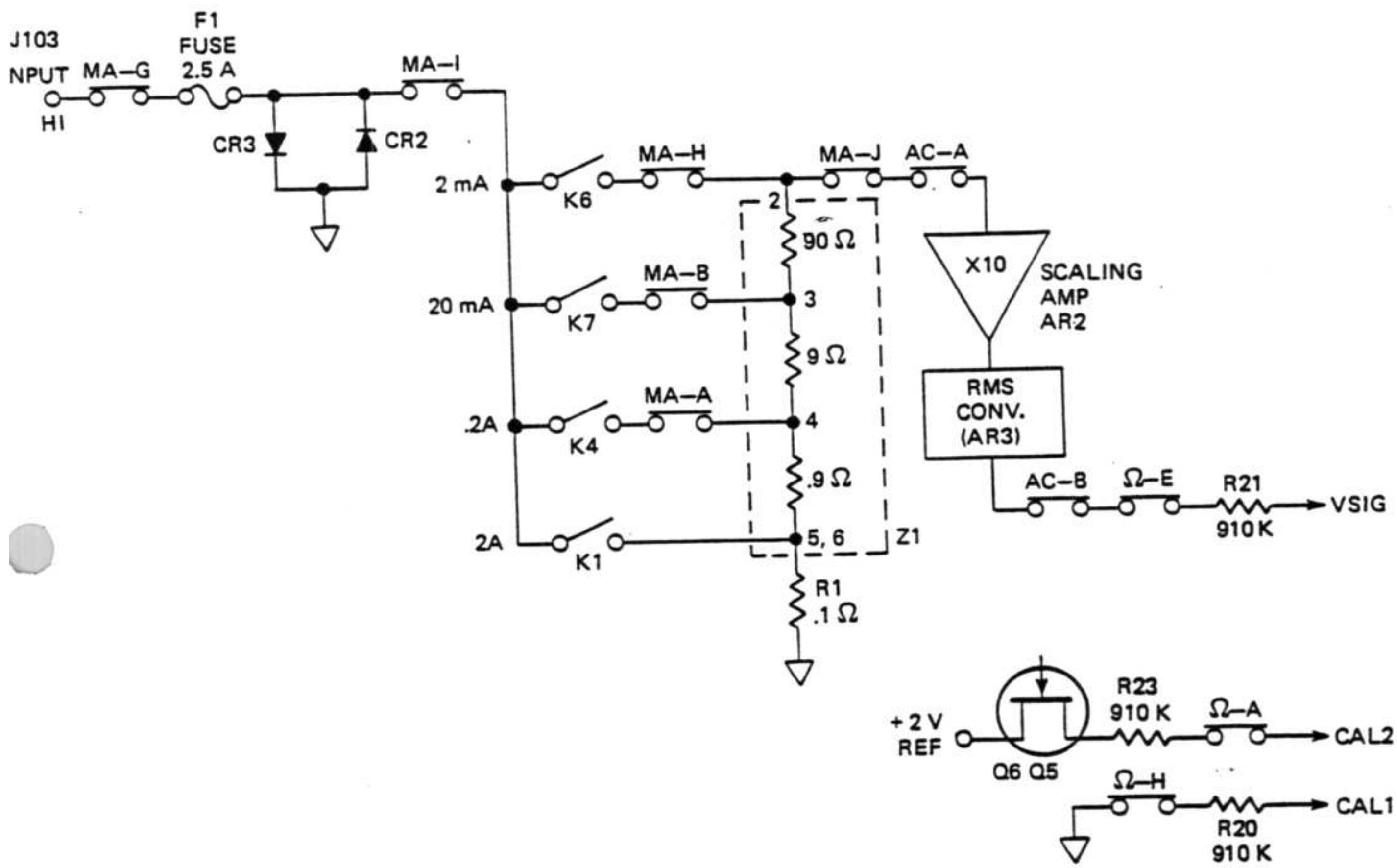


Figure 4.11 - 5001 AC-mA Front-End Diagram

switches are turned on by the µP when the 5001 is in the AC-mA function:

a) FET Q6, the +2 V reference switch

b) FETs Q16 (VSIG), Q15 (CAL 1), and Q18 (CAL 2) for the isolator

c) FET Q14 (x1 gain switch) for the isolator

4.4.5.3.1 The full-scale DC - mA output of +1 VDC is applied to the isolator as VSIG along with CAL 1 and CAL 2 function signals. After buffering by the isolator, these three signals are digitized and stored. Upon storage, the measurement reading for display in mA units is computed once again using the DC Volts formula shown below:

$$V_{OUT} = \frac{2\ (VSIG - CAL\ 1)}{CAL\ 2 - CAL\ 1}$$

4.4.5.4 Fuse 1 and voltage clamps CR2 and CR3 provide current overload protection for the AC-mA circuitry as in the DC-mA function (see paragraph 4.4.4.4).

4.4.6 Ohms Measurement Technic

4.4.6.1 As required during the following description, the user should refer to Figures 4.12, 4.13 and 4.14.

4.4.6.2 In the 5001, ohms measurement of an unknown resistor R_X is achieved by connecting an ohms voltage reference source (-4V or -.4V) between one end of a reference (fixed) decade resistor network (Z3) in series with R_X and the 5001's isolator/digitizer input circuitry. The voltage drop across each resistor is measured and the ohms ratio of the known to the unknown resistors computed and displayed in kΩ units under µP control.

NOTE

The resistors in the reference resistor network are the same ones used for DC Volts attenuation. Unlike the DC Volt function, when only resistance ratios affect the measurement accuracy, in Ohms function the absolute values of the decade resistors are used to determine the accuracy of ohms measurement.

4.4.6.3 Figure 4.12 shows two simplified diagrams for ohms measurement in the 5001: a) measurement for use in the .1 - 10 K range and b) measurement for use in the 100 K - 10 MEG ranges. In conjunction with these diagrams are the corresponding two expressions for determining R_X. For the meaning of VSIG, CAL 1, CAL 2 and CAL 3 function signals as noted in the diagrams, refer to paragraphs 4.4.6.4 and 4.4.6.5 as well as Figures 4.13 and 4.14 for greater detail.

4.4.6.4 For ohms measurement in the 5001, VSIG as well as CAL 1, CAL 2 and CAL 3 function signals require isolator/digitizer application. These four isolator inputs correspond to the following voltages:

a) **VSIG** - the INPUT HI voltage across R_X.

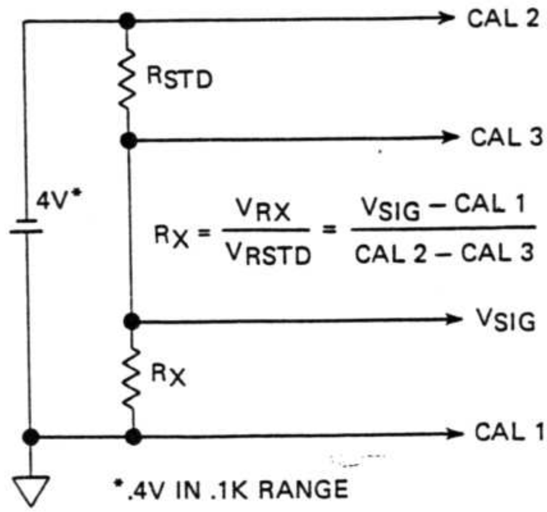
b) **CAL 1** - the INPUT LO voltage across R_X.

c) **CAL 2** - the -4V or -.4V reference voltage.

d) **CAL 3** - the low voltage across the known decade resistor network.

From Figures 4.12 and 4.13, VSIG and CAL 1 develop across unknown resistor R_X as well as the INPUT HI and LO terminals, respectively. VSIG is connected to INPUT HI (J103) through resistors R2 and R21. CAL 1 is connected to INPUT LO (J101) at analog common through resistors R1 and R20 as well as switch Ω-H. INPUT HI is also connected to one end of the decade resistor network at Z3p1 through switch MA-G and K3. CAL 3 is only used in the .1 K through

.1 – 10K RANGES (A)



100K – 10 MEG RANGES (B)

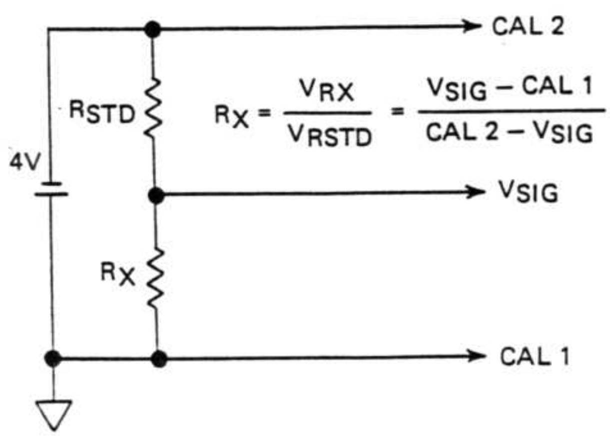
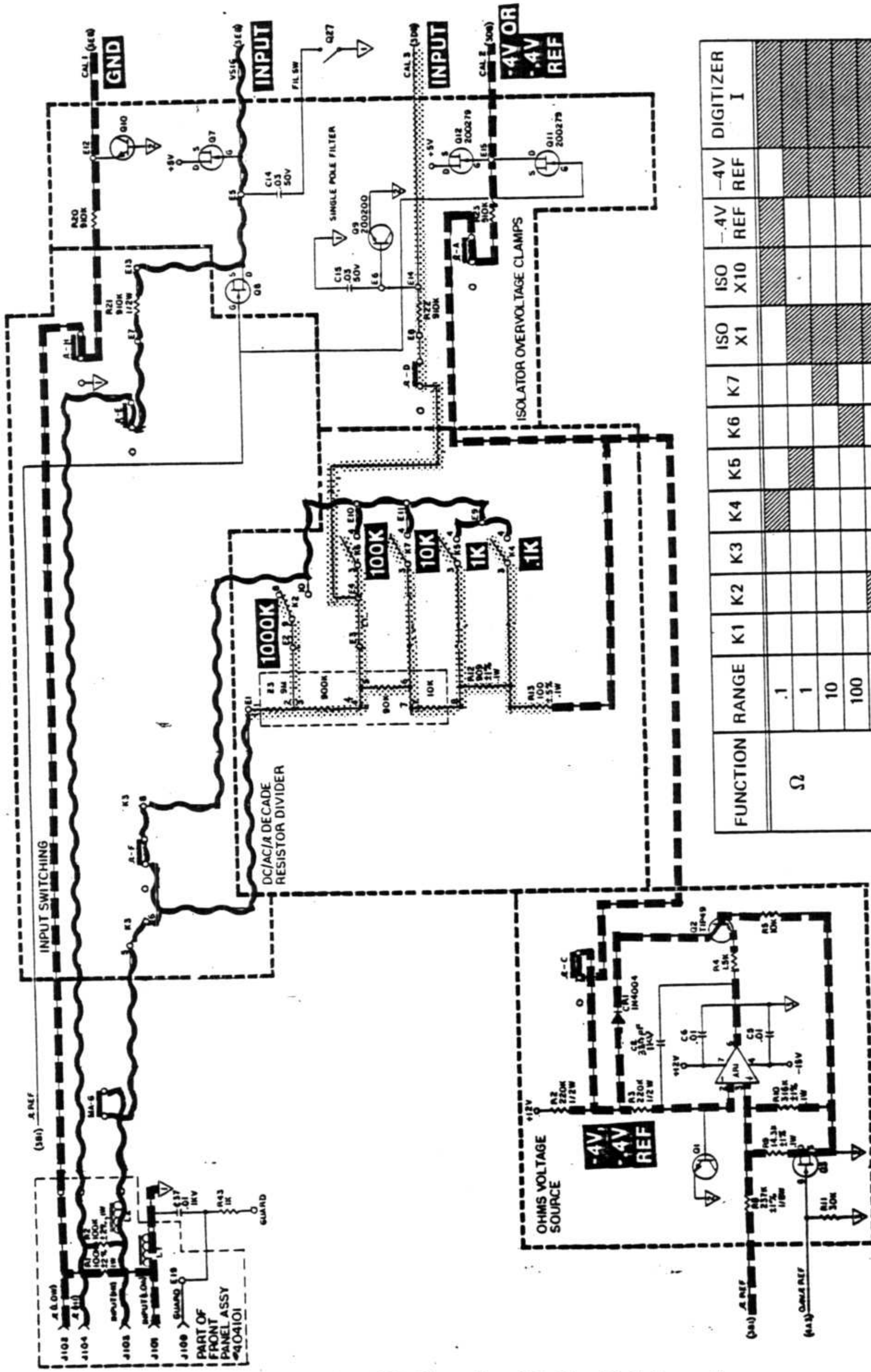


Figure 4.12 - 5001 Simplified Ohms Measurement Technics and Corresponding R_X Expressions



FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	ISO X10	-.4V REF	-4V REF	DIGITIZER I
Ω	.1				■					■	■		■
	1					■			■			■	■
	10							■	■			■	■
	100						■		■			■	■
	1K		■						■			■	■
	10K								■			■	■

■ ENERGIZED

Figure 4.13 - 5001 Ohms Input Path with Schematic

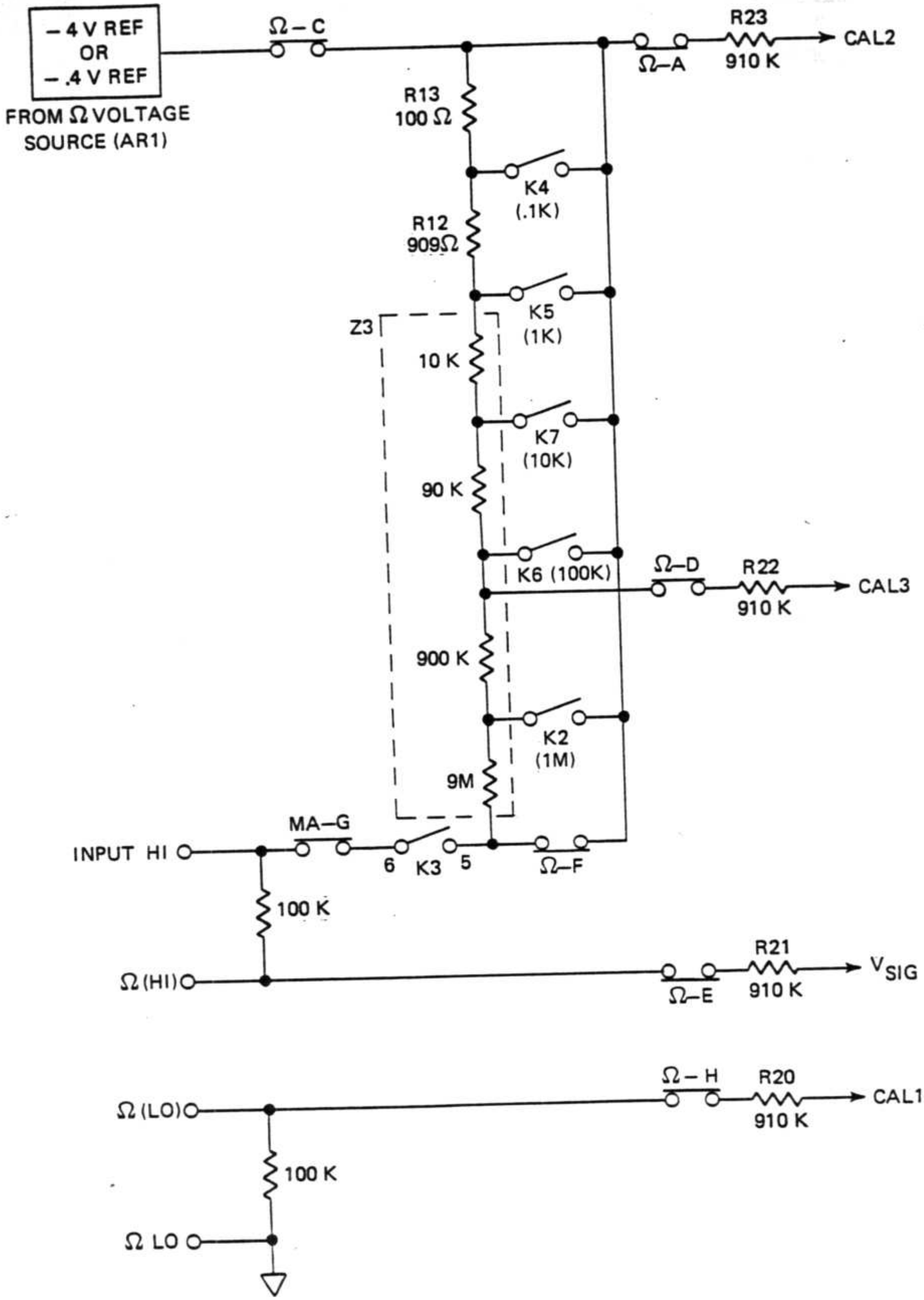


Figure 4.14 – 5001 Ohms Front-End Diagram

10 K ranges, and is almost equal in voltage to VSIG, but differs by an amount equal to the I x R drop of the selected range relay, K4 through K7. CAL 2 is connected to the opposite end of the resistor network at resistor R13 through resistor R23 and switch Ω-A.

4.4.6.5 After buffering by the isolator, each of the four function signals (VSIG, CAL 1, CAL 2 and CAL 3) is applied to the digitizer, measured for 100 µSec, and its digitized value stored in memory. Using one of the two following expressions, the µP then computes the ohms measurement for LED display:

a) $$\frac{VSIG - CAL\ 1}{CAL\ 2 - CAL\ 3} = R_X$$

(.1 - 10 K Ranges)

b) $$\frac{VSIG - CAL\ 1}{CAL\ 2 - VSIG} = R_X$$

(100 K - 10 MEG Ranges)

4.4.6.6 **Ohms Reference Voltage (CAL 2)** - the source for CAL 2 is the conditioned -7 VDC signal generated by Zener diode VR4 located in the 5001's digitizer section. Signal conditioning of the -7 VDC signal is produced mainly by non-inverting buffer AR1 and output voltage level selector Q3, both in the ohms voltage source section. The voltage output from AR1 is -4 VDC for all ohms ranges except the .1kΩ range when the output of AR1 is reduced by Q3 to -.4 VDC. This voltage drop in the .1kΩ range results from the µP turning on Q3 which then grounds input resistor R9 to AR1. Also, AR1's input is protected from overvoltage by Q1 and its output is protected by power transistor Q2 and diode CR1.

4.4.6.7 **Switching and Attenuator Control** - in Ohms function, the 5001's µP enables selection of the appropriate range resistor and relay in the reference decade resistor network. Refer to the chart in Figure 4.13. This reconfiguring of range resistors (Z1, R12, and R13) and relays (K2 and K4) selects the proper current to flow through the unknown resistance R_X in each range. Also, depending on the ohms measurement range selected, the µP also controls the voltage reference to CAL 2 (-4V or -.4V) and enables isolator FETs Q16, Q15, Q17 and Q18 for VSIG, CAL 1, CAL 3 and CAL 2, respectively. Finally, the µP enables the x1 FET gain switch Q14 for the isolator for all measurement ranges except the .1kΩ range when the x10 FET Q19 is enabled instead.

4.4.7 Analog Hardware Filtering

4.4.7.1 Using analog hardware (and digital software) filtering permits maximum noise reduction during signal conditioning in the 5001. The analog filter (FIL) is keyboard selected and activated by transistor Q27 on all ranges except the 1 VAC and 10MΩ ranges.

NOTE

Digital filtering is a software program activated on all applicable functions and ranges.

4.4.7.2 When the FIL switch is depressed, the FIL-B section of the filter switch sets a bit pattern that is read by the µP and routed to shift register output U8p14. This signal level switches the output voltage of comparator U7p13 that enables FET switch Q27 to ON and shunts C14 across VSIG to common. The single pole RC filter (R21 - 910kΩ, C14 - .03 µF) permits a -20dB noise attenuation above 55 Hz. Attenuation increases at 20 dB per decade at higher frequencies.

4.4.8 Isolator Function

4.4.8.1 **Isolator Input Buffer** - refer to Figure's 4.15 and 4.16 which show simplified isolator schematic and isolator signal circuitry, respectively. Also shown are the isolator's bootstrap amplifier, µP-controlled multiplexing for FET switching and a timing/sequence chart

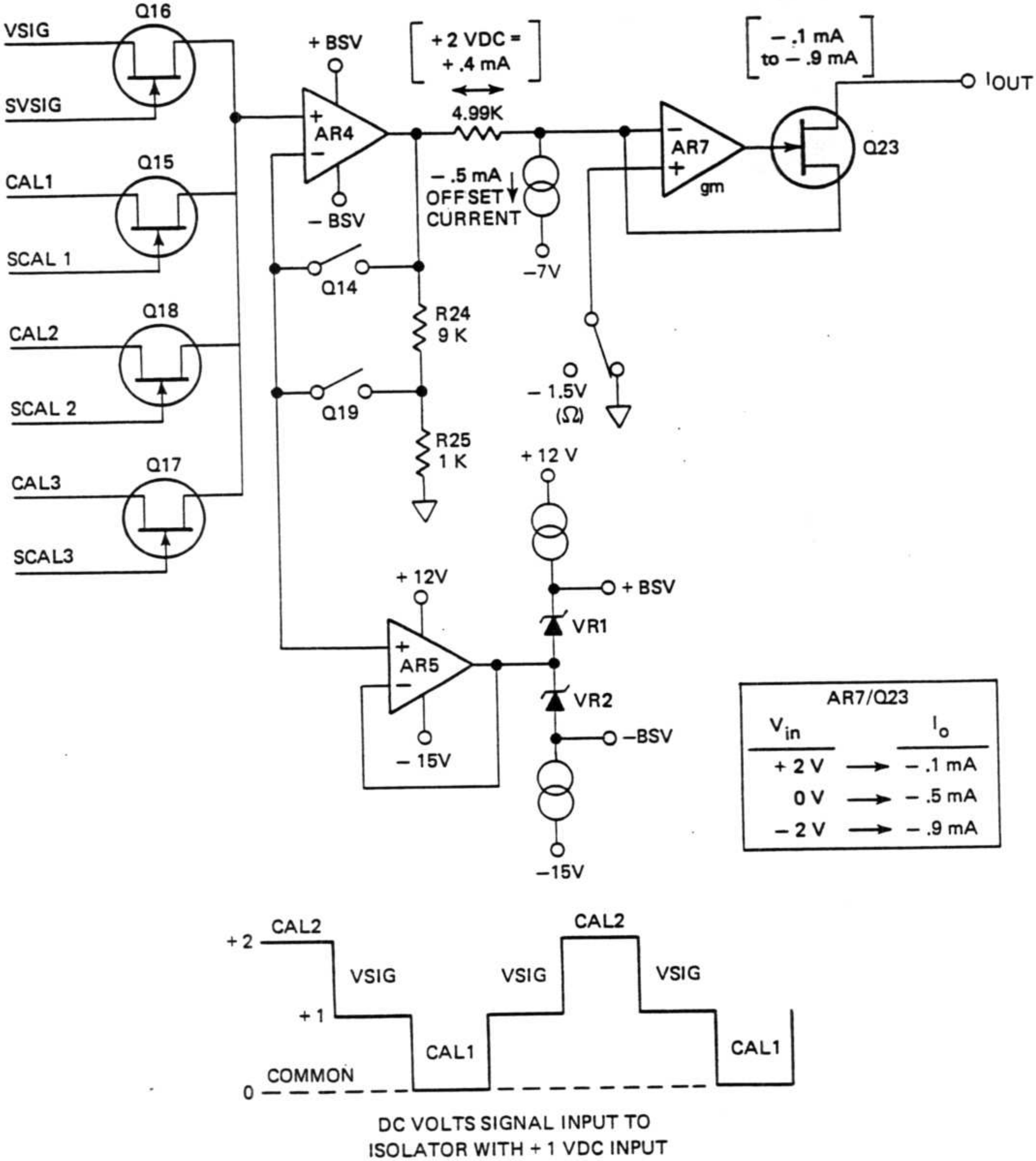


Figure 4.15 – 5001 Simplified Isolator Schematic

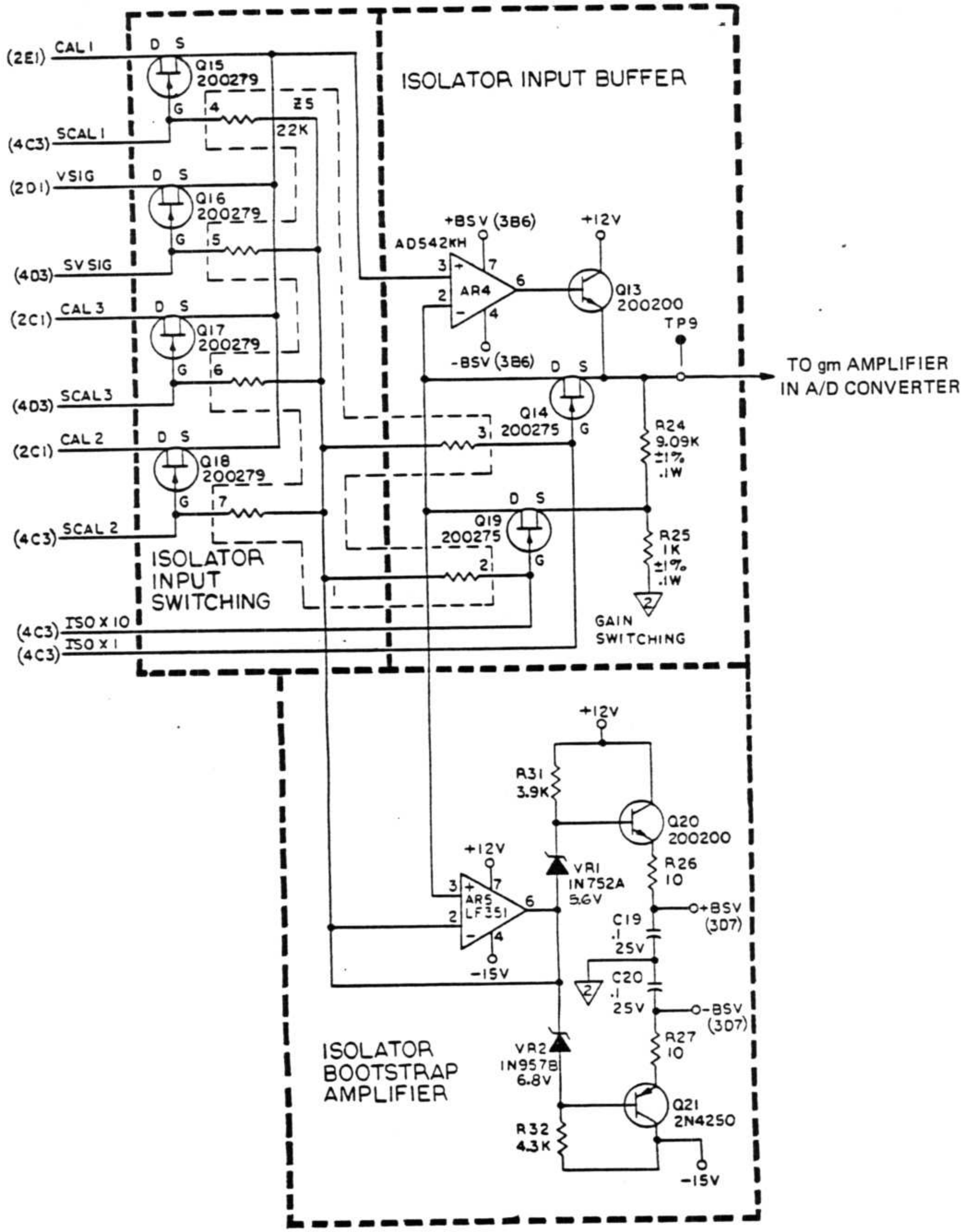


Figure 4.16 - 5001 Isolator Signal Circuitry

for VDC signal input to the isolator.

4.4.8.2 The isolator serves as a buffer circuit with a high input impedance that minimizes isolator loading from the FET switching circuits. To provide the highest linearity for the isolator output, a bootstrap amplifier which tracks the isolator input signal has been incorporated. This amplifier varies the isolator amplifier supply voltages according to the operating range of the digitizer. Isolator output is processed by a transconductance amplifier necessary for proper digitizer operation.

4.4.8.3 **Isolator Input Switching** - the isolator receives the selected function signals (VSIG, CAL 1, CAL 2 and CAL 3) from the four FET input switches Q15 to Q18. These FET switches are enabled by their corresponding FET control signals SVIG, SCAL 1, SCAL 2 and SCAL 3 which are clocked through the shift register U8 under µP control. The sequencing and timing of FET input switching corresponds to the specific computation formula for each 5001 function and range.

4.4.8.4 **Isolator Gain Switching** - when the VSIG and CAL voltages are applied at the buffer input (AR4p3), an isolator gain switching network under µP control through the function/range logic is activated. This network comprises FET switches Q14 and Q19 along with resistors R24 and R25. The network adjusts the level of the isolator input signal by either a X1 (Q14) or X10 (Q19) gain. Gain switching therefore scales the isolator output to a $\pm$ 2V full-scale signal which is then applied to the transconductance amplifier.

4.4.8.5 **Bootstrap Amplifier** - this circuitry, including AR5, uses the isolator feedback voltage to generate the isolator supply voltages that ensure high linearity and common mode rejection (CMR). This is achieved by connecting the isolator's input voltage to a unity gain buffer. AR5's output then "tracks" the isolator input voltage generating the required bootstrap supply voltages. Voltages produced by AR5 are approximately +5 VDC higher and -6.2 VDC lower than the isolator input voltage. As the bootstrap voltage "tracks" the isolator input voltage, the input resistance increases up to 1000 MΩ. Use of the bootstrap amplifier also improves the isolator's CMR performance.

4.4.9 Analog to Digital Conversion

4.4.9.1 General

4.4.9.1.1 Analog to digital (A/D) conversion in the 5001 uses a combination of charge-balance (CB) and single-slope (SS) integration cycles to digitize the 5001's analog input signals to an equivalent number of digital clock cycles or "counts." The output voltages of the isolator are bipolar. They are first converted to a unipolar current by the transconductance amplifier and then applied to the digitizer. The digitizer functions by balancing the input current with the CB and SS currents. The CB and SS currents are used to charge and discharge the integrator under control of the CB and SS comparators.

4.4.9.2 Measurement Cycle

4.4.9.2.1 Refer to Figures 4.17 and 4.18 which show a typical digitizer waveform and simplified digitizer block diagram, respectively.

4.4.9.2.2 The µP control program initializes the digitizer process, then provides the timing and control of the CB integration period. After 100 mSec, then the CB counting phase ends and the SS phase begins for a variable period of time. During the SS phase, the CB counter is cleared and the integrator output returns to its reference level. The digital counts accumulated in memory are used to calculate the display reading.

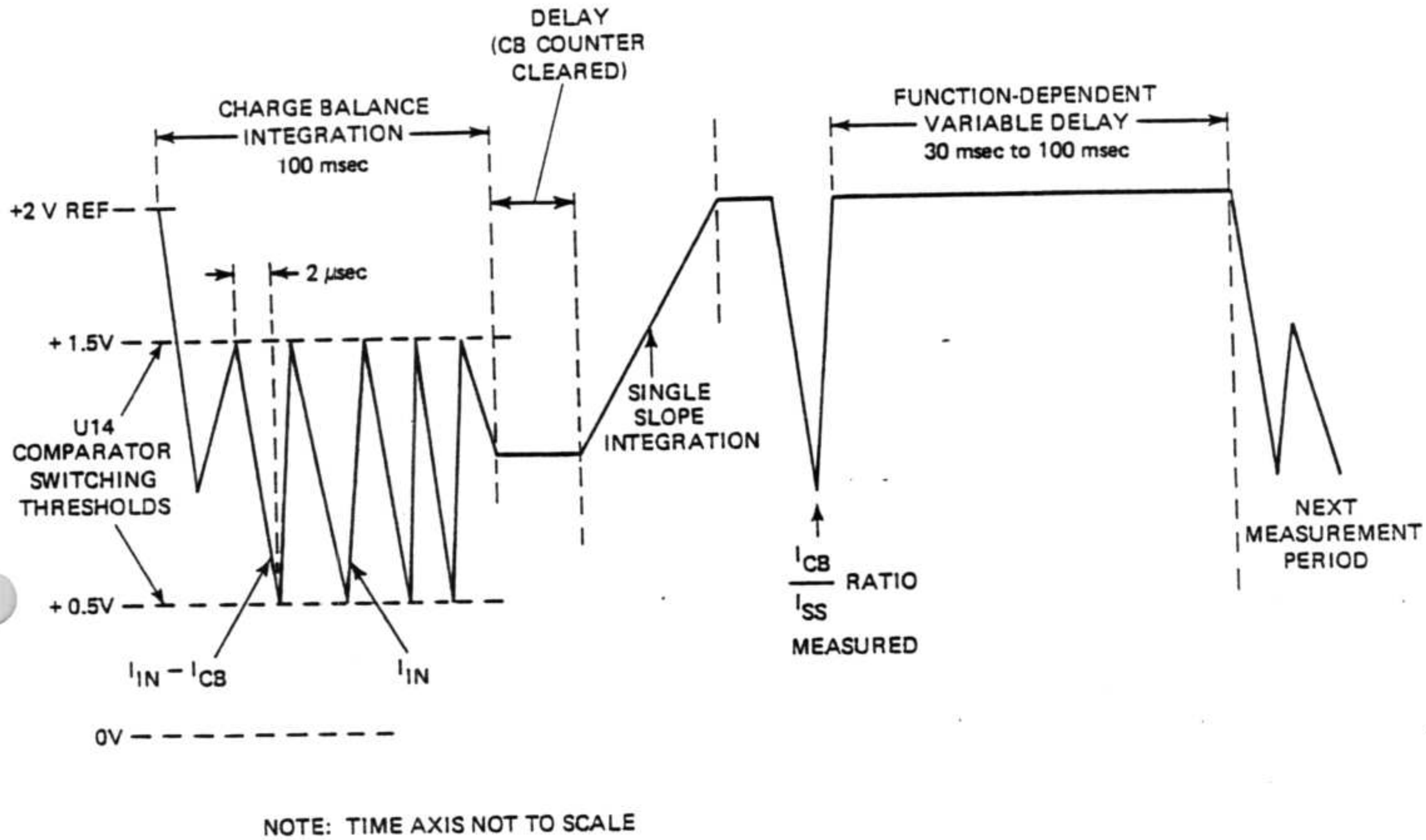


Figure 4.17 - Typical 5001 Digitizer Waveform

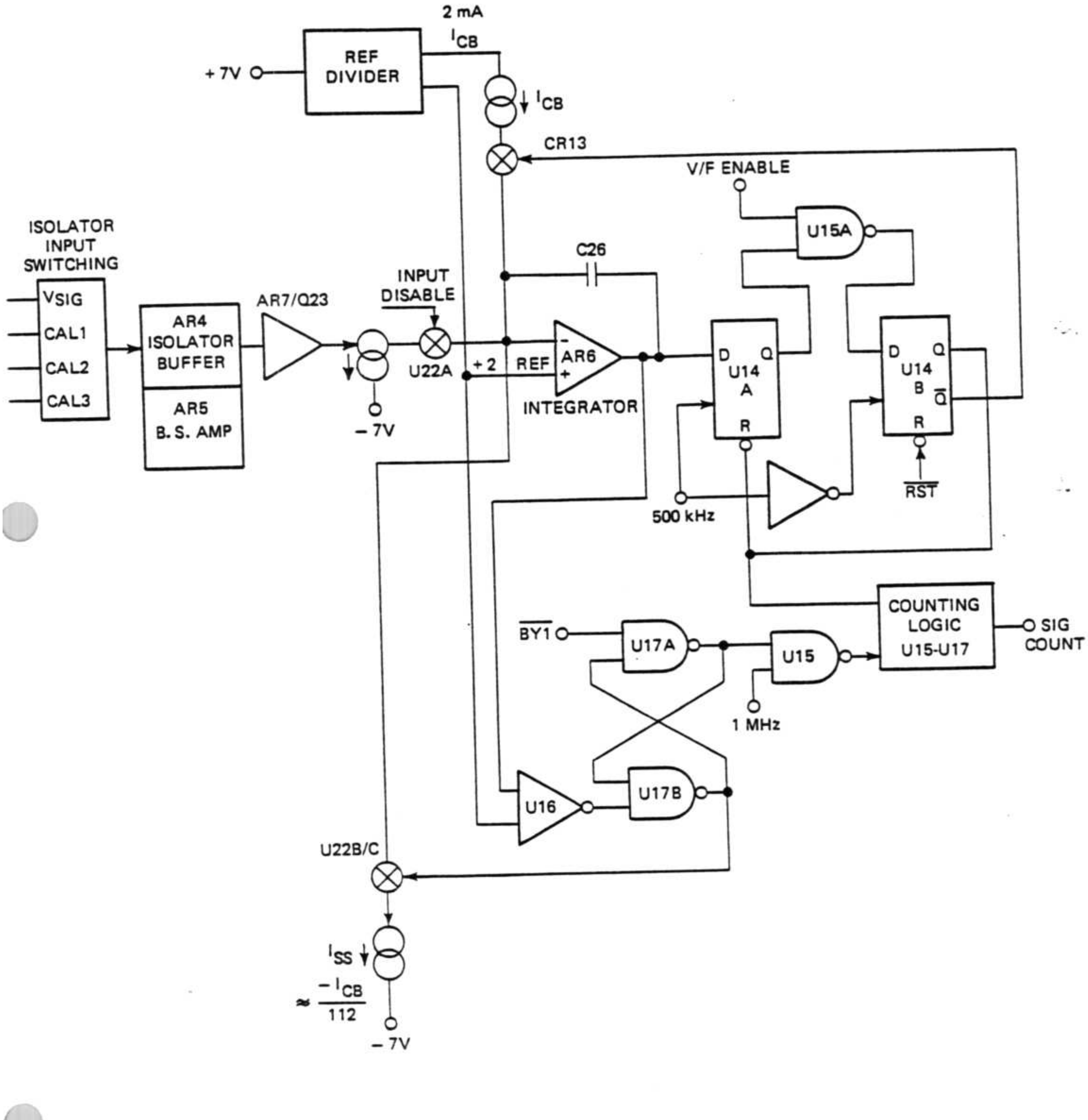


Figure 4.18 - 5001 Simplified Digitizer Block Diagram

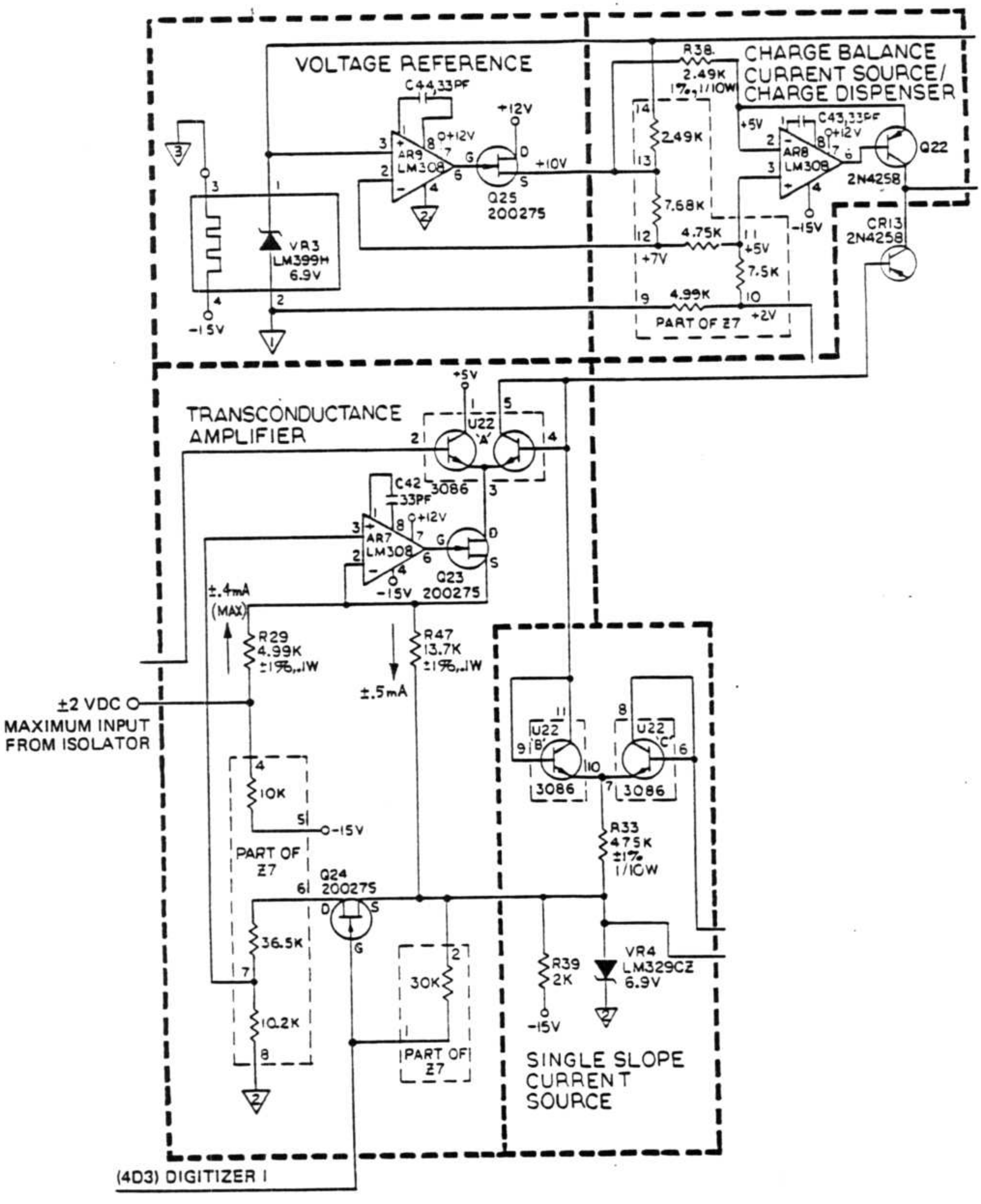


Figure 4.19 - 5001 Digitizer Reference Voltage and Current Sources

4.4.9.3 Reference Voltage and Current Generators.

4.4.9.3.1 Refer to Figure 4.19 which shows the reference voltage and current sources in the 5001's digitizer.

4.4.9.3.2 Reference voltages and current sources are required for the proper operation of many digital multimeter circuits. Two reference voltages (+7 V and -7 V) are produced in the digitizer section of the 5001. After being generated, these reference voltages are propagated and modified for specific applications. These voltages, in turn, generate the required currents needed for the digitizer's CB (I = 2 mA) and SS (I = 17 uA) circuit functions.

NOTE

The self-calibration scheme and Non-Vol Memory in the 5001 relax the need for precise reference voltage and current sources. All references have an accuracy of ± 5 percent. Calibration constants in the Non-Vol Memory compensate for inaccuracies in the + 7 V reference; the 5001's continuous self-calibration scheme compensates for errors in the - 7 V reference.

4.4.9.3.3 The +7 V reference is produced by voltage regulator VR3, which consists of a temperature-regulated Zener diode. This reference voltage is routed to the attenuator and switching circuits where it supplies the voltage reference divider (R14, R15 and R17). Also, the +7 V reference is buffered by AR9/Q25, then applied to the CB current source/charge dispenser transconductance amplifier AR8/Q22 to generate the 2 mA ± 5% current through R38. In addition, the +7 V reference, using AR9/Q25 and Z7 generates the +2 VDC reference for the CB and SS integration and comparator operations.

4.4.9.3.4 The -7V reference is produced by Zener regulator VR4. This reference voltage is routed to the attenuator and switching circuits where it is applied to the ohms reference source to produce the -4V and -.4V signals. Also, the -7V reference is applied to the SS current resistor R33 to generate the SS current source. In addition, the -7V reference, using Z7p2, 3 (13.7kΩ), provides a -.5mA offset current in the transconductance amplifier. Finally, when in Ohms function, the -7V reference, using Z7p6, 7, and 8 generates a -1.5V offset voltage for the input of the transconductance amplifier at AR7p3.

4.4.9.4 Transconductance (gm) Amplifier

4.4.9.4.1 Because the 5001's digitizer is current-based, voltage from the isolator is converted to a current by transconductance amplifier AR7 before this signal is applied to the integrator.

Also, the unipolar input current required by the integrator is provided by a -.5mA offset current applied to AR7. This offset current shifts the bipolar input current level of AR7 ensuring that the output current fluctuations never become positive. Typical bipolar to unipolar waveforms are shown in Figure 4.20.

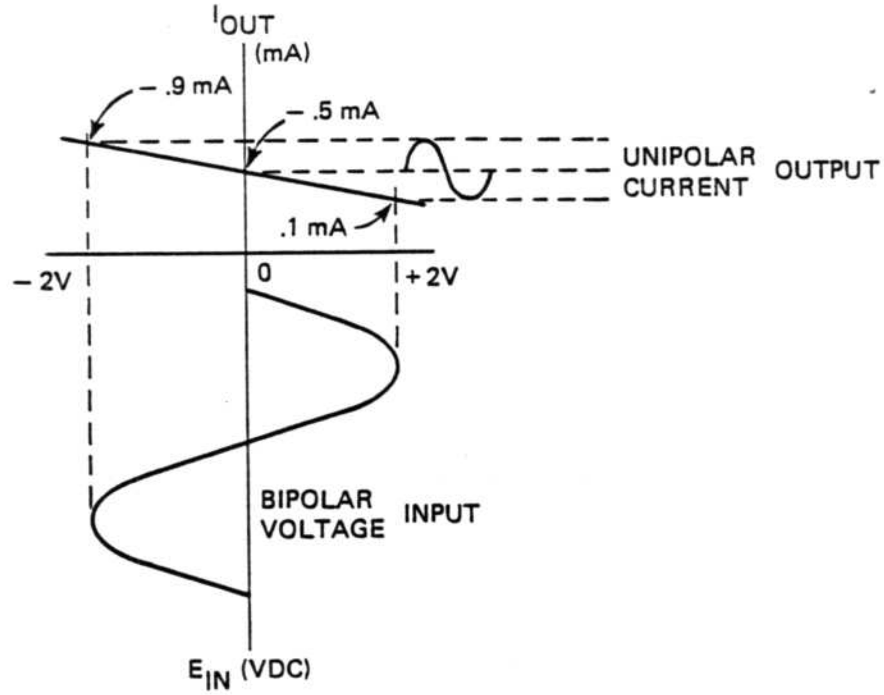
4.4.9.5 Charge Balance (CB) and Single Slope (SS) Cycle

4.4.9.5.1 A CB cycle is initiated when the digitizer's CB Enable (V/F ENABLE) line is set high, thereby activating CB comparator U14. When the signal INPUT DISABLE goes low, the output current from the transconductance amplifier is switched to integrator AR6.

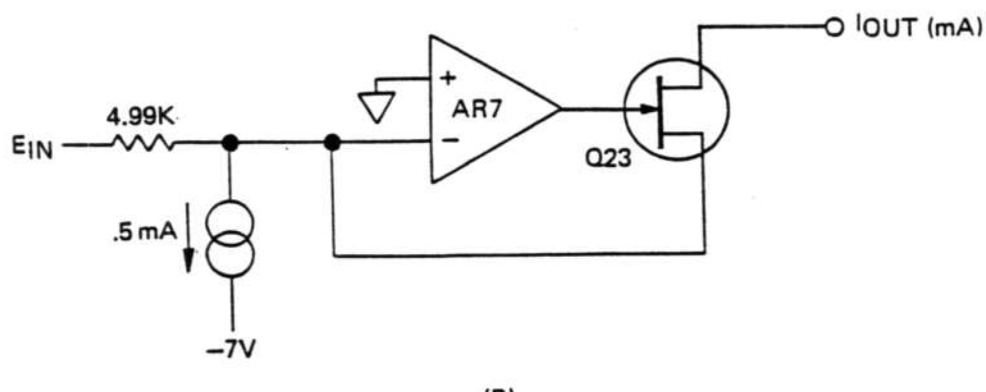
4.4.9.5.2 The output current from the transconductance amplifier is switched to AR6 for 100 mSec. The output from AR6 remains approximately +1V. (This results from AR6 ramping positive from I_{IN} and negative from I_{CB}, both currents tending to cancel each other out.) This voltage also is applied to the CB comparator U14p12 which modifies the integrator's output level by switching on the CB current switch

V_{IN}: +2 V to − 2V

I_{OUT}: − .1 mA to − .9 mA



(A)



(B)

Figure 4.20 - Typical Bipolar - Unipolar Waveforms (A) with Simplified Schematic (B)

CR12/13 when the integrator's output level exceeds U14's input threshold level.

4.4.9.5.3 The Q output from U14A and the V/F ENABLE pulse are gated by U15A and applied to the D input of U14B. The input is clocked by the rising of the 500 kHz signal. The Q output enters the counting logic circuitry of U15C and U17D from which the signal counts are routed to the µP's prescaler U24. The Q output from U14B triggers the CB current (I_{CB}) switches CR12 and CR13. Also, the CB comparator samples the output voltage level of the integrator every 2 µSec. If the integrator's output voltage goes above +1.5V, the CB comparator's threshold level, I_{CB} is turned on, reversing the slope of the integrator to a voltage level between 0.5 and 1.5 VDC.

4.4.9.5.4 The CB loop continues for the 100 mSec period; then the INPUT DISABLE signal goes high and the input control switch U22A of the integrator turns OFF the input current from AR7. Simultaneously, the V/F ENABLE pulse goes low, disabling I_{CB} by switching off CR13. Since 50,000 clock pulses occur in a 100 µSec CB period, U14B can switch and be counted to a maximum of 25,000 times. Each U14B output pulse is routed through U15C and U17D to U24 where it increments the ÷ 256 count prescaler of the µP. After scaling, the SIG COUNT is applied to the µP at $\overline{NMI}$ input (U10p6). With the integrator's input switch U22A and CB switch CR13 disabled, the µP uses a 5 mSec delay to determine the count in the prescaler. Then the µP returns the digitizer's count prescaler to zero using the $\overline{BYO}$ signal at U15Cp13.

4.4.9.5.5 At the end of the 5 mSec delay period, the integrator has a residual charge which must be measured by single-slope (SS) integration under µP control. The µP initiates SS conversion by pulsing $\overline{BY1}$ to logic zero which turns on the SS current source switch U23A and the 1 MHz clock. The I_{SS} current is then applied to the integrator forcing it to "ramp" from its residual charge level back to the +2V reference level while the 1MHz clock pulses (Ø2) are counted at U15Bp9. When a reference crossing is detected by comparator U16, its output (U6p7) switches, triggering flip-flop U17A/U17B. This turns OFF current source switch U23A and disables the 1MHz clock. All clock pulses are counted, starting with SS enabling signal $\overline{BY1}$ and ending with the comparator's reference crossing, then routed through U15B/U15C and U17D to the SIG COUNT input of prescaler U24. U24 divides this count by 256 and then applies the result to the µP at $\overline{NMI}$ input (U10p6).

4.4.9.5.6 About three or four times a second, the integrator is reconfigured under µP control to measure the ratio of the CB and SS current sources. I_{CB} is enabled for 2 µSec by a V/F ENABLE signal. This "ramps" the integrator down to approximately +1 VDC from its +2 VDC reference level. I_{SS} then is enabled by $\overline{BY1}$ at U17A and the integrator "ramps" back to +2 VDC. Counting stops when the SS comparator (U16) switches and the 1MHz clock, being counted by U24, is disabled. The I_{CB}/I_{SS} ratio is determined by the µP's clearing counter U24 (where $I_{CB} \cong 2mA$, $I_{SS} \cong 17$ µA, and the ratio = 118). Since I_{CB} is on for 2 µSec per clock, while I_{SS} is on for 1 µSec per clock, the actual weighted ratio for I_{CB}/I_{SS} is approximately 236 (2 x 118 = 236).

4.4.9.5.7 The µP uses this ratio to combine the CB counts with the correctly - weighted SS counts. The combined number of counts corresponds directly to the input signal voltage level, and is employed in calculating the following expression:

$$\frac{2\,(VSIG - CAL\ 1)}{CAL\ 2 - CAL\ 1}$$

4.4.9.5.8 Finally, if the next signal to be measured is VSIG, a variable delay ranging from 30 to 100 µSec is executed by the µP.

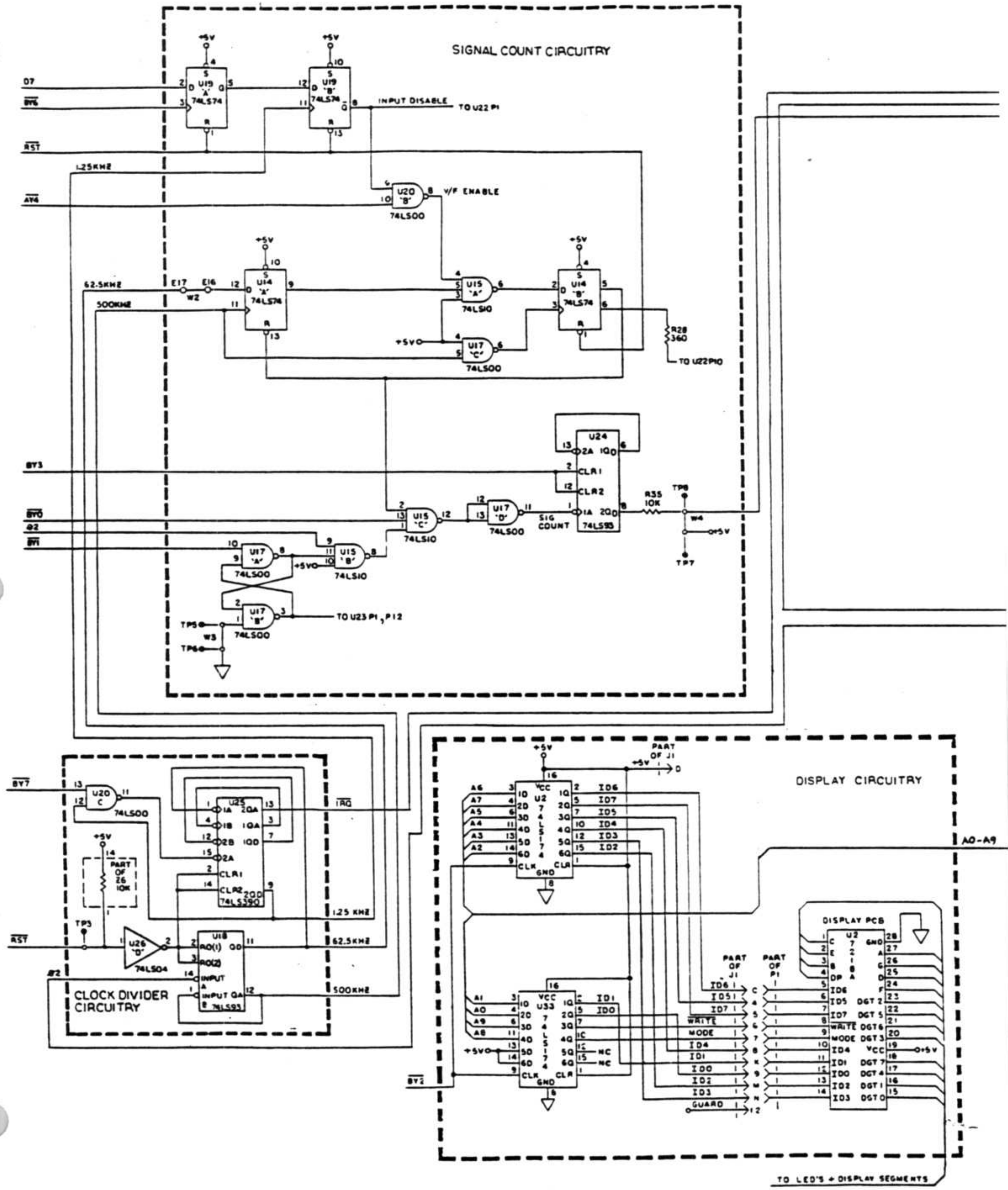


Figure 4.21 - 5001 Digital Block Diagram

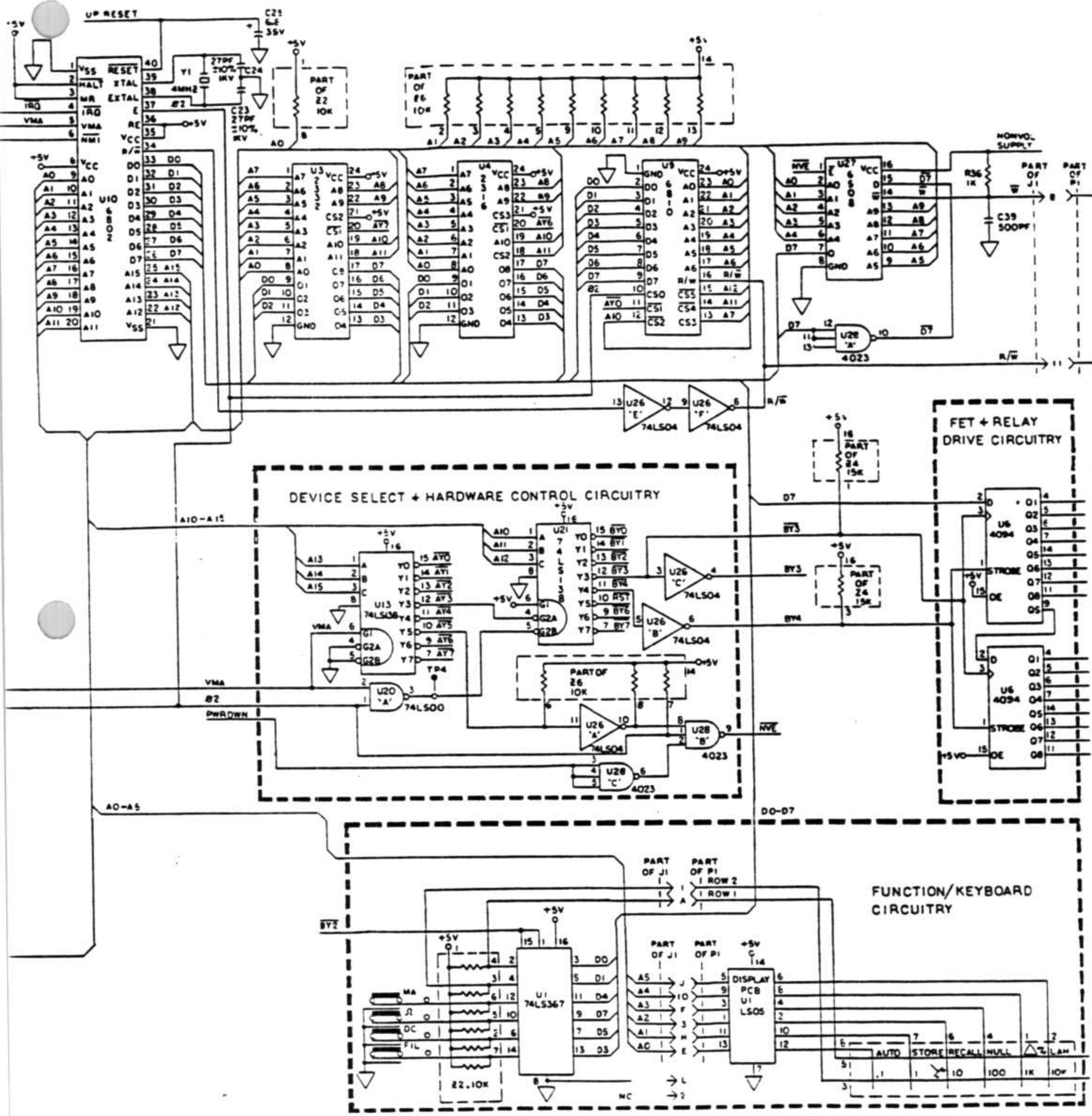


Figure 4.21 - 5001 Digital Block Diagram *continued*

4.5 DIGITAL THEORY OF OPERATION

4.5.1 General Description

4.5.1.1 Refer to foldout Figure 4.21. Central to the digital control of the 5001 is U10, a 6802 µP, which along with its associated ROM and RAM devices, control and time all digital multimeter operations. Digital control of the 5001 includes:

a) Executing the program instructions residing in ROM program memory.

b) Reading data from various locations in the 5001.

c) Storing data to RAM memory.

Program instructions for the 5001's µP are stored in ROMs U3 and U4, each providing 4k and 2k bytes of memory, respectively. Data memory includes a single RAM U9 with 128 x 8 bits of memory for temporary storage along with a Non-Volatile Memory U27 providing 1k x 1 bits of storage for the calibration constants.

4.5.1.2 In general, the front panel keyboard and digitizer provide the µP with measurement information for processing. In turn, the µP outputs display information to the front panel LEDs as well as sending control information to the digitizer. Each major element of 5001 digital operation is discussed separately in the following subsections.

4.5.2 Microprocessor Circuitry

4.5.2.1 The MPU consists of the following hardware which represent the minimum requirement for the µP to execute its program instructions:

a) A 6802 µP (U10).

b) Program memory (U3, U4).

c) Data memory (U9).

d) A 4 MHz clock crystal (Y1).

e) Address decoders (U13, U21).

f) Non-Volatile Memory comprised of CMOS RAM U27, 3-volt lithium cell BT1, and Zener diode VR5.

g) Miscellaneous logic hardware consisting of a NAND gate U20 and hex inverter U26.

h) Miscellaneous interrupt control hardware.

4.5.2.1.1 **µP Reset Circuitry** - when power is first applied to the µP, an RC time constant is generated by a 45kΩ resistor (Z4, three 15kΩ series resistors) and a 6.8 µF capacitor (C25). This time constant is input at the RESET terminal of the µP (U10p40). This input holds the µP low in reset long enough for the +5.0 V power supply and clocks to stabilize. When power is first applied, pin 40 is initially at ground; however, it slowly increases to +5.0 supply volts as a function of the RC time constant. At +5.0 volts, the RESET input is high and the µP is enabled to initiate its start-up routine.

4.5.2.1.2 **VMA and R/$\overline{W}$ Signals** - these two timing signals produced by the µP are described in the next two paragraphs:

a) **Valid Memory Address (VMA)** - this signal is used by the two address decoders, preventing them from decoding invalid addresses on the address bus. When the µP outputs a valid address, the VMA signal line goes high (logic 1). When the µP is simply performing an internal operation, allowing the address lines to be indeterminate, the VMA line goes low (logic 0), indicating that no valid memory address is presently on the address bus. Also, since the address bus can be non-defined at times, the VMA signal is necessary to differentiate between valid addresses and indeterminate and/or invalid address information.

b) **Read-Write (R/$\overline{W}$)** - this signal indicates to devices residing on the address/data bus whether the µP is currently in a read or write operation. When a device is "read" by the µP, it addresses the device, enables it, and sends the Read-Write signal high indicating that a "read" operation is occurring. When the µP "writes" to a device, the µP puts the Read-Write Signal line low indicating that a "write" operation involving the output of data over the data bus is occurring.

4.5.2.2 **Program Memory** - this contains the permanent 5001 programs as well as the troubleshooting DIAG (see Subsection 5.4.12) and SA (see Subsection 5.5) programs. Program memory in the 5001 uses two conventional 4k byte ROMs (U3, U4). To access program instructions from program memory, the µP drives address lines A0 - A11 which are connected to the two ROMs. (These address lines are also connected to the data memory RAM and the address decoders.) Also, the µP reads and writes information over the eight data bus lines D0 - D7.

4.5.2.3 **Data Memory** - this contains the short-term information being stored for data processing under µP control. Data memory in the 5001 uses a conventional 128 x 8 bit RAM (U9). See Subsection 4.5.2.8 for a description of the Non-Volatile Memory of the 5001.

4.5.2.4 System Clock

4.5.2.4.1 The 1MHz system clock Ø2 is generated by the µP which uses an on-board oscillator circuit requiring an external 4 MHz crystal (Y1). The crystal oscillator is connected to the µP at the EXTAL (U10p38) and XTAL (U10p39) inputs. Although the 4 MHz crystal's signal is used for the µP's internal operation, this frequency is divided by 4 and shaped internally before it is output as the 1 MHz square-wave system clock at terminal C(U10p37). The system clock is used to synchronize (clock) the 5001's various hardware and software functions.

4.5.2.4.2 The system clock signal is routed to the clock divider section where specific frequencies are generated. The first division occurs at U18, a ripple counter that divides Ø2 by two for the 500 kHz frequency required by the charge-balance comparator. U8 generates a second frequency of 62.5 kHz by dividing Ø2 by 16 for the SA system clock. The 62.5 kHz frequency is applied to U25 which divides the 62.5 kHz frequency to produce the 1.25 kHz clock for the digitizer control logic and the IRQ inputs to the µP.

4.5.2.5 **Address Decoders** - the following two paragraphs describe the 5001's decoding hardware along with their operation.

4.5.2.5.1 **Address Decoding Hardware** - this consists of U13 and U21 which are used by the µP as three-to-eight (3/8) decoders, each having 3-bit input codes. That is, depending on what a particular input code is and whether the qualifying signals on the decoder's input are also true, each address decoder will specifically require 1/8 outputs.

a) U13 - this decoder is enabled when the VMA signal line is high; it decodes an input on address lines A13 - A15. Since the outputs of U13 are not gated with system clock Ø2, the low-going pulse widths of U13's outputs after decoding vary from 700 - 1000 nSec.

b) U21 - this decoder is gated with the system clock and enabled when the Ø2 line is high. The low-going pulse widths of U21's outputs after decoding do not vary, but remain at 500 nSec.

4.5.2.5.2 **Address Decoder Inputs/Outputs** - the inputs to U13 and U21 are address lines A10 - A15 along with other control and timing signals. Outputs from the two decoders U13 and U21 consist of $\overline{AY0}$ - $\overline{AY7}$ and $\overline{BY0}$ - $\overline{BY7}$, respectively. These outputs are normally high and are used for chip selection and hardware control. Additional hardware in the address decoding circuitry include several inverters and NAND gates.

4.5.3 Chip Select and Hardware Control

4.5.3.1 **Input Signals** - these consist of the address lines A10 - A15, system clock Ø2, µP timing signal VMA, and the +5V signal line of the power supply level detector (called simply the power-off signal).

NOTE

The power-off signal is a qualifier in that it prevents the operation of the Non-Volatile Memory when the power is not at a sufficient level.

4.5.3.2 **Output Signals** - the following is a listing and brief description of the various output signals generated by the chip select and hardware control circuitry.

a) $\overline{AY0}$ - the chip select signal for U9, the 128 x 8 bit RAM.

b) $\overline{AY1}$ - the "write" clock signal at the GPIB bus port.

c) $\overline{AY2}$ - the "read" clock signal at the GPIB bus port.

d) $\overline{AY4}$ - the digitizer control signal. This pulsed signal is used to momentarily turn the I_{CB} on during the I_{CB}/I_{SS} measurement.

e) $\overline{NVE}$ - the Non-Volatile Memory enable signal which is synchronized and gated with system clock Ø2.

f) $\overline{AY6}$ - the chip select signal for U4, the 4k x 8 bit ROM.

g) $\overline{AY7}$ - the chip select signal for U13, the 4k x 8 bit ROM.

h) $\overline{BY0}$ - the digitizer prescaler clock signal. This clock signal is used to empty any residual counts from the divide-by-256 counter.

i) $\overline{BY1}$ - the single slope enable signal. This pulsed signal enables the SS current to be generated, thereby controlling the digitizer.

j) $\overline{BY2}$ - the display and keyboard enable signal. This signal is used to latch display information from the address bus. It is generated by the µP and is used to enable the status of the keyboard function switch to be placed on the data bus.

k) $\overline{BY3}$ - the prescaler counter clear signal. This signal clears the prescaler of any residual counts prior to the start of an integration period. Also, $\overline{BY3}$ is used to clock information into the FET and relay drive registers. This signal is also called the relay drive shift register clock.

l) $\overline{BY4}$ - the FET and relay drive shift register signal. The rising edge of this signal forces information in the shift registers to be transferred to their corresponding outputs.

m) $\overline{RST}$ - the signature analysis (SA) control signal. This signal is not used during the normal operation of the 5001, but rather during SA troubleshooting (see Subsection 5.5).

n) BY6 - the charge balance measurement control signal. This signal is used in conjunction with data line D7 to turn the input current on or off.

o) $\overline{BY7}$ - the interrupt request ($\overline{IRQ}$) hardware clear signal. This signal resets the hardware for the $\overline{IRQ}$ line on the input to the µP.

4.5.4 Non-Volatile Memory

4.5.4.1 The 5001 uses a Non-Volatile Memory to store calibration (CAL) constants for later recall. The constants are stored during laboratory calibration and are recalled from memory whenever the function or range of the 5001 is changed. The Non-Volatile Memory is comprised of the following hardware:

a) CMOS RAM (U43)

b) NAND gate (U42)

c) 3-volt lithium battery (BT1)

d) Zener diode (VR12)

e) constant current regulator (Q21)

f) steering diodes (CR17, CR21)

4.5.4.2 **Non-Volatile Memory Power Supply** - during normal 5001 power-on, the Non-Volatile Memory circuit receives a +9V of unregulated current from the digital power supply. The current from the unregulated supply is controlled by Q26, a FET connected as a constant current source. This constant current (normally 7-13 mA) flows to ground through VR5, producing a stable +5.6V at CR5's anode. This +5.6 volts causes CR5 to forward-bias, supplying approximately +5.0 V to the U42 and U43. The presence of +5.0V on the cathode of CR4 causes this diode to turn off, thereby preventing battery charging.

Also, during AC power-off periods, battery BT1 causes CR4 to forward-bias so that approximately 2.5V is available to power U42 and RAM U43. This same voltage reverse-biases CR5 which then prohibits battery flow into the power supply.

A Non-Volatile Memory Write-Protect circuit prevents accidental modification of the contents of RAM U43 during normal power-on. This circuit is comprised of R/$\overline{W}$ buffer U26-F, a 1 kΩ pull-up resistor R36, and CAL switch S1 located behind the front panel. When S1 is open, RAM U43p14 remains continually HI which prevents any RAM "write" operation, so that its contents cannot be modified. When the CAL switch is depressed (closed), the µP can drive the WRITE pin on the RAM LO, enabling modification of U43's memory.

Also, a Non-Volatile Memory Power-off Protect circuit has been used in the 5001. This prevents the loss of CAL constants in U43 during power-on, power-off, and power brown-outs. The circuit is comprised of a voltage level detector U32, along with voltage-divider resistors R44 and R45. U32 is configured to detect voltage variations in the +5 VA power supply.

4.5.5 FET and Relay Drive Control

4.5.5.1 FET and relay drive registers U6 and U8 are provided with control bits $\overline{BY3}$ and $\overline{BY4}$ which progressively step the data through the two registers. The clock pulse $\overline{BY3}$ applied to U6p3 and U8p3 clocks the data input signal D7, in bit serial format, at U8p2. Succeeding loads will continually shift previously input data serially until data resides at U8p9. The very next load will shift input data into U6p2. Data input will be progressively stepped through both shift registers until they are fully loaded.

4.5.5.2 Clock signal $\overline{BY4}$ then strobes the latched output from the two loaded registers U6 and U8 onto the appropriate FET and relay switch driver.

4.5.5.3 FET switch drivers (U7, U11 and U12) perform two basic operations. First, the FET drivers are wired as comparators with a reference voltage of 2.5 VDC wired to one input of each comparator. The second input is connected to the register's output. The drivers then determine the on-off pattern received from the register. Second, data is buffered by the specific FET drivers and then routed to the selected FET switches.

4.5.5.3.1 In operation the comparator's (U7, U11 and U12) reference voltage of 2.5 VDC is produced at Z4p4. One input to each comparator receives the 2.5 VDC reference and second input receives the output pattern from shift register U8, which varies from zero to +5 VDC. U8's input, either above or below crossover, sets the comparators' high or low output state. When the FET switch driver/comparator's output is an open-circuit, the selected FET is enabled. When the FET switch driver/comparator's output is -15 VDC, the selected FETs are disabled.

4.5.5.3.2 Data is clocked into the relay shift register U6p2 as the clock and strobes shift data from U8. The data pattern presented at the output of U6 (Q2 to Q8) is buffered by relay driver U5, activating the range relays requested by the keyboard.

4.5.6 Keyboard and Function Switching

4.5.6.1 Refer to Figure 4.22 showing the 5001 keyboard block and timing diagrams. Front-panel entries control all functions and software capabilities provided by the 5001. The 5001's keyboard and function switch circuitry consists of the following hardware:

a) a six-column, double-row matrix keyboard located on the display PCB.

b) multipole double-throw pushbutton switches S1 - S5 on the main PCB.

c) open-collector inverting buffer U1 on the display PCB which buffers the µP's address lines which drive the six-column keyboard. This IC U1 is called the "address" buffer.

d) tri-state buffer U1 on the main PCB which enables the µP to read keyboard input signals. This IC U1 is called the "read" buffer.

e) a 10 kΩ pull-up resistor network Z2 which ensures that the 5001's µP will read a HI (logic "1") from "read" buffer U1, if its inputs from the keyboard become open. This condition exists if no key is depressed.

4.5.6.2 Keyboard and Function Switching Operation

4.5.6.2.1 When the 5001's µP determines if any front-panel key is depressed (active), the processor reads from "read" buffer U1 while address lines A0 - A5 are high. The "1's" on A0 - A5 lines are sent through the address buffer U1 and appear as "0's" on the keyboard columns.

4.5.6.2.2 When a key is depressed, the µP will read a "0" on one of the row outputs through the "read" buffer U1 with the remaining row reading as "1."

4.5.6.2.3 When a "0" does appear, the µP then scans each keyboard column one-at-a-time by reading from "read" buffer U1 with only one of the A0 - A5 lines high and the others low. This process continues until the appropriate keyboard column has been driven low and a "0" appears once again from "read" buffer U1. When a "0" does appear, the 5001's µP suspends any further keyboard scanning and processes the key in software.

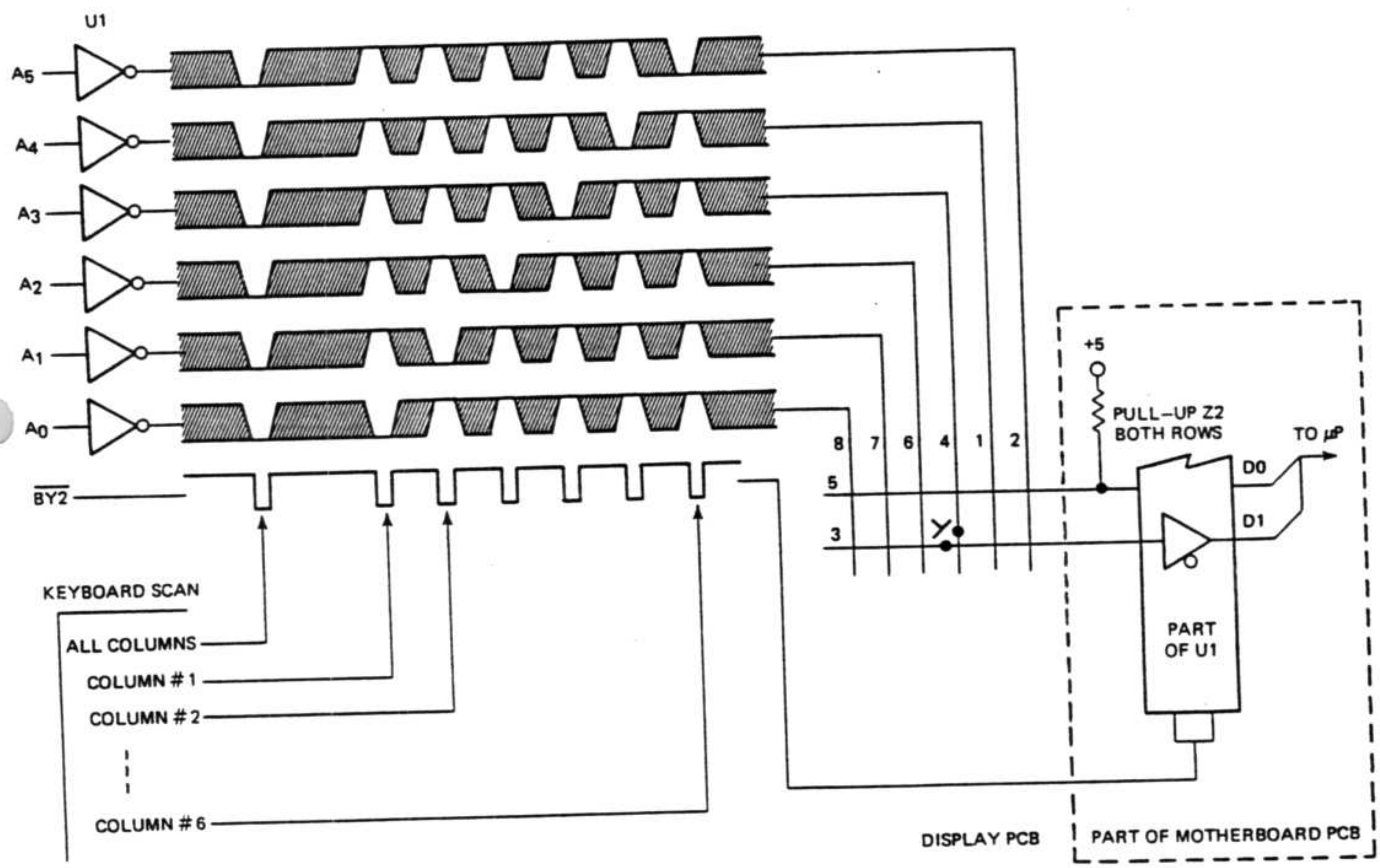


Figure 4.22 - 5001 Keyboard Block Diagram

4.5.7 Display Operation

4.5.7.1 General Description

4.5.7.1.1 Measurements processed by the 5001 appear on the front-panel 7-segment LED display. The display LEDs are configured to show numerics and limited alphabetics representing analog input data and µP instructions. The front-panel LED annunciators indicate the status of the 5001's six software operations that are driven by the same display hardware.

4.5.7.2 Display Hardware

4.5.7.2.1 The display hardware is configured on both the 5001's main (section 10) and display PCBs. Located on the main PCB are the two 6-bit display latches U2 and U33, shown on schematic 431648-6 located in section 10. Located on the display PCB are the 7-segment LED readouts DS1 through DS7; the six LED status annunciators CR1 through CR2; inverter IC U1; and display driver U2, shown on schematic 431649-1. A simplified block diagram for the LED display hardware is shown in Figure 4.23 and schematics 431648-1 and 431649-1 present the display hardware circuitry.

4.5.7.3 Display Description

4.5.7.3.1 The front-panel LEDs are controlled by the LSI display driver U2 using the two display latches U2 and U33 through the 5001's µP. The two display latches U2 and U33 are loaded at their inputs with LED display instructions from the address bus by the µP. By latching the LED display instructions, the display driver is provided with additional time to perform its routine chores. Latch data and chip select instructions use address lines A0 through A9. The clock signal for latches U2 and U33 is provided by signal $\overline{BY2}$ which edge-triggers the latch on low-to-high clock transitions.

4.5.7.3.2 Whenever the 5001's µP updates the LED pattern controlled by display driver U2, it clocks a string of bytes into driver U2 from the outputs of display latches U2 and U33. The first byte is a status byte informing the display driver that eight data bytes will follow. The display driver distinguishes between status bytes and data bytes by sampling the A8 MODE line (U33p10) during each write cycle. The line is high during status byte and low during data byte inputs. See Figure 4.24 for a simplified timing diagram.

4.5.7.3.3 The chip-select signal $\overline{BY2}$ is shared by both the display and keyboard circuitry. This signal line is supplied to the display circuitry as the rising-edge "write" strobe (see previous paragraph) and to the keyboard circuitry as the falling-edge "read" strobe.

4.5.7.3.4 After all eight data bytes have been latched into display driver U2, it begins to "refresh" the 7-segment display and annunciator LEDs. This "refreshment" process is initiated by the display driver supplying a multiplexed excitation pattern (a to g) to all seven LED row driver outputs (DS1 to DS7). The display driver then turns on one column (digit) driver which illuminates the addressed LEDs in that column. After a fraction of a millisecond, the display driver turns off the column driver, changes the 7-segment excitation pattern, and then turns on the next column driver. This process continues until all LEDs have been "refreshed."

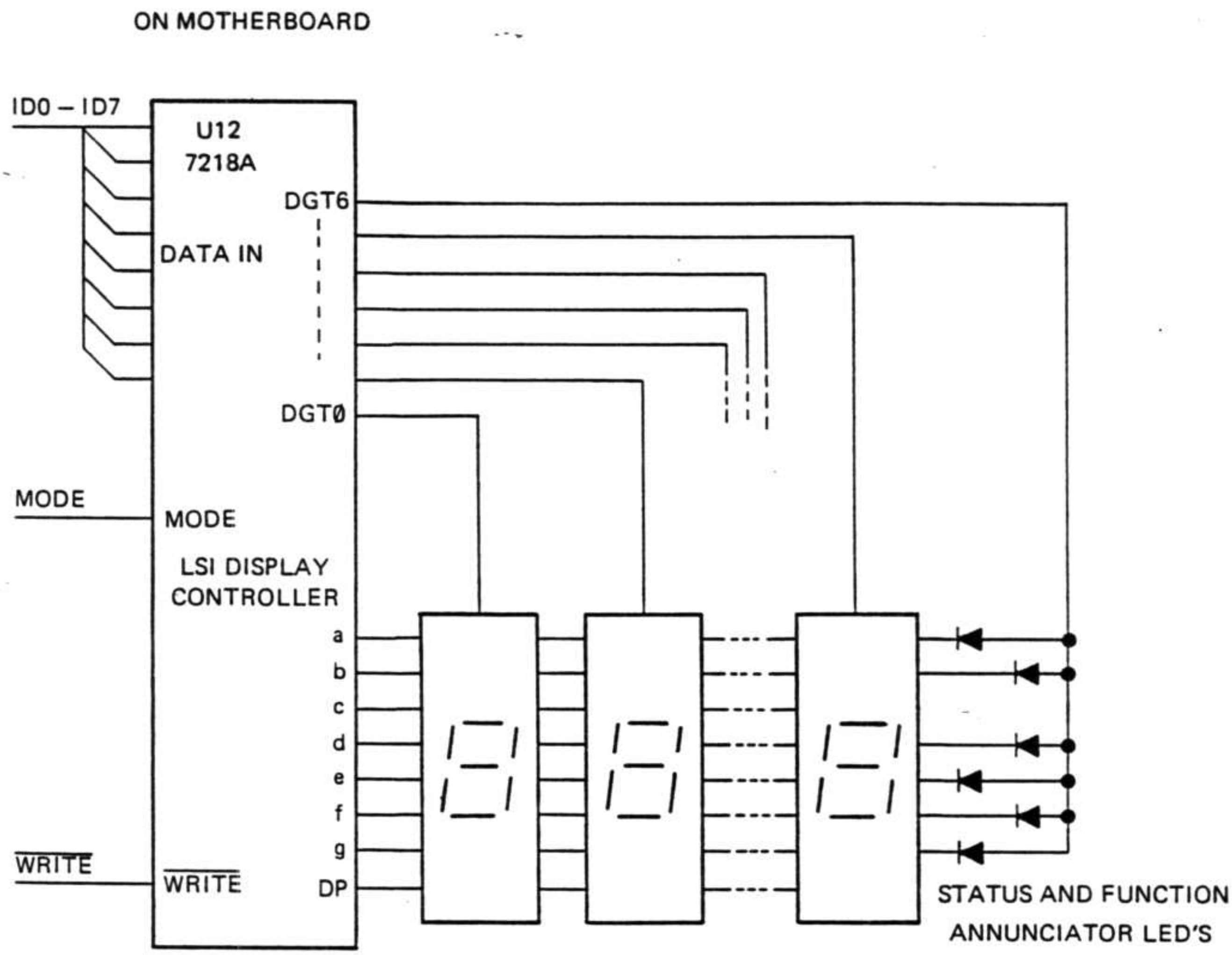


Figure 4.23 - 5001 LED Display Block Diagram

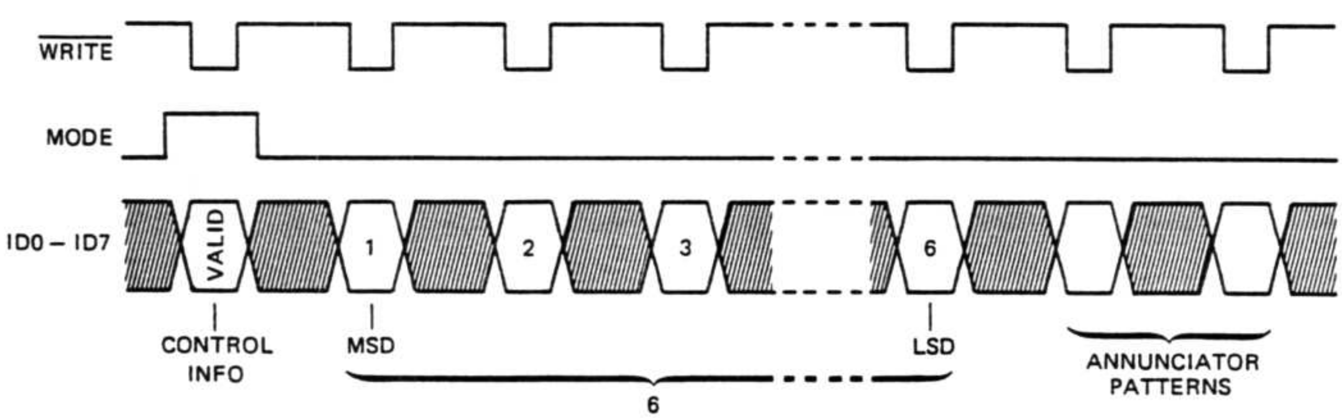


Figure 4.24 - 5001 Display Timing Diagram

5.1 SCOPE

5.1.1 The Maintenance Section is comprised of four major subsections: Specification Checks, Calibration Procedures, Basic Troubleshooting, and Signature Analysis. The calibration procedures include performance tests and calibration adjustments.

5.2 PERFORMANCE VERIFICATION PROCEDURE (PVP)

5.2.1 Scope

5.2.1.1 This section contains the 5001's PVP that compares the operation of the instrument against the published specifications presented in the front of this manual. It is intended to be used for incoming inspection and as a periodic check to determine if the calibration of the instrument meets published specifications. The PVP provides sufficient checks to verify proper operation and whether the instrument is within the 90-day accuracy limits. The required ambient temperature of the environments is 23 ± 5 degrees centigrade.

5.2.2 Required Equipment

5.2.2.1 A list of equipment is given in Table 5.1 for conducting a 5001 Performance Verification. The specific types of equipment recommended are listed under the Suggested Equipment heading. This list is only a guide for selecting suitable equipment having characteristics equal to or better than the items listed.

5.2.3 DC Voltage Sources

5.2.3.1 To produce voltage levels of necessary accuracy, special techniques are required. Suitable methods of generating these voltages are shown in Figure 5.1, Tables 5.2 and 5.3. A precise and traceable source of 10 volts is required not only for calibrating the 10 volt range, but also as a reference for generating highly accurate .1, 1, 100 and 1000 volt levels. The 10 volt source used must satisfy the following requirements:

a) It must be traceable to the National Bureau of Standards;

b) It must have a total accuracy of ± 10 ppm;

c) It must have a low output impedance.

5.2.3.2 A source filling these requirements is shown in Figure 5.1. This circuit consists of null detector, 7-decade voltage divider, a DC voltage supply, and a bank of saturated standard cells. Two advantages of this particular hookup are that; (a) there is minimal loading of the standard cells and (b) stability, not accuracy, is the primary requirement of the DC voltage supply. The output of this circuit is set to a precise 10 volts by setting the voltage divider to the value of the standard cells. The DC voltage supply is then adjusted to produce a null on the null detector. The accuracy of the 10 volt source is within ± 10 ppm. The remainder of the DC sources can be generated by the circuits shown in Table 5.4 and 5.5. Each of these hookups use a calibrated 10 volt source having the characteristics of the one previously described.

5.2.4 Source Errors and 5001 Accuracy

5.2.4.1 The accuracy of the DC voltage sources is obtained by adding the various sources of error in each hookup; errors in this discussion are defined in parts per million (ppm). Table 5.2 shows the errors of each voltage source, the total accuracy for each hookup, the accuracy of the 5001, and the degree to which the sources exceed the required accuracy of the 5001.

Table 5.1 – Required Equipment for Performance Verification

FUNCTION	QTY	ITEM	MINIMUM USE SPECIFICATIONS	SUGGESTED EQUIPMENT
DC	(1)	Saturated Standard Cell Bank (6 cells)	1 ppm, certified	EPPLEY 106
	(2)	DC Voltage Sources	10 V range: ± (0.002% setting + 10 μV) 100 V range: ± (0.002% setting + 0.00002%) 1000 V range: ± (0.002% setting + 0.00002%)	FLUKE 332B
	(2)	Voltage Dividers, Adjustable	resolution of 0.1 ppm of input with 7 decades	FLUKE 720A
	(1)	Decade Resistance Box	accuracy ± (0.01% + 0.0005Ω/decade) 1 kΩ to 10 MΩ	ESI DB62
	(2)	Null Detector/Microvoltmeters	1 μV sensitivity	FLUKE 845AR
AC	(1)	AC Voltage Source	± (0.02% setting + 0.002% range) ± (0.04% setting + 0.002% range) Total accuracy of ± (0.06% setting + 0.004% range) from 10 mV - 750 V, range of 45 Hz - 20 kHz.	FLUKE 5200A FLUKE 5215A
Ω	(8)	Resistance Standards	Known within:	
		100Ω	30 ppm	ESI SR1 with corrections
		1 kΩ	30 ppm	ESI SR1 with corrections
		10 kΩ	30 ppm	ESI SR1 with corrections
		100 kΩ	30 ppm	ESI SR1 with corrections
		1 MΩ	30 ppm	ESI SR1 with corrections
		10 MΩ	30 ppm	ESI SR1 with corrections
OTHER	(1)	Momentary Switch, SPST	-	-
	(1)	Insulated Adjustment Tool	-	JFD 5284
	(1)	100Ω, 10 kΩ, 1 MΩ 1/4 Watt 5% Carbon Resistors	5%	-
	(1)	1 μF Nonpolar Capacitor	-	-
mA	(1)	AC-DC Current Calibrator	± 0.05 setting ± 0.05 range DC to 10 kHz	VALHALLA 2500

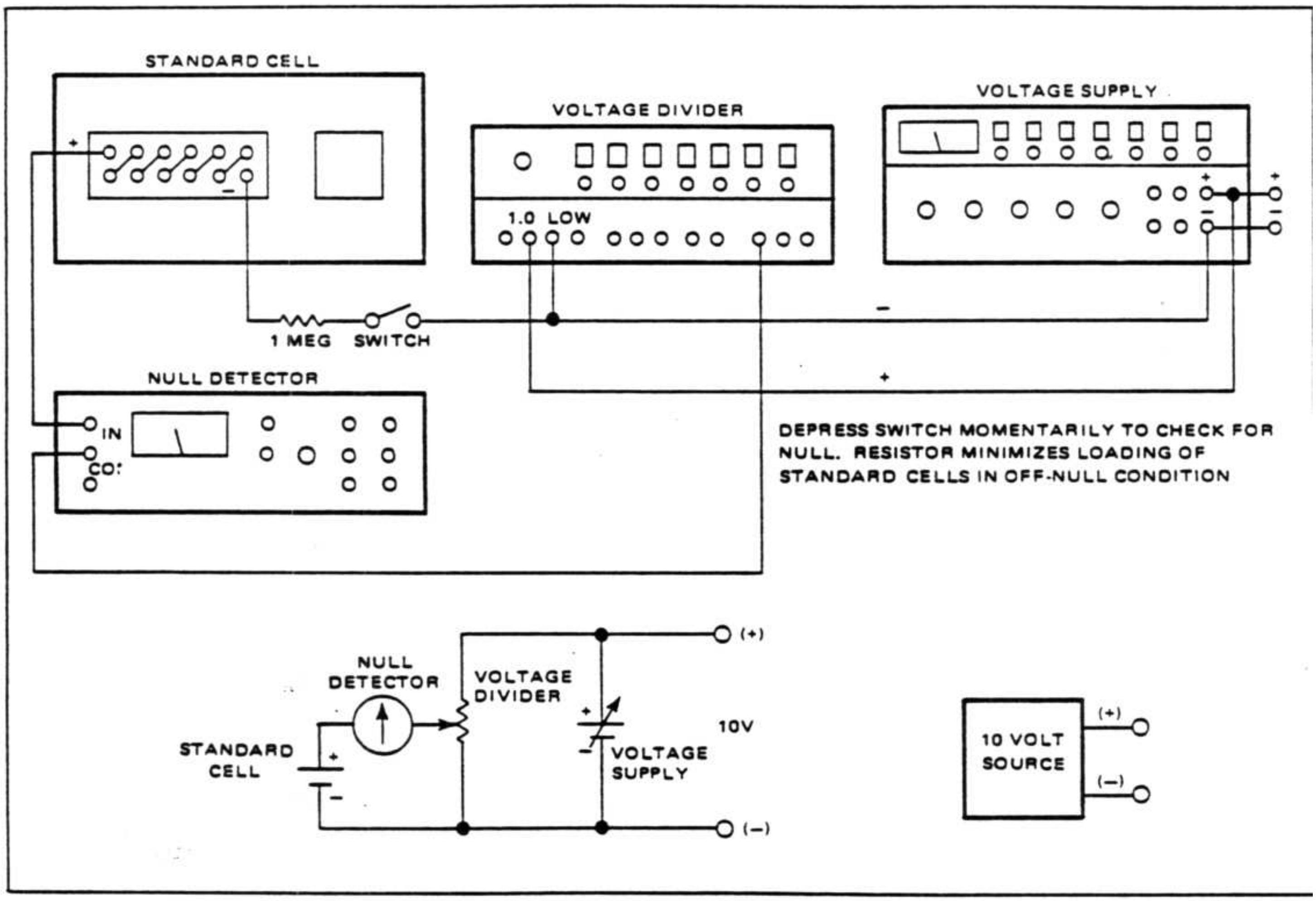


Figure 5.1 - 10 Volt Source

Table 5.2 - DC Source and 5001 Accuracies

Range	10 Volt Source	Voltage Divider	Total Accuracy	24 Hr. 5001 Full Scale Accuracy	Times Better
10	10 ppm	-	10 ppm	100 ppm	10
1	10 ppm	1 ppm	11 ppm	100 ppm	9
.1	10 ppm	1 ppm	11 ppm	100 ppm	9
100	10 ppm	1 ppm	11 ppm	100 ppm	9
1000	10 ppm	1 ppm	11 ppm	100 ppm	9

5.2.5 AC Voltage Source

5.2.5.1 The AC Voltage Source recommended in Table 5.1, or its equivalent, has sufficient accuracy to directly calibrate the 5001. The calibrator accuracy compared to the 24 hour specifications of the 5001 is given in Table 5.3.

Table 5.3 - AC Source and 5001 Accuracies

INPUT		ACCURACIES		
AC Source		AC Source (Maximum Error)	24 hr 5001 Accuracy	Times Better
Volts	Freq			
1.0V	45Hz to 10kHz	±.05%	±0.52%	10
10V		±.05%	±0.52%	10
100V		±.05%	±0.52%	10
500V		±.05%	±0.64%	13
1.0V	10kHz to 20kHz	±.05%	±0.75%	15
10V		±.05%	±0.75%	15
100V		±.05%	±0.75%	15
300V		±.05%	±1.10%	22

5.2.6 Test Procedures

WARNING

The following procedures include the use of high voltage sources producing potentially lethal voltages. Avoid contact with high voltage terminals.

5.2.6.1 Allow two hours for warm-up. Connect the instrument and the test equipment as shown in the figure supplied with each accuracy check. Select the controls and inputs as called out in the tables and monitor the instrument readout for the indicated values.

5.2.6.2 The Specification Check instructions for the 5001 are described in Tables 5.4 through 5.11. A description follows:

a) The DCV high and low range checks presented in Tables 5.4 and 5.5 utilize a 10 volt standard cell to develop the DC accuracy. The voltage standard and voltage divider are referenced to the standard cell through the null detector. The DC source and 5001 accuracy are listed in Table 5.2. The .1 V range measurements are preceded by a Null setting to achieve the listed accuracy.

b) The RMS AC voltage ranges (Table 5.6) are generated by the AC calibrator. This setup is a direct input of the AC calibrator voltages in the 5001 AC ranges.

c) The kΩ specification checks (Table 5.7) are also a direct input of the standard resistor values to the 5001 kΩ ranges. The .1 kΩ range measurements are preceded by a Null setting to achieve the listed accuracy.

d) The DC and AC current specification check instructions presented in Tables 5.8 and 5.9 employ an AC/DC current calibrator to convert the input voltage to a current output. The DC current calibration utilizes the DC voltage standard as in DC calibration and the AC current calibration utilizes the AC calibrator as in AC calibration.

Table 5.4 - DC Function Check (Low Ranges)

DIGITAL MULTIMETER		INPUT SIGNAL				
FUNCTION	RANGE	DC VOLTAGE STANDARD	VOLTAGE DIVIDER SETTING	NOMINAL READING	LIMITS (90 DAY SPEC.)	NOTE
DC	.1 V*	10.00000	.01000	.100000	.099981 - .100019	23°C±5°C
		10.00000	.02000	.200000	.199966 - .200034	(After NULL in .1 V Range
	1 V	10.00000	.10000	1.00000	0.99984 - 1.00016	
		10.00000	.20000	2.00000	1.99972 - 2.00028	

* NULL Instructions

a) Short test leads at point of measurement.
b) If Null LED is lit, depress the NULL key to disable Null function.
c) Depress NULL key again.
d) The displayed reading will be .000000 V ± .000001 VDC.

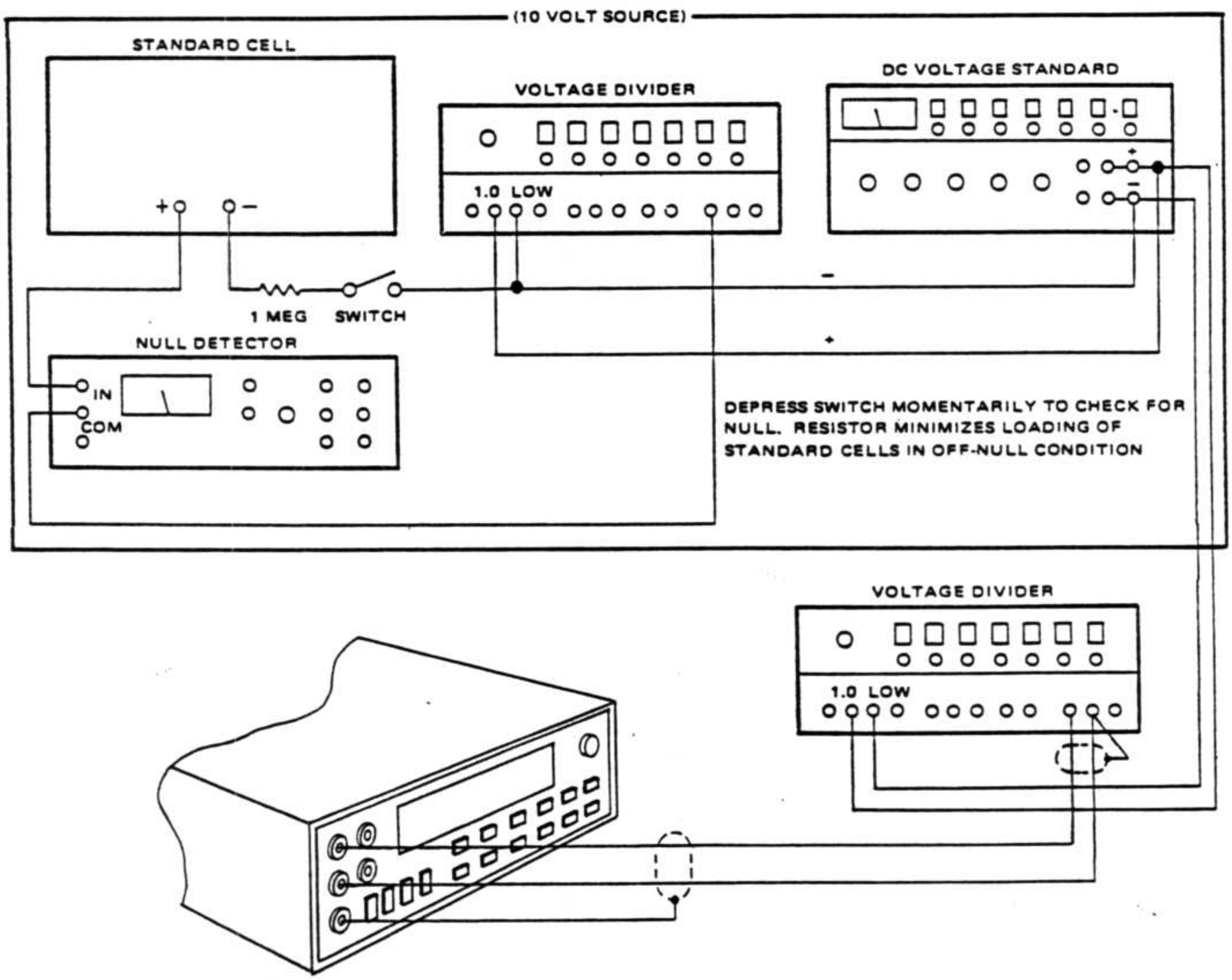


Table 5.5 - DC Function Check (High Ranges)

DIGITAL MULTIMETER		INPUT SIGNAL				
FUNCTION	RANGE	DC VOLTAGE STANDARD	VOLTAGE DIVIDER SETTING	NOMINAL READING	LIMITS (90 DAY SPEC.)	NOTE
DC	10	10.0000V	1.0000	10.0000	9.9981 - 10.0019	23°C±5°C
		20.0000V	.50000	20.0000	19.9966 - 20.0034	
	100	100.000V	.10000	100.000	99.981 - 100.019	
		200.000V	.05000	200.000	199.66 - 200.034	
	1000	1000.00V	.01000	1000.00	999.81 - 1000.19	

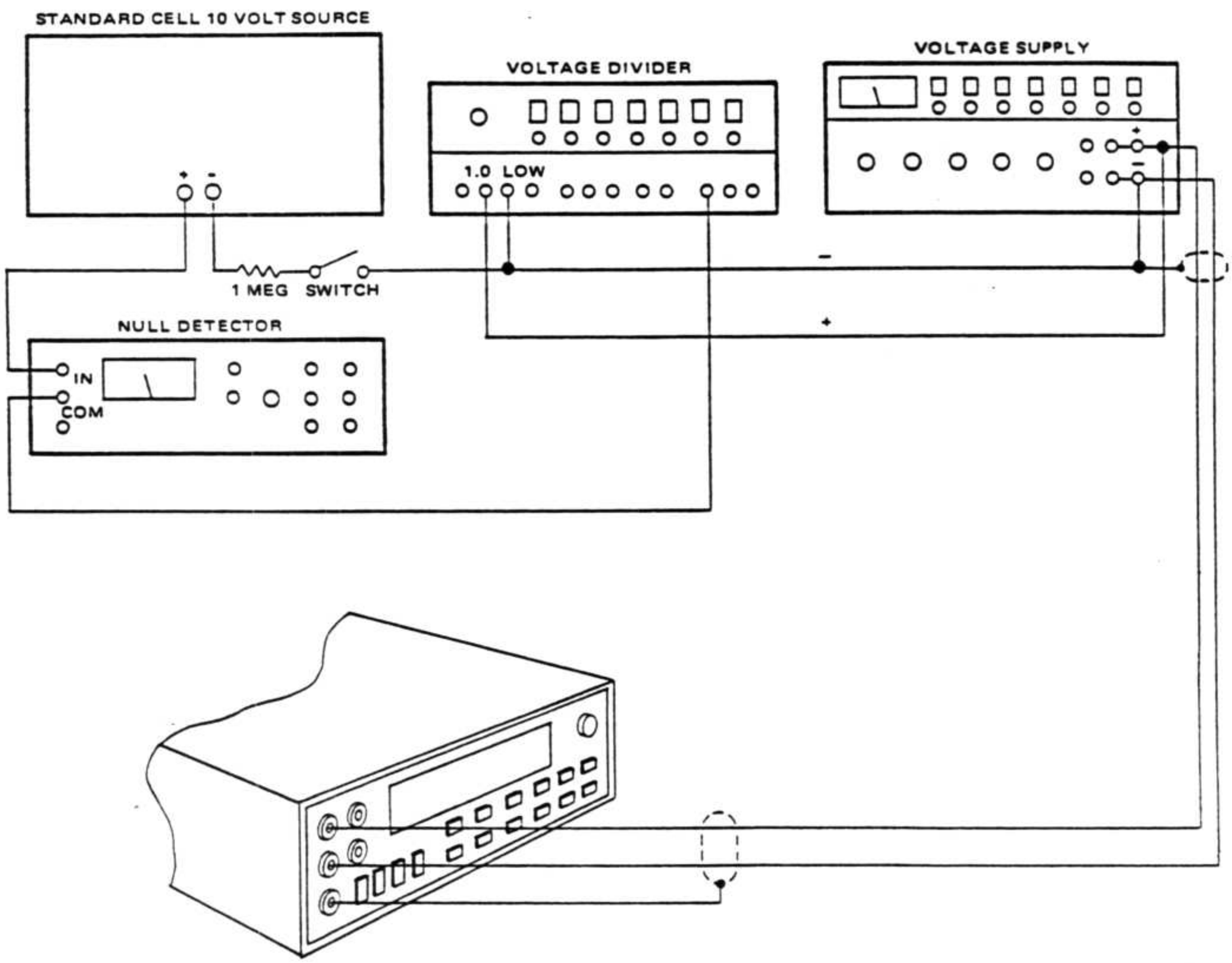


Table 5.6 - RMS AC Function

DIGITAL MULTIMETER		INPUT SIGNAL			
FUNCTION	RANGE	AC RMS VALUE	NOMINAL READING	LIMITS (90 DAY SPEC.)	NOTE
AC	1	1 V @ 400 Hz	1.00000	.99350 - 1.00650	23°C±5°C
		1 V @ 20 kHz	1.00000	.99120 - 1.00880	
	10	10 V @ 400 Hz	10.0000	9.9350 - 10.0650	
		10 V @ 20 kHz	10.0000	9.9120 - 10.0880	
	100	100 V @ 400 Hz	100.000	99.350 - 100.650	
		100 V @ 20 kHz	100.000	99.120 - 100.880	
	1 k	750 V @ 400 Hz	750.00	744.00 - 756.00	
		300 V @ 20 kHz	300.00	296.10 - 303.90	

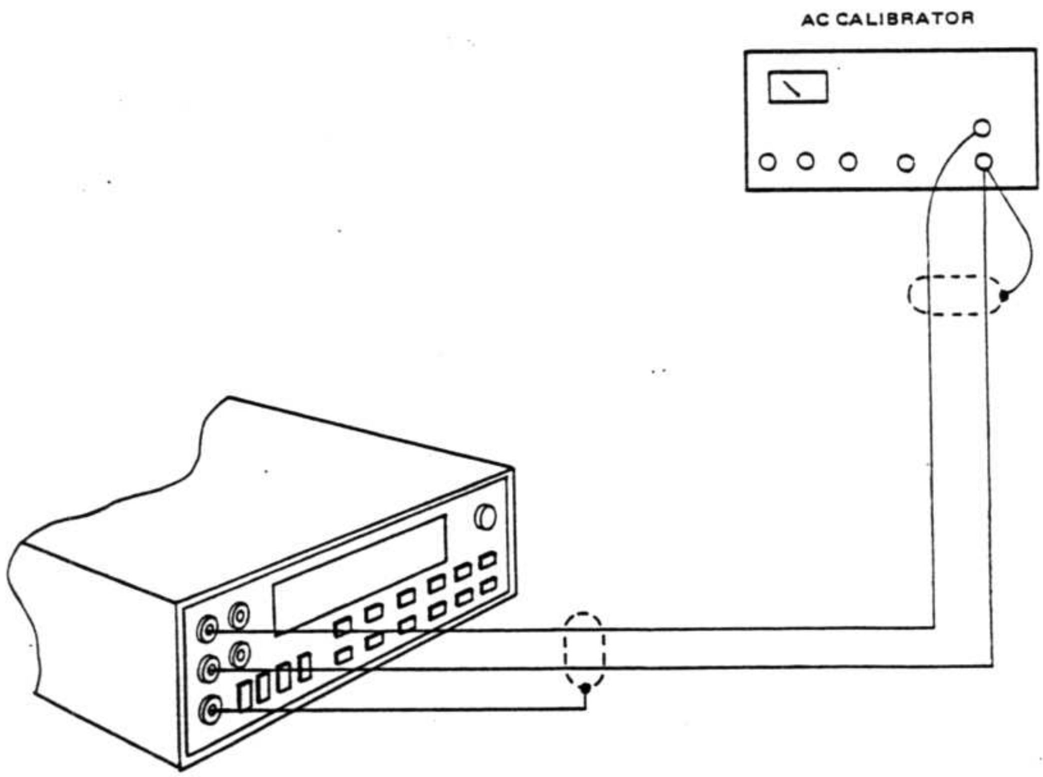


Table 5.7 - K Ohms Function

DIGITAL MULTIMETER		INPUT SIGNAL		
FUNCTION	RANGE	NOMINAL STANDARD VALUE	TOLERANCE (90 DAY SPEC.)	NOTE
kΩ	.1 kΩ*	100Ω	±34 digits	23°C±5°C (After Null in .1 kΩ range)
	1 kΩ	1 kΩ	±39 digits	
	10 kΩ	10 kΩ	±39 digits	
	100 kΩ	100 kΩ	±39 digits	
	1000 kΩ	1 MΩ	±39 digits	
	10000 kΩ	10 MΩ	±85 digits	

* NULL Instructions

a) Short leads at point of measurement.
b) If Null LED is lit, depress the NULL key to disable Null function.
c) Depress NULL key again.
d) The displayed reading will be .000000 kΩ ± .000001 kΩ.

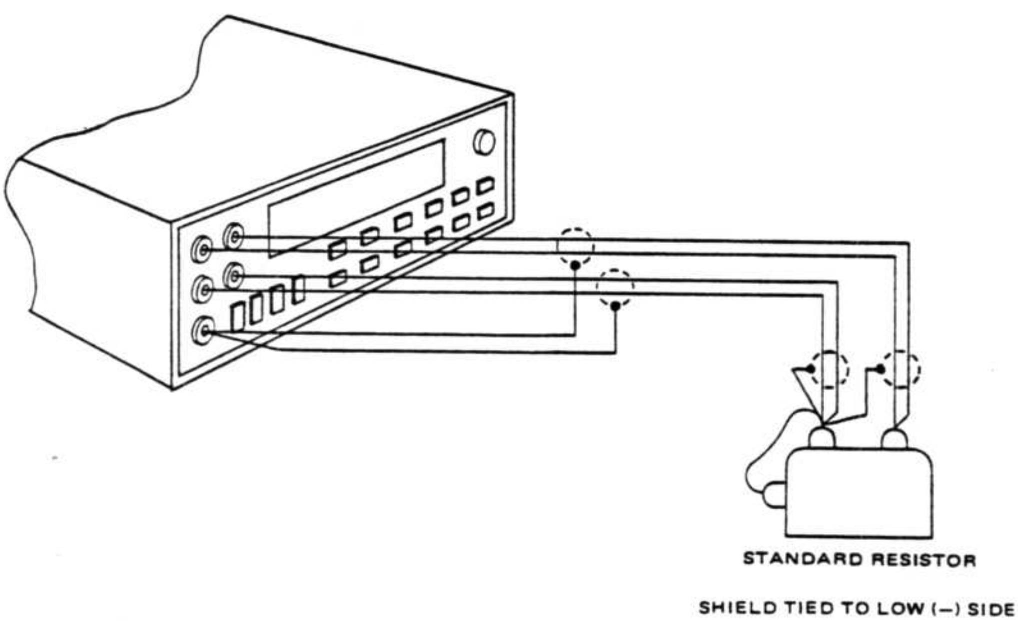


Table 5.3 - DC Current Function Check

DIGITAL MULTIMETER		INPUT SIGNAL				
FUNCTION	RANGE	DC VOLTAGE STANDARD	CURRENT CALIBRATOR SETTING	NOMINAL READING	LIMITS (90 DAY SPEC.) (4-1/2 DIGIT MODE)	NOTE
DCmA	1	1.00000	1 mA	1.0000	.9983 - 1.0017	23°C±5°C
		2.00000	1 mA	2.0000	1.9968 - 2.0032	
	10	1.00000	10 mA	10.000	9.983 - 10.017	
		2.00000	10 mA	20.000	19.968 - 20.032	
	100	1.00000	100 mA	100.00	99.83 - 100.17	
		2.00000	100 mA	200.00	199.68 - 200.32	
	1000	1.00000	1 A	1000.0	996.2 - 1003.8	
		2.00000	1 A	2000.0	1992.7 - 2007.3	

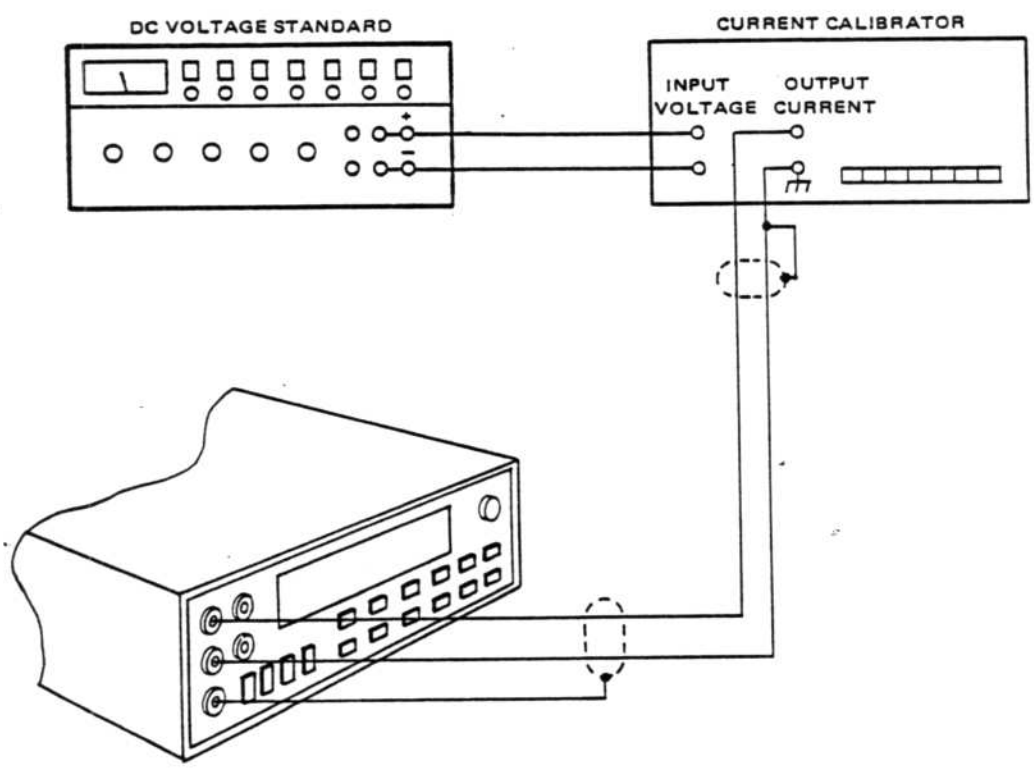


Table 5.9 - AC Current Function Check

DIGITAL MULTIMETER		INPUT SIGNAL				
FUNCTION	RANGE	DC VOLTAGE STANDARD	CURRENT CALIBRATOR SETTING	NOMINAL READING	LIMITS (90 DAY SPEC.) (4-1/2 DIGIT MODE)	NOTE
ACmA	1	1.00000	1 mA	1.0000	.9921 - 1.0079	23°C±5°C
		2.00000	1 mA	2.0000	1.9856 - 2.0144	
	10	1.00000	10 mA	10.000	9.921 - 10.079	
		2.00000	10 mA	20.000	19.856 - 20.144	
	100	1.00000	100 mA	100.00	99.21 - 100.79	
		2.00000	100 mA	200.00	198.56 - 201.44	
	1000	1.00000	1 A	1000.0	990.6 - 1009.4	
		2.00000	1 A	2000.0	1982.6 - 2017.4	

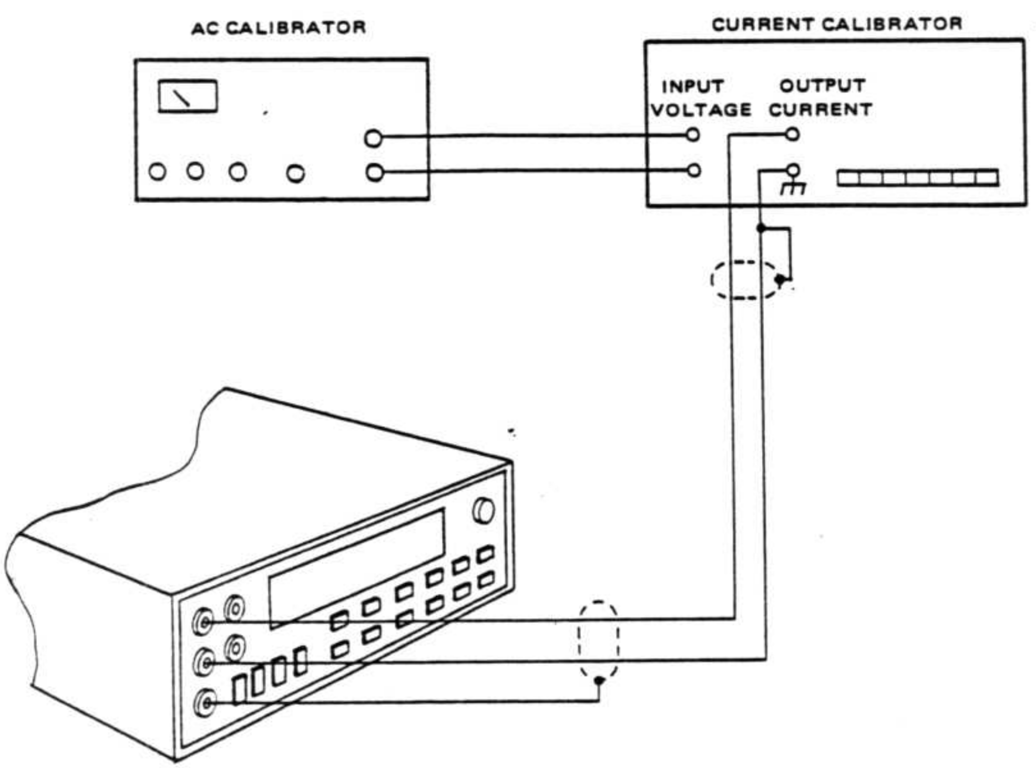


Table 5.10 - Normal Mode Noise Rejection (In DC Volts Function)

DIGITAL MULTIMETER		INPUT SIGNAL				
FUNCTION	RANGE	DC	AC	NOMINAL READING	TOLERANCE	NOTE
DC	10	0.5 V	7.07 V RMS 60 Hz*	00.5000	± 100 digits	-60 dB

* 50 Hz for 50 Hz Instruments

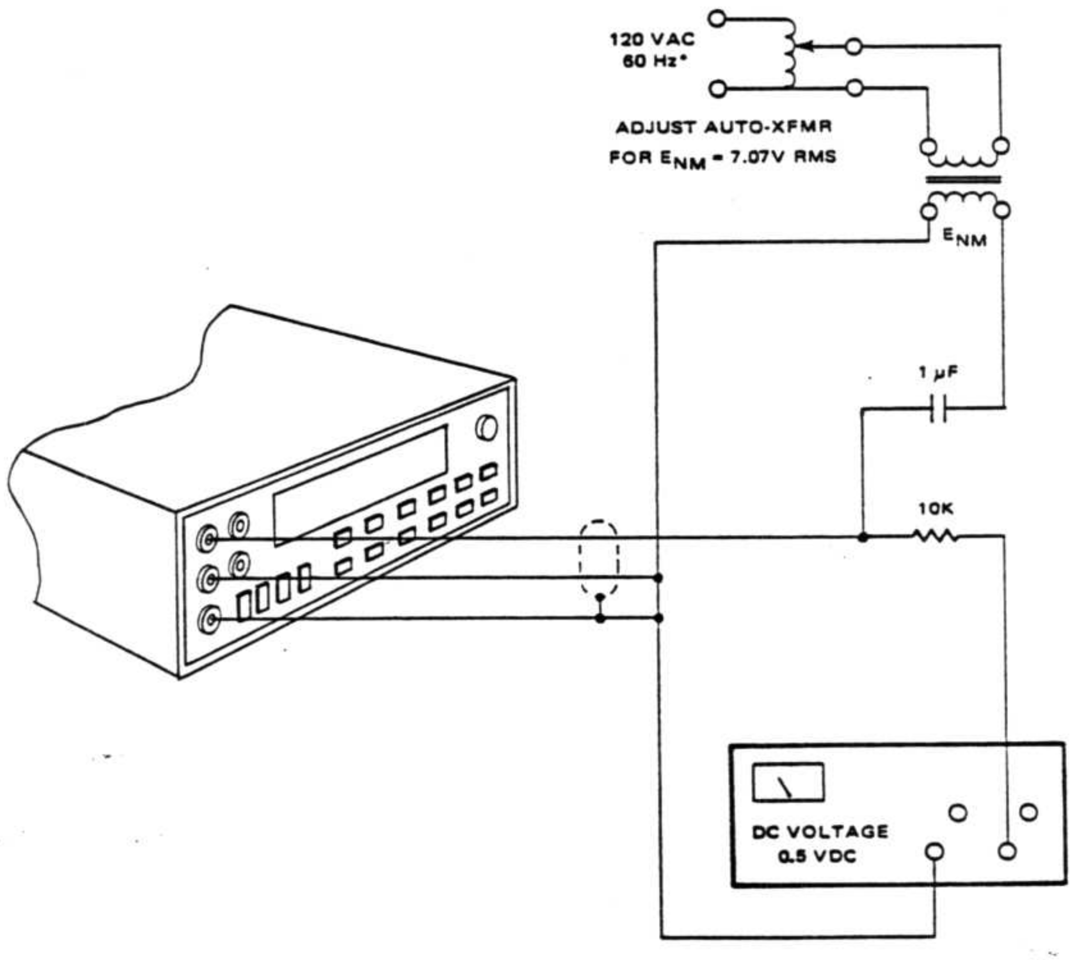


Table 5.11a - Common Mode Rejection (In DC Volts Function)

IGITAL MULTIMETER		INPUT SIGNAL		TOLERANCE SEE NOTE 1	NOTE
FUNCTION	RANGE	S1			
DCV	1 V	Off			1) With switch S-1 in the OFF position, use the Null function to zero the display.
		DC	1000 V	±100 µV	
		AC	107 V RMS 60 Hz*	300 µV peak-to-peak	

* 50 Hz for 50 Hz Instruments

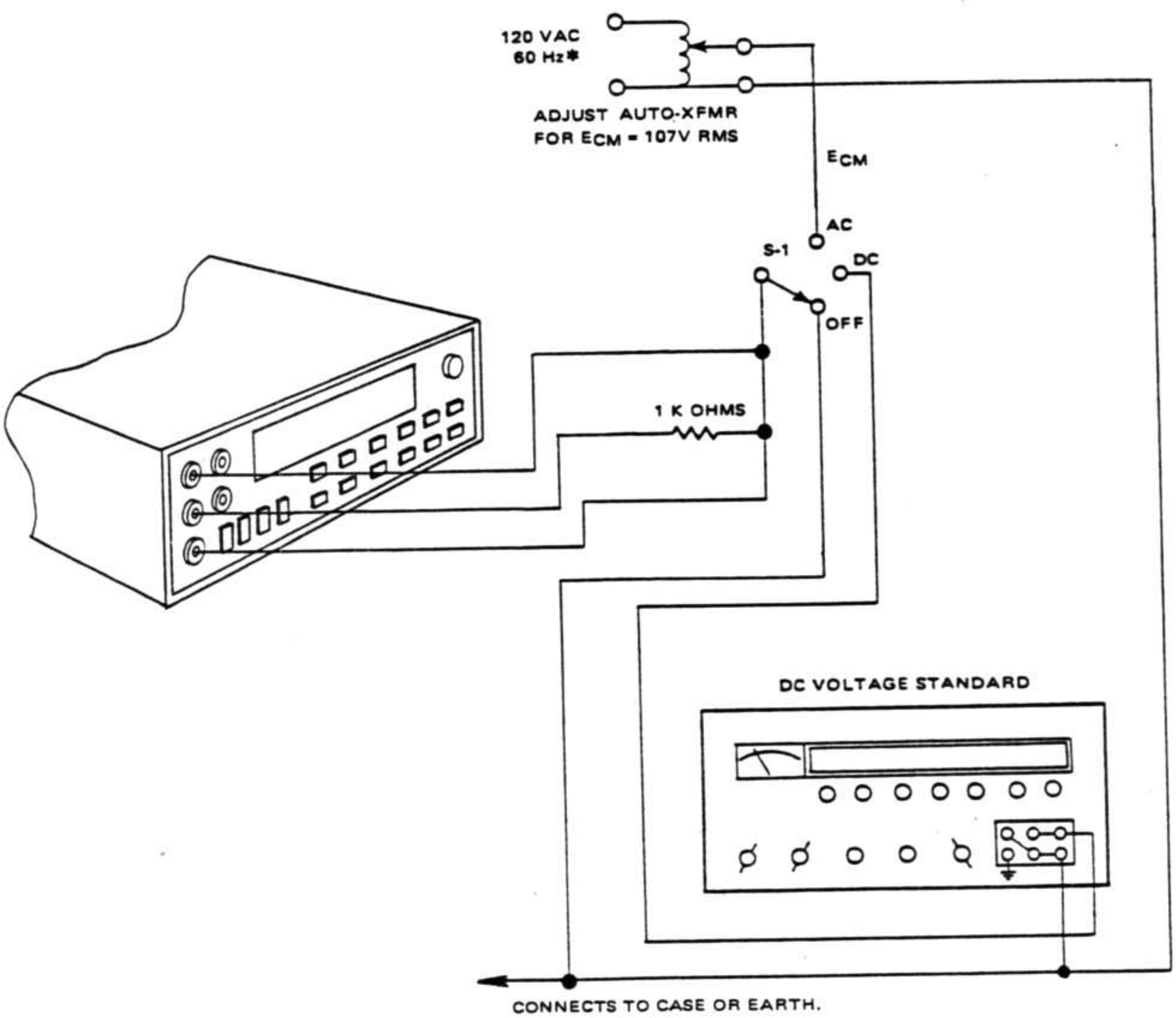
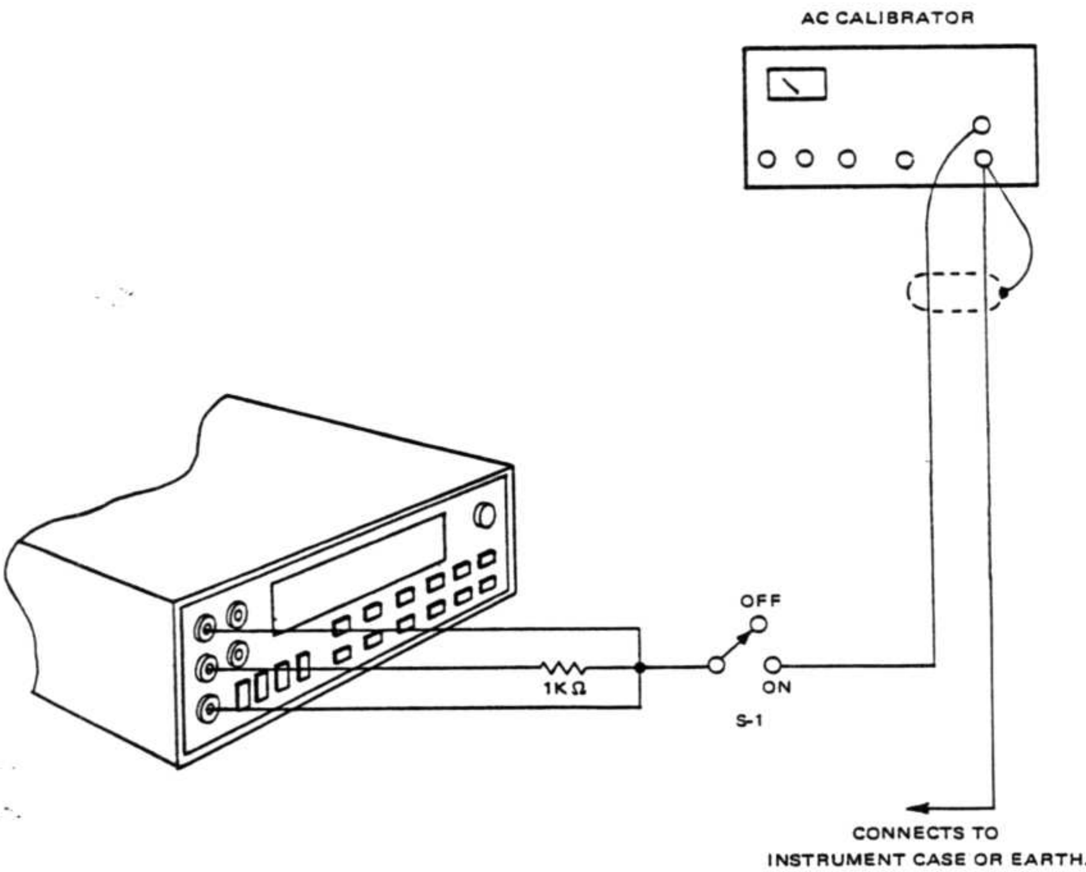


Table 5.11b - Common Mode Rejection (In AC Volts Function)

DIGITAL MULTIMETER		INPUT SIGNAL	TOLERANCE SEE NOTE 1	NOTE
FUNCTION	RANGE			
ACV	1 V	7.07 V RMS DC-60 Hz	±10 mV	1) With switch S-1 in the OFF position, use the Null function to zero the display.



e) The Normal Mode Noise Rejection check (Table 5.10) and the DC Common Mode Rejection ratio check (Table 5.11a) are configured using the DC voltage standard, switches, and transformer components. Special notations on Table 5.11a describe the specification check procedures.

f) The AC Common Mode Rejection ratio check (Table 5.11b) is configured using the AC Voltage standard along with other components. Special notations in Table 5.11b describe the specification check procedures.

WARNING

The following procedures include the use of high voltage sources producing potentially lethal voltages. Avoid contact with high voltage terminals.

5.3 CALIBRATION

5.3.1 Introduction

5.3.1.1 This instrument was calibrated to published specifications under closely controlled conditions prior to shipment. The procedures in this section are designed to recalibrate the instrument and keep the instrument operating within specifications.

5.3.2 Required Equipment

5.3.2.1 A list of equipment required for calibration is given in Table 5.1. The specific equipment types are given only as a guide. If substitutions are made, the substituted equipment must meet or exceed the specifications of the equipment listed.

5.3.3 DC & AC Voltage Sources

5.3.3.1 See Sections 5.2.3, 5.2.4, and 5.2.5 for the DC and AC voltage source.

5.3.4 Calibration Principles

5.3.4.1 Calibration procedure for the 5001 utilizes microprocessor-controlled adjustments. The calibration adjustments are executed through keyboard input commands.

5.3.4.2 The Non-Volatile Memory Constants of the 5001 enable the microprocessor to perform software corrections to readings. Inputs are applied to the 5001 from the calibration standard and the reading is incremented or decremented via keyboard control until the reading equals the input standard. During this process, the numeric constants for analog offset voltages and scale factor corrections are loaded into the Non-Volatile Memory by the microprocessor (µP). These constants are then used by the µP to correct each 5001 reading before display.

5.3.4.3 In order to enter a correction constant into the Non-Volatile Memory, three conditions are required:

a) The correct input standard for the function and range selected is applied to the 5001.

b) The calibration switch (CAL-SW) must remain depressed during the adjustment process.

c) A keyboard input command is required to store nominal offset/scale factors or to increment or decrement the reading to equal the applied input standard.

IMPORTANT REMINDER

KEYBOARD CALIBRATION COMMANDS ARE "NOT" EFFECTIVE UNLESS THE CAL-SW IS HELD IN THE DEPRESSED POSITION. NUMBERS ARE ENTERED INTO THE NON-VOLATILE MEMORY ONLY WHEN THE CAL-SW IS IN THE "DEPRESSED POSITION."

5.3.4.4 The CAL-SW is a momentary contact switch accessible through an opening on the front panel (see Figure ~~4.1~~ 3.1, No. 5 for location). The switch can be depressed by inserting an appropriate size screwdriver or similar tool through the opening.

5.3.4.5 The 5001 Function, Range and Input Standard for each entry into the Non-Volatile Memory is listed in Table 5.12. One offset correction factor is entered in the VDC, VAC and Ohms Function and a scale factor is entered for each range in each function (23 total). A negative Scale Factor is also entered for the DC Function.

5.3.5 Entry of Calibration Constants

5.3.5.1 The 5001 procedure to enter corrections using the keyboard command is as follows:

a) Offset Correction Factors: Zero volts or ohms are applied to the 5001.

b) Scale Factor Corrections: A full scale input is applied in each function and range.

c) Depress the CAL-SW and hold depressed while executing entries.

d) Three input keys on the keyboard which perform the UP count, DOWN count, and NOMINAL functions are described below. Refer to Figure 5.2.

   1) UP Key: Performed by depressing the NULL key and referred to as NULL/UP. This key increments the numbers in memory while the CAL-SW is held depressed.

   2) DOWN Key: Performed by depressing the LAH key and referred to as LAH/DOWN. This key decrements the numbers in memory while the CAL-SW is held depressed.

   3) NOMINAL Key: Performed by depressing the △% key and referred to as △%/NOMINAL. This key initializes the numbers in memory while the CAL-SW is held depressed, as explained in the next paragraph.

5.3.5.2 The △%/NOMINAL key is used to initialize the numbers in Non-Volatile Memory. When this key is depressed and released, either a zero is entered into the Non-Volatile Memory as an offset correcton factor for the presently selected function, or a calculated nominal correction factor is entered as the scale factor for the presently selected range. To enter a nominal offset correction factor, simply apply a "small" input signal (less than 25% of Full Scale) and press the △%/NOMINAL key. To enter a nominal scale factor proceed as follows:

a) Connect an input signal which is approximately full scale. For instance, connect 10.00 VDC when setting nominals on the 10 VDC range (one exception - when setting nominals on the 1 K VAC range, connect 500 VAC rather than 1000 volts).

b) Depress the △%/NOMINAL key and release. If the input differs from full scale during the above procedure, the time required to perform the final increment/decrement of the scale factor will be increased.

5.3.5.3 The LAH/DOWN key decrements the numbers in the Non-Volatile Memory. This action is described as follows:

a) When entering an offset correction factor, this key changes the reading in a "negative-going" direction. For example, if the 5001 reading is .00023 for zero input in the DC function, each time the LAH/DOWN key is depressed and released, the reading will decrease one digit. Upon reading .00000, calibration of DC offset correction factor is complete. Further depression of this key will cause the reading to increase with a negative polarity indication.

b) When entering scale factors, each depression of the LAH/DOWN key will decrease the displayed reading one digit when a Full Scale Input is applied.

c) When the decrements required for corrections are numerous, holding the LAH/DOWN key depressed longer than two seconds will decrement the readings at a faster rate as long as the key remains depressed.

5.3.5.4 The NULL/UP key increments the numbers in the Non-Volatile Memory. This action is described as follows:

a) When entering an offset correction factor, this key changes the reading in a "positive-going" direction. For example, if the 5001 reading is .00023 for zero input in the DC function, each time the NULL/UP key is depressed and released, the reading will decrease one digit. Upon reaching .00000, calibration of the DC offset correction factor is complete. Further depressing of this key will cause the reading to increase with a positive polarity indication.

b) When entering scale factors, each depression of the NULL/UP key will increase the displayed reading one digit as a Full Scale input is applied.

c) When the increments required for corrections are numerous, holding the NULL/UP key depressed longer than two seconds will increment the readings at a faster rate as long as the key remains depressed.

5.3.6 Calibration Procedure

NOTE

If during the following procedure, 5001 readings are found to be in error by more than 10%, initialize the Non-Volatile Memory (power-on with CAL-SW depressed, as described in Section 5.3.7.1) with "reasonable" Cal factors to prevent improper function of the Cal Memory. If repairs were completed recently, refer to Section 5.3.7 for instructions.

5.3.6.1 AC Frequency Linearity Check

This check is necessary to ensure that the AC function will meet its specifications after a front panel (Non-Vol) calibration. Instruments which have undergone severe mechanical vibrations may not pass this check and they should be adjusted before calibration is continued.

a) Power-on the 5001. Select AC function. Apply the inputs listed in Table 5.13.

b) Verify that Rdg. #1 minus Rdg. #2 falls within the tolerance stated in Table 5.13. In the event that one or more are outside the stated tolerance, refer to Section 5.3.7 for the adjustment procedure.

Table 5.12 - Non-Volatile Memory Constants

Memory Constant	Calibration Conditions Function	Range	Input
DC Offset	DC	.1 V	Zero
.1 V Scale Factor	DC	.1 V	+.1 VDC
1 V Scale Factor	DC	1 V	+1 VDC
DC Negative Scale Factor	DC	1 V	-1 VDC
10 V Scale Factor	DC	10 V	+10 VDC
100 V Scale Factor	DC	100 V	+100 VDC
1 kV Scale Factor	DC	1kV	+1 kVDC
AC Offset	AC	1 V	10 mV RMS, 1 kHz
1 V Scale Factor	AC	1 V	1 V RMS, 1 kHz
10 V Scale Factor	AC	10 V	10 V RMS, 1 kHz
100 V Scale Factor	AC	100 V	100 V RMS, 1 kHz
1 kV Scale Factor	AC	1 kV	500 V RMS, 1 kHz
Ohms Offset	kΩ	.1 kΩ	Zero (4-wire)
.1 kΩ Scale Factor	kΩ	.1 kΩ	100Ω
1 kΩ Scale Factor	kΩ	1 kΩ	1 kΩ
10 kΩ Scale Factor	kΩ	10 kΩ	10 kΩ
100 kΩ Scale Factor	kΩ	100 kΩ	100 kΩ
1000 kΩ Scale Factor	kΩ	1000 kΩ	1 MΩ
10,000 kΩ Scale Factor	kΩ	10,000 kΩ	10 MΩ
1 mA DC Scale Factor	DC mA	1 mA	+1 mA DC
10 mA DC Scale Factor	DC mA	10 mA	+10 mA DC
100 mA DC Scale Factor	DC mA	100 mA	+.1 Amp DC
1000 mA DC Scale Factor	DC mA	1000 mA	+1.0 Amp DC
1 mA AC Scale Factor	AC mA	1 mA	1 mA, 200 Hz
10 mA AC Scale Factor	AC mA	10 mA	10 mA, 200 Hz
100 mA AC Scale Factor	AC mA	100 mA	.1 Amp, 200 Hz
1000 mA AC Scale Factor	AC mA	1000 mA	1.0 Amp, 200 Hz

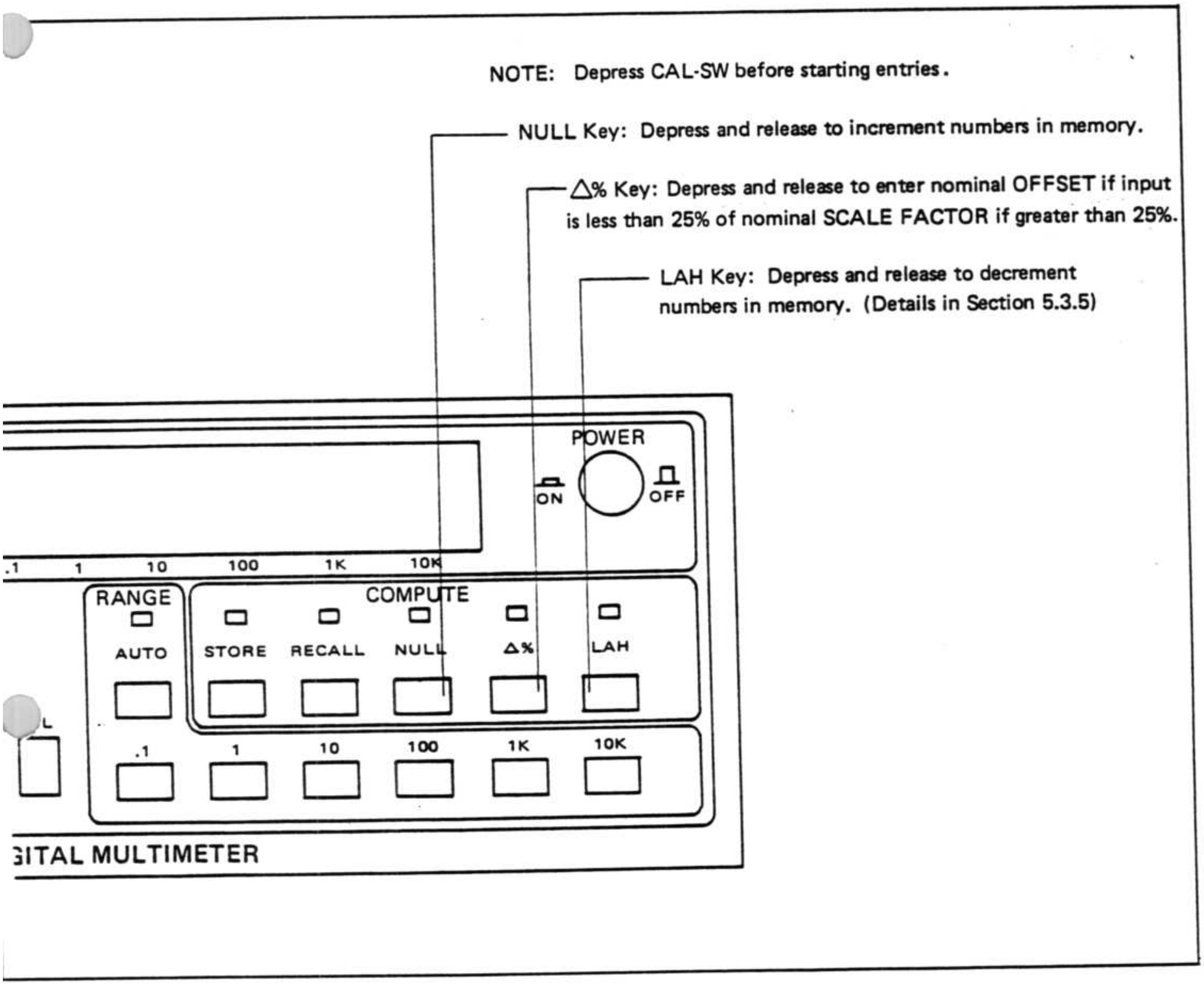


Figure 5.2 - Non-Volatile Memory Entry Keys

Table 5.13 - AC High Frequency Compensation Check

ange	AC Voltage Standard	Set Standard to 2 kHz 5001 Reading #1	Set Standard to 20 kHz 5001 Reading #2	Tolerance Rdg.#1-Rdg. #2
1	1 V RMS			600 digits
10	10 V RMS			600 digits
[illegible]	100 V RMS			600 digits
1000	300 V RMS			300 digits

5.3.6.2 Preliminary Instructions

a) Verify that all shields and covers are installed.

b) Short the INPUT terminals and GUARD terminal together.

c) Allow at least 2 hours warmup with covers installed before proceeding.

5.3.6.3 Calibration Instructions for Entry of Final Values into Non-Volatile Memory.

a) Connect the 5001 to the Input Standard as specified for the first calibration point in Table 5.14. Apply 0.00000 VDC to the 5001 by dialing the voltage divider to zero.

b) Depress and hold the Calibration Switch. Depress the △%/NOMINAL key momentarily.

c) If the reading is not zero (4 digits p-p noise allowed), proceed to step d); if equal to zero, release the Calibration Switch and proceed to step f).

d) Increment or decrement the reading with the LAH/DOWN or NULL/UP keys until the reading is zero.

e) Release the Calibration Switch.

f) Connect the 5001 to the Input Standard as specified for the next calibration point in Table 5.14.

g) If the 5001 reading is not equal to the Input Standard, proceed to step h); if equal to the Standard, release the Calibration Switch and proceed to step k).

h) Depress and hold the Calibration Switch. Depress the △%/NOMINAL key momentarily.

i) If the 5001 reading is not equal to the Input Standard, increment or decrement the reading with the LAH/DOWN or NULL/UP keys until the reading is equal to the Input Standard.

j) Release the Calibration Switch.

k) Repeat steps f) through j) for each calibration point in Table 5.14.

5.3.7 Adjustments After Repairs

5.3.7.1 Initializing Non-Volatile Memory

5.3.7.1.1 After repairs (in Non-Volatile Memory circuit) or battery replacement, unit will need to be totally recalibrated. For faster calibration, manual calibration constants can be stored automatically by performing the following procedure.

Power up the DMM with CAL-SW depressed. This automatically stores "0" as the offset constant for DC, AC and Ohms functions. This also stores "1" as the scale factor for all 23 ranges in the 5001. Error 4 will then be displayed to indicate that the CAL constants in Non-Volatile Memory have been modified.

5.3.7.2 AC Frequency Linearity Adjustment for Units with Serial Numbers after 500500.

5.3.7.2.1 If repairs are made in the analog section of the 5001 or if the unit undergoes a severe mechanical shock, the following procedure may be necessary.

5.3.7.2.2 To determine whether or not this procedure is required, complete Section 5.3.6.1, AC Frequency Linearity Check. If one or more ranges are out of tolerance at high frequencies

(10-20 kHz), adjustments are made by adjusting or modifying the components listed in Figure 5.3 and described in paragraphs a) through d).

a) If reading in 1 V range is out-of-tolerance, adjust trimmer capacitor C12.

b) If reading in 10 V range is out-of-tolerance, adjust trimmer capacitor C13.

c) If reading in 100 V range is out-of-tolerance, modify FSV capacitor C54 (on the circuit side of the PCB). C54 changes reading at 20 kHz approximately 50 digits/pF.

d) If reading in 1 kV range is out-of-tolerance, modify FSV capacitor C56 (on the circuit side of the PCB). C56 changes reading at 20 kHz approximately 2 digits/pF.

NOTE

Maximum allowable input at 20 kHz is 300 V RMS.

5.3.7.3 AC Frequency Linearity Adjustment for Units with Serial Numbers before 500500.

5.3.7.3.1 If repairs are made in the analog section of the 5001, or if the unit undergoes a severe mechanical shock, the following procedure may be necessary.

5.3.7.3.2 To determine whether or not this procedure is required, complete Section 5.3.6.1, AC Frequency Linearity Check. If one or more ranges are out-of-tolerance, adjustments are made by modifying the components listed in Figure 5.4 and described in paragraphs a) through h).

a) If gain in all ranges is too high: Bend R6, C4, C1 away from AR2 or change C4 to 2.7 pF.

b) If gain in all ranges is too low: Bend R6, C4, C1 towards AR2 or change C4 to 3.3 pF.

c) If gain in 1 V range is too high, increase C12 by .5 pF.

d) If gain in 1 V range is too low, decrease C12 by .5 pF. (C12 is located between E2 and E3 on the circuit side of PCB.)

e) If gain in 10 V range is too high, add 3 pF across C13.

f) If gain in 10 V is too low, decrease C13 by 3 pF.

g) If gain in 100 V range is too high, add 33 pF across C16.

h) After changing values for C4 or C12, readjust the frequency response for all ranges if necessary by bending C1, C4 and R6. The 100 V and 300 V adjustments can be made by bending C1, C4 and R6.

Table 5.14 - Calibration Points for Entry of Final Values Into Non-Volatile Memory

Function	Range	Input Standard	Input Connections	Notes
DC	.1 V .1 V 1 V 1 V	0.00000 VDC +0.1 VDC +1.0 VDC -1.0 VDC	Table 5.4	
	10 V 100 V 1 kV	+10.0 VDC +100.0 VDC +1000.0 VDC	Table 5.5	Note 1 - 10 mV AC Scale Factor may interact. Repeat adjustment until both 10 mV and 1.0 VAC display equal input standards.
AC	1 V 1 V 10 V 100 V 1 kV	10.0 mV RMS, 1 kHz* 1.0 V RMS, 1 kHz* 10.0 V RMS, 1 kHz 100.0 V RMS, 1 kHz 500.0 V RMS, 1 kHz	Table 5.6 * Note 1	Note 2 - The value of the Resistance Standard must be known to within the tolerance indicated in Table 5.1.
kΩ	1 kΩ .1 kΩ 1 kΩ 10 kΩ 100 kΩ 1000 kΩ 10,000 kΩ	0.0Ω, 100.0Ω: * Note 3 100.0Ω, 1.0 kΩ, 10.0 kΩ, 100.0 kΩ, 1.0 MΩ, 10.0 MΩ: * Note 2	Table 5.7	Note 3 - 4-Wire ohm Connection must be used to obtain rated accuracy.
DC mA	1 mA 10 mA 100 mA 1000 mA	+1.00 mA DC +10.0 mA DC +100.0 mA DC +1.00 A DC	Table 5.8	
AC mA	1 mA 10 mA 100 mA 1000 mA	1 mA, 200 Hz 10 mA, 200 Hz 100 mA, 200 Hz 1 Amp, 200 Hz	Table 5.9	

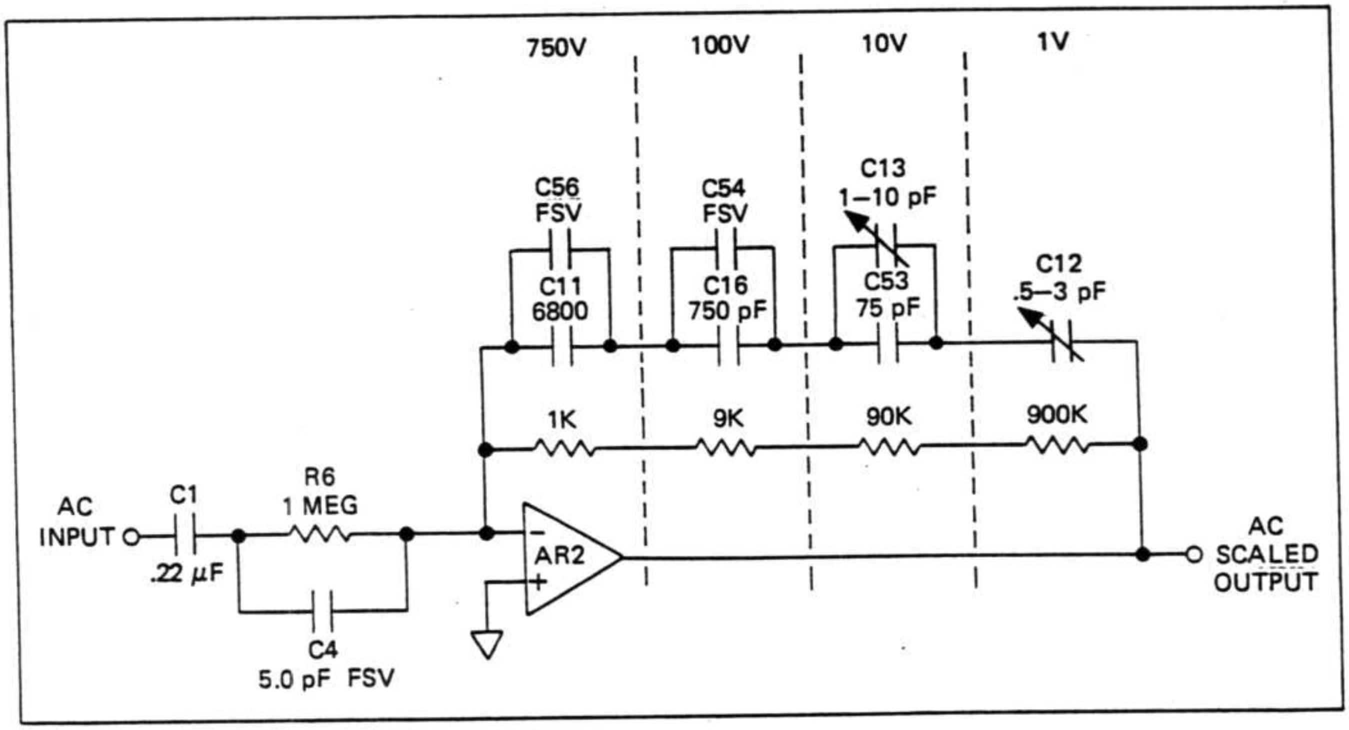


Figure 5.3 – AC Frequency Linearity Adjustment (Serial Numbers after 500500)

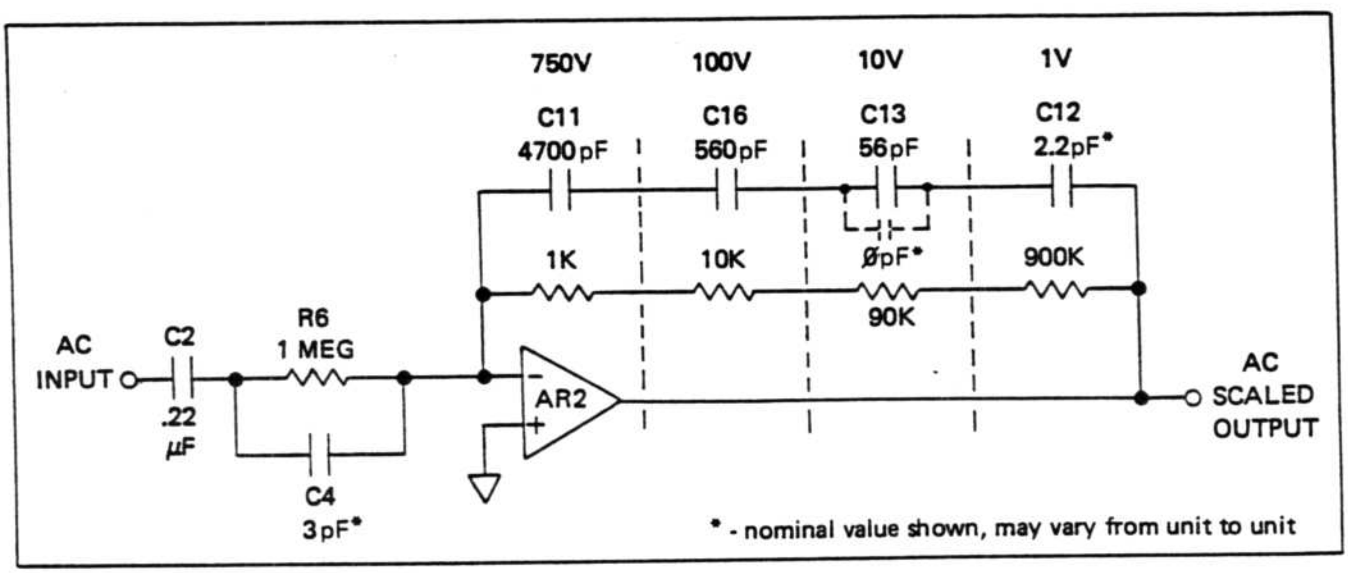


Figure 5.4 – AC Frequency Linearity Adjustment (Serial Numbers before 500500)

5.4 BASIC TROUBLESHOOTING

5.4.1 Introduction

5.4.1.1 This subsection describes basic troubleshooting procedures for the Model 5001 Digital Multimeter and assumes a good knowledge of the instrument's normal operation. Both operator and maintenance personnel can systematically identify and remedy malfunctions in the 5001 by using these diagnostic procedures for fault detection. The 5001 Instruction Manual is an important service reference, hence reading the entire publication is highly recommended.

5.4.1.2 The 5001 has three main electrical sections. They include its (1) power supplies and reference voltages, (2) analog circuitry, and (3) digital circuitry. Each section has its own set of troubleshooting procedures as referenced below.

a) **Power Supplies/Reference Voltages** –see Subsections 4.3 and 5.4.7, respectively, for applicable information covering theory and power supply troubleshooting.

b) **Analog Circuitry** - see Section 4 for applicable information on analog operation theory. Besides conventional troubleshooting techniques, analog circuits in the 5001 can be checked using the special Digitizer Diagnostics (DIAG) troubleshooting mode. DIAG is a software program stored in the 5001 and used to either verify the proper performance of the instrument or to diagnose many isolator/digitizer malfunctions. Refer to Subsection 5.4.10 for a thorough description of the DIAG mode.

c) **Digital Circuitry** - see Section 4 for applicable information on digital operating theory. Besides conventional troubleshooting procedures, digital circuits in the 5001 can be checked using Signature Analysis (SA). Refer to Subsection 5.5 for a detailed description of the SA mode. Briefly, SA is a special 5001 troubleshooting mode permitting the diagnosis of most digital circuitry problems in the 5001. The SA program uses the 5001's own microprocessor (μP) to generate continuous repetitive data patterns which are read at preselected data nodes in the logic circuitry. These patterns are identified using a signature analyzer which displays unique 4-digit alphanumeric codes called test signatures. These are then compared to a set of reference signatures for assessing a specific logic circuit.

5.4.1.2.1 Incorporating DIAG and SA troubleshooting capabilities into the 5001 permits a level of diagnostic service approaching 100 percent.

5.4.1.3 Besides basic troubleshooting, including the DIAG mode, this subsection (5.4) also provides information on the following: safety procedures, 5001 disassembly, signal and circuit references, schematics, DC power supply voltages, and performance tests with waveform references.

5.4.2 Safety Considerations

5.4.2.1 Before starting any 5001 maintenance operation, service personnel should note all **WARNING** and **CAUTION** advisories. All such **WARNING** and **CAUTION** advisories are boxed in the text.

5.4.2.1.1 The equipment described in this subsection involves voltages hazardous to life and safety. The **WARNING** and **CAUTION** advisories are included in this manual to alert all operator and service personnel of these electrical hazards, thereby minimizing the risk of personal injury and equipment

5001, ensure that:

a) The 5001 is configured to operate on the voltage available from the power source.

b) The 5001 has the proper fuse installed for the intended power source.

c) All other services connected or in proximity to the 5001 are properly grounded or connected to the protective third-wire ground.

5.4.3 5001 Disassembly

WARNING

Removal of 5001 instrument covers expose potentially lethal voltages. Avoid contact with internal electrical connections while the 5001 is connected to an AC power source.

5.4.3.1 Top and Bottom Covers - the following procedure should be used to remove the top and bottom covers of the 5001. Refer to Figures 5.5 and 5.6 in completing this procedure.

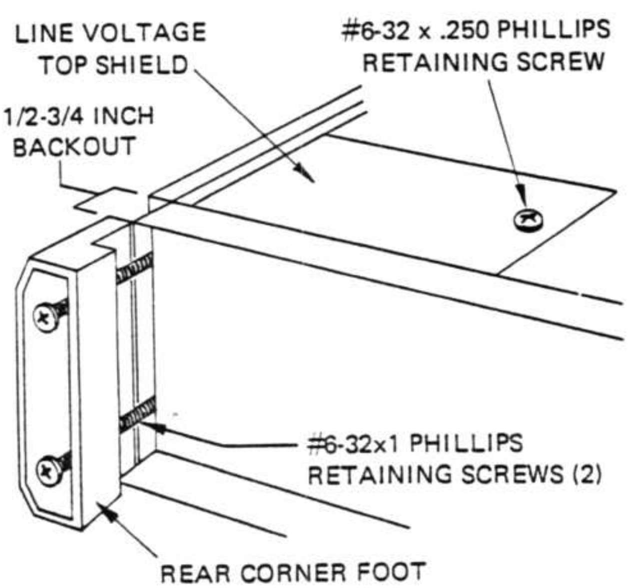


Figure 5.5 - Rear Corner Foot Retraction

NOTE

It is not necessary to remove the two rear corner-feet or any of their retaining screws to remove the top or bottom cover of the 5001. The four bench feet are attached to the bottom cover and do not require separate removal.

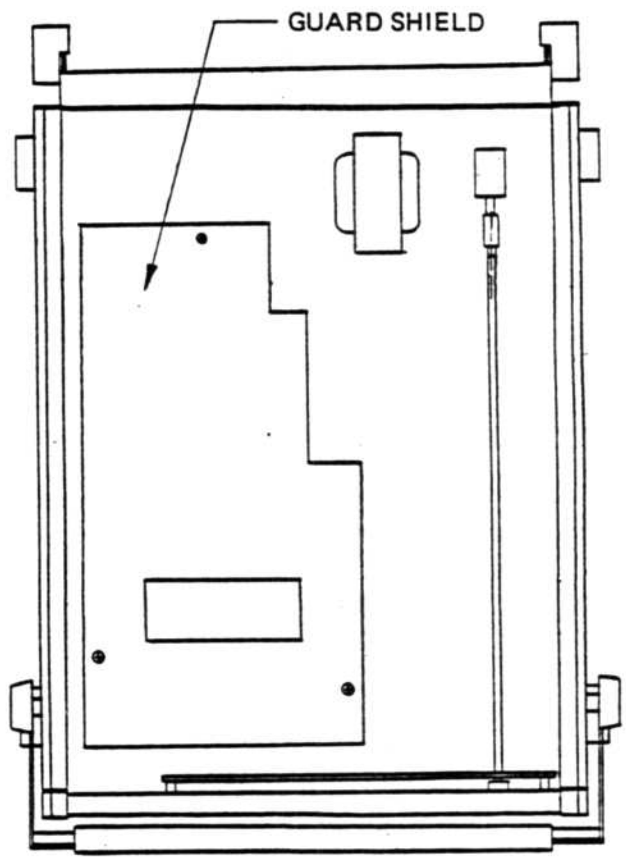


Figure 5.6 - Guard Shield Removal

a) Loosen and retract the two Phillips-head retaining screws from each rear corner-foot.

b) Back out each screw between 1/2 and 3/4 inch.

c) With the two rear corner-feet now loosened, slide both the top and bottom covers towards the rear corner-feet.

d) Lift the top and bottom covers from the 5001's instrument case.

NOTE

If your 5001 is equipped with GPIB Option 55T, first remove the GPIB PCB as shown in the Option 55T Instruction Manual (Pub. No. 980568), Figures 2.1 to 2.7. Use the described procedure in that manual for reinstallation.

e) Remove the guard shield, if necessary, by extracting the three Phillips-head screws securing the shield to the standoffs.

f) Remove the transformer line voltage top shield by extracting the one #6-32 X .250 Phillips-head screw securing it to the transformer box.

g) To reassemble the covers and guard shields, reverse steps a) through g) just described.

NOTE

It is usually unnecessary to remove either the side cover-panels or rear panel for 5001 troubleshooting. However, should it become necessary to remove these panels, follow the procedure detailed below for bench-operated units only.

5.4.3.2 Side Cover Panels - refer to Figure 5.7 as required in completing this procedure.

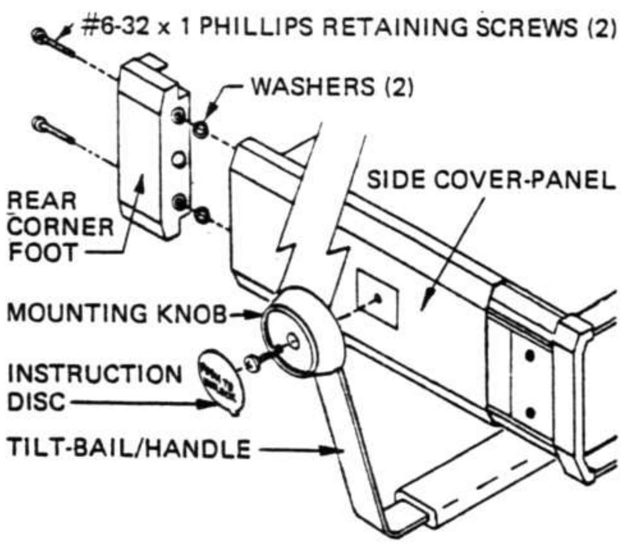


Figure 5.7 - Side Cover Panel Removal

a) Remove the tilt-bail/handle from the 5001 by first prying off the instruction disc from each mounting knob, then extracting the two Phillips-head retaining screws (one on each side) securing the tilt-bail to the side panels.

b) Remove the previously loosened Phillips-head retaining screws, along with their washers, from each rear corner-foot; then detach the two rear corner-feet from the instrument.

c) Remove the two side cover-panels by sliding them toward the rear in their retaining tracks until they are disengaged.

5.4.3.3 Rear Panel - refer to Figure 5.8 and the following procedure when necessary to remove this panel for 5001 troubleshooting.

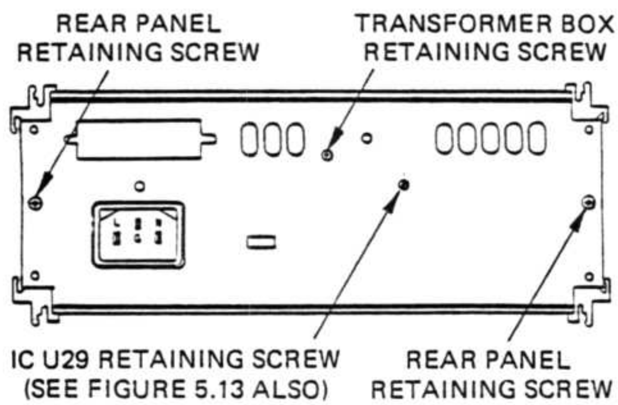


Figure 5.8 - Rear Panel Removal

a) With the two rear corner-feet removed (see Subsection 5.4.3.2-b), extract the screw securing the transformer box and remove the nut securing the ground lug to the rear panel.

b) Remove the two (one on each side) Phillips-head retaining screws on the rear panel which were previously covered by the rear corner-feet.

c) Loosen and remove the nylon #4-40 x 1/2 screw, along with its associated #4 hex nut and two white beryllium washers, fastening soldered IC U29 to the rear panel. Then, carefully remove the free rear panel from the 5001 instrument case. (IC U29 will remain soldered to the main PCB after removing the rear panel.) See Figure 5.13 on page 5-28 which shows the U29 assembly.

5.4.3.4 Main PCB Assembly - refer to Figures 5.9 and 5.10 and use the following procedure to remove the main PCB assembly.

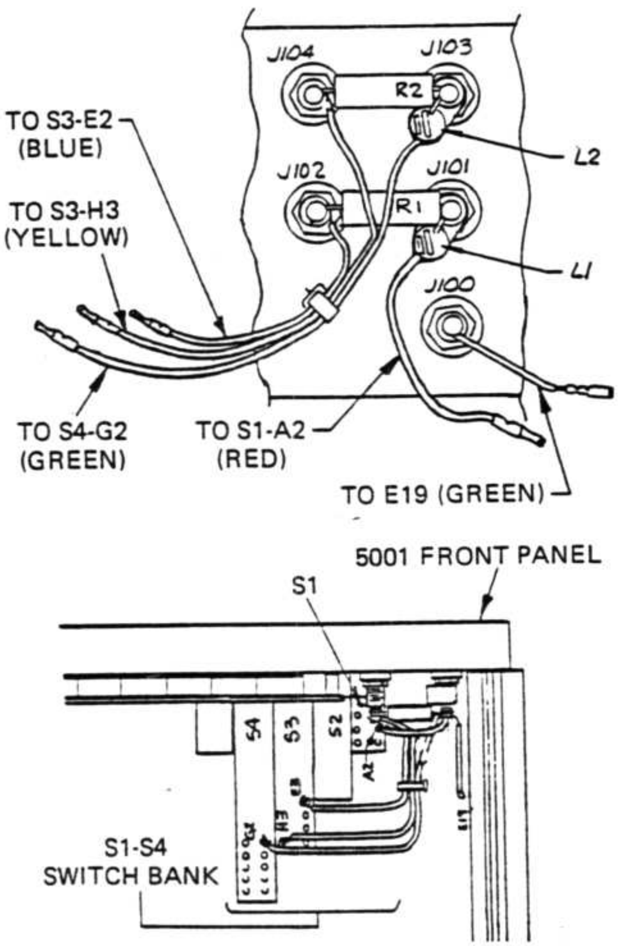


Figure 5.9 - Front Panel Input Terminal Disconnection with Detailed Top View

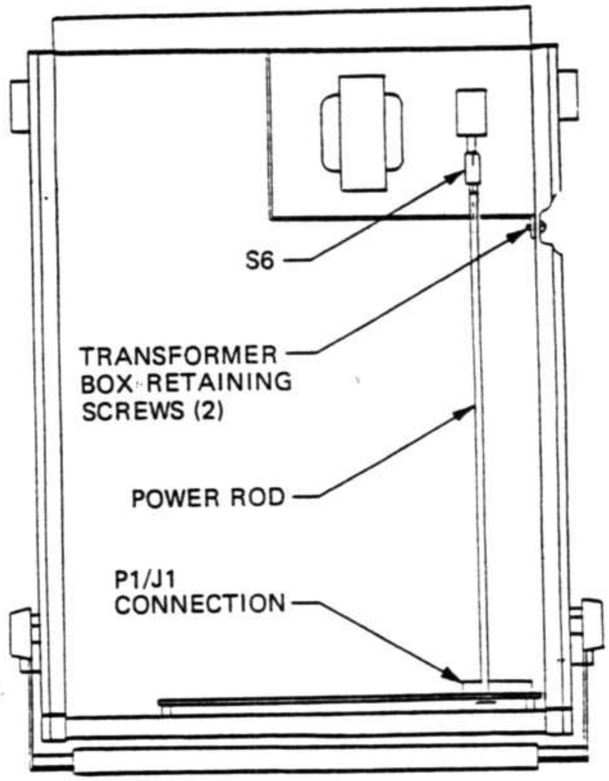


Figure 5.10 - Transformer Box Release and P1/J1 and S6/Power Rod Disconnection

a) With the rear panel and the top and bottom covers removed, disconnect the five connections for the front panel input terminals from the main PCB assembly.

b) Release the transformer box from the side panel by removing the two securing Phillips-head screws.

c) Ease the main PCB assembly toward the rear of the 5001, disconnecting J1 from P1 on the front panel and, also, the power rod from S6. Continue sliding the assembly toward the rear of the unit until it is completely disengaged.

d) To reassemble the main PCB assembly, reverse steps a) to c), just described.

5.4.3.5 Front Panel/Front Panel Display PCB Assembly - refer to Figures 5.11 and 5.12 during the following procedure.

a) With the two side cover panels removed, the four front corner-insert screws (Phillips-head #8-32 x 5/16) are exposed. Loosen and remove all four screws along with the two front corner inserts. Removing the corner inserts exposes the four front panel retaining screws (Phillips-head #6-32 x 1/2).

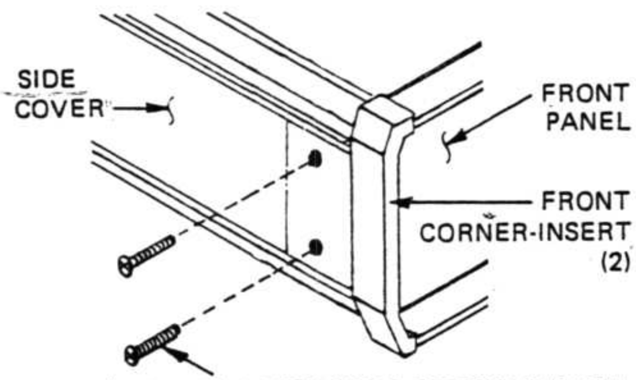


Figure 5.11 - Front Corner Insert Removal

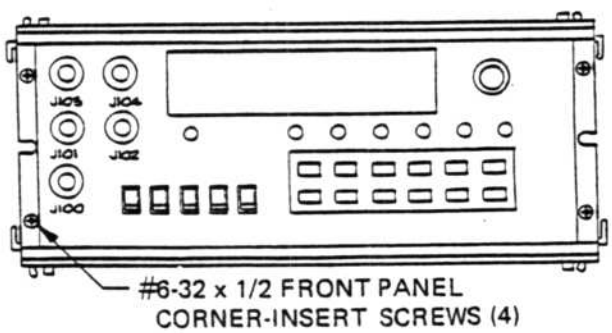


Figure 5.12 - Front Panel Removal

b) If not already completed (see Subsection 5.4.3.4-a and Figures 5.9 and 5.10), disconnect the five connections for the front panel input terminals from the main PCB assembly; then loosen and remove the four front panel retaining screws.

c) Ease the front panel away from the instrument until connector J1 on the main PCB is disconnected from P1 on the display PCB and completely disengaged from the instrument case.

d) Remove, if necessary, the four Phillips-head screws securing the LED Display and Keyboard PCB to the front panel of the unit.

e) At this point, the LED Display and Keyboard are available for servicing.

f) To reassemble the Front Panel/Front Panel Display PCB Assembly, reverse steps a) to e), just described.

5.4.4 Troubleshooting Aids

5.4.4.1 Refer as required to the Simplified Block Diagram shown in Figure 4.1 on page 4-2 during 5001 troubleshooting. Also, Figures 5.14 and 5.16 show the necessary 5001 test point (TP) locations on the main PCB assembly with the latter figure specific to the Input Switching and Attenuator circuitry. Section 6 provides a detailed set of schematics for each circuit section of the 5001 PCB assembly. Also, refer to Subsection 5.4.5 as necessary for a description of schematics and their interconnections in the 5001. A complete Parts List by assembly section is provided in Section 7 of this manual.

5.4.4.2 Refer to Table 5.15 on page 5-31. The specific types of equipment listed are acceptable for servicing the 5001 and are provided as a guide for selecting suitable equipment. Instruments having operating characteristics equal to or better than those indicated in this table may be substituted.

5.4.5 5001 Schematics

5.4.5.1 To complete 5001 documentation in this manual, sets of schematic drawings, some containing

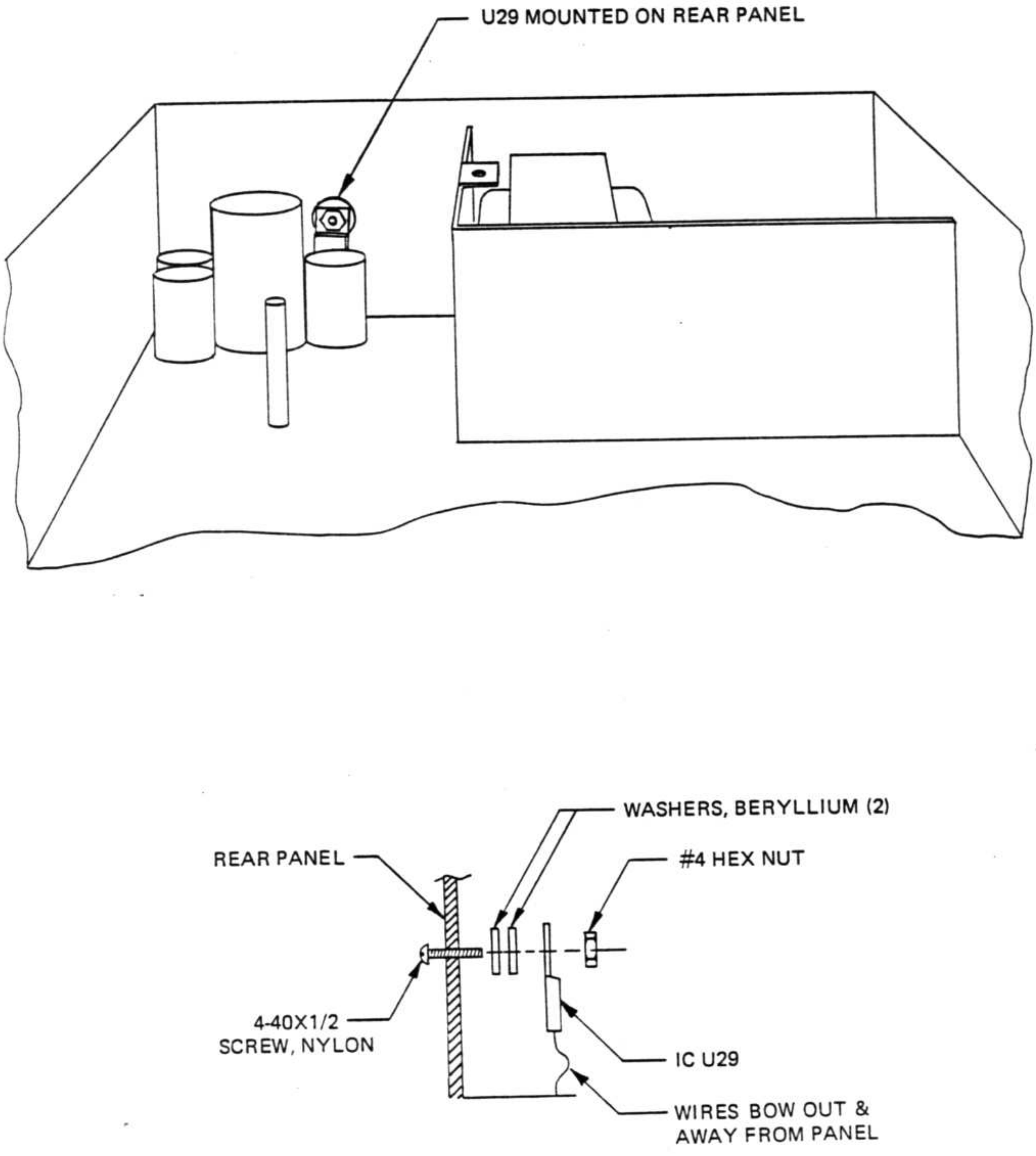
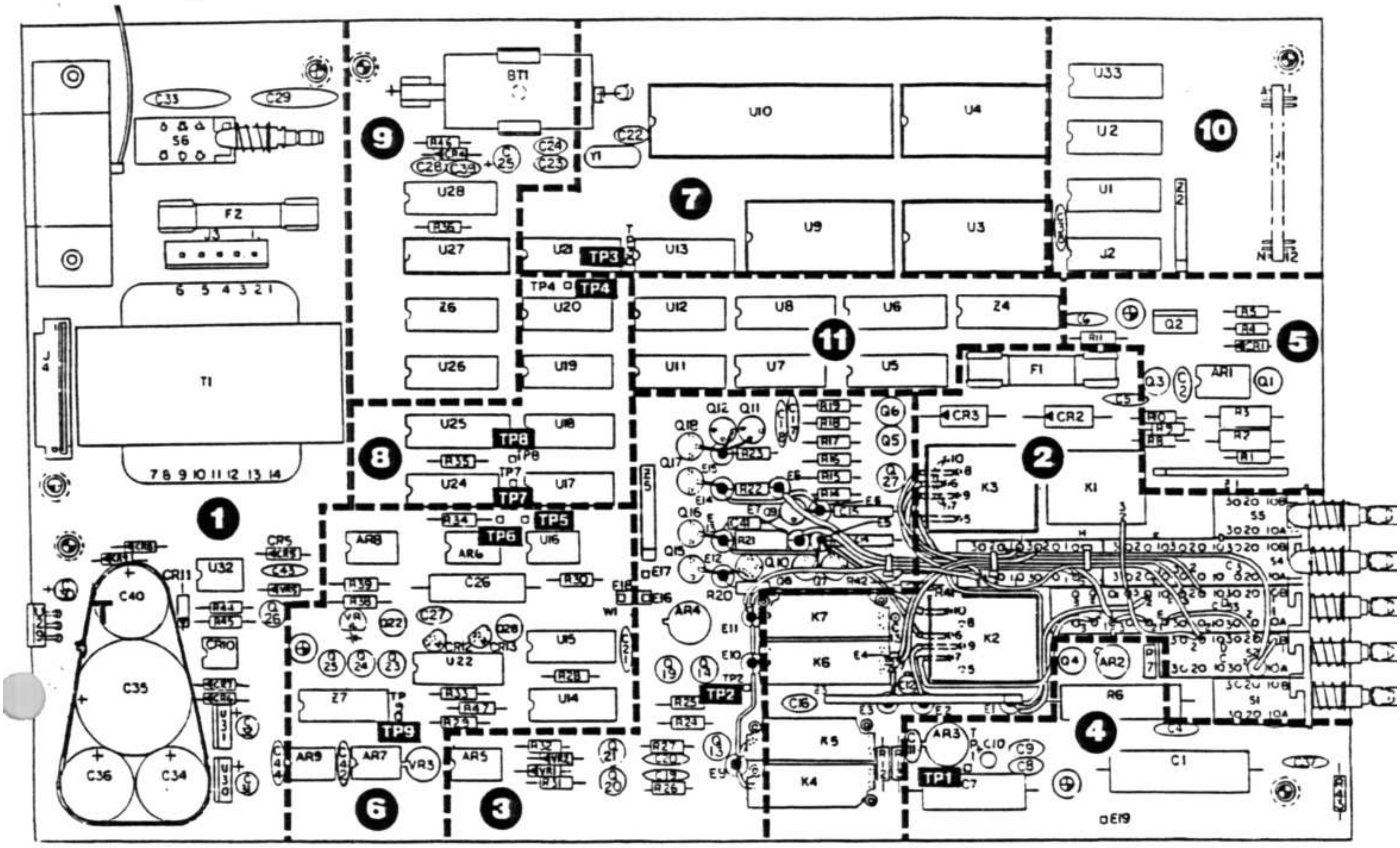


Figure 5.13 - IC U29 Rear Panel Mounting and Detailed Side View



LEGEND - 5001 PCB Assembly Section			
1.	POWER SUPPLY	7.	MICROPROCESSOR and MEMORY
2.	FUNCTION and RANGE SWITCHING	8.	CLOCK CIRCUITRY
3.	ISOLATOR	9.	NON-VOLATILE MEMORY
4.	AC CONVERTER	10.	DISPLAY and KEYBOARD DRIVE
5.	OHMS VOLTAGE SOURCE	11.	RELAY and FET SWITCH DRIVE
6.	DIGITIZER		

Figure 5.14 - 5001 PCB Assembly Section Showing Test Points

several sheets each, are provided. Each set of schematics is identified by a drawing number and a sheet number is placed in the lower right corner of each drawing.

5.4.5.2 Schematic drawings and interconnections from one sheet to the next use a road map grid system, with numbers along the horizontal edge and letters along the vertical edge of each drawing. For example, a line terminating with a connection reference of 2B4 would mean: Sheet 2, Row B and Column 4.

5.4.5.3 In 5001 schematics, plugs and jacks are designated by the letters P and J, respectively. Plugs refer to the free or movable ends of connectors; jacks to the fixed or stationary ends. "P" or "J" numbers from 1 to 99 refer to motherboard loations, whereas "P" or "J" 100 and 200 series designations refer to front and rear panel locations, respectively. "E" terminals are used for direct connections to the main PCB.

NOTE

For component reference designators, refer to Table 5.16 on page 5-31 which lists the common components used on 5001 schematics. Component reference designators used on 5001 schematics follow standard industry practice.

5.4.6 5001 Signal Description

5.4.6.1 The various signals propagated through the analog and digital sections of the 5001 are identified by appropriate labels and abbreviations (mnemonics). Refer to Table 5.17 starting on page 5-32. Notice the following four column headings.

a) **LABEL** - indicates the signal identifier.

b) **DESCRIPTION** - indicates the signal function.

c) **FROM** - indicates the point of signal generation.

d) **TO** - indicates the point of signal destination.

5.4.7 5001 Power Supply Voltage Checks

5.4.7.1 DC voltage distribution throughout the 5001 is a reliable status indicator and any deviation from normal can be easily observed. Refer to Table 5.18 which lists the typical operating voltages for the major 5001 circuits on the main PCB. In using this table, note that the left column identifies the circuits, and the instructions are listed across the top. The chart information progresses from left to right. For example, using the circuit listing "Digital Supply," it reads:

a) Required voltage column reads +5 V.

b) Parts layout reference column: a guide to test point locations (see Figure 5.14).

c) Meter probe column specifies the test point connection. It reads positive J5-3 and negative common TP6.

d) Move the test probes from left to right until the correct voltages appear on the meter.

e) Troubleshoot the previous circuit that registered the incorrect voltage readings.

5.4.7.2 Regulated reference voltage supplies are generated for the exact demands of the digitizer and CAL reference voltages. To troubleshoot the +7 V REF and -7 V REF supplies refer to schematic 431648-2/3 for those components and check their nominal circuit voltages listed in Table 5.19.

Table 5.15 - Suggested Equipment for 5001 Troubleshooting

EQUIPMENT TYPE	MINIMUM USE SPECIFICATION	EQUIPMENT MODEL
DC Power Supply	Adjustable 0-20 VDC	—
Oscilloscope	100 MHz Bandwidth	Tektronix-465
Digital Multimeter	0.1% DCV	Racal-Dana 4002A
Counter	.1 Hz Resolution; 10 MHz External Reference Input	Racal-Dana 9000A
Signature Analyzer	—	Hewlett-Packard 5004A

Table 5.16 - Component Reference Designators

NOTE: xx refers to numbers

DESIGNATOR	NAME	FUNCTION
ARxx	Op-Amp	General application
BTxx	Battery	Non-Volatile Memory stand-by power
Cxx	Capacitor	Value shown on schematic
CRxx	Diode or LED	General application
Exx	Terminals	PCB connections
Fxx	Fuse	Power line and mA function
Jxx	Connector	General application
Kxx	Relay	Switching circuits
DSxx	7-segment Diodes	Front panel display
OCIxx	Optical Isolator	Coupling analog and digital signals
Pxx	Connector	Mates with equivalent Jxx connector
Qxx	Transistor	General application
Rxx	Resistor	Value shown on schematic
Sxx	Switch	All types
Txx	Transformer	All types
Uxx	IC	All (SSI, MSI, LSI)
Wxx	Jumper	Semi-permanent connectors
Yxx	Crystal	Oscillator
Zxx	Resistor Network	General application
VRxx	Zener Diode	Voltage regulator

Table 5.17 - 5001 Signal Description

LABEL	DESCRIPTION	FROM	TO
$\overline{\text{AY0}}$	RAM chip select	U13p15	U9p11/RAM
$\overline{\text{AY1}}$	GPIB interface select	U13p14	J2p7
$\overline{\text{AY2}}$	GPIB interface select	U13p13	J2p15
$\overline{\text{AY3}}$	Hardware control enable	U13p12	U21p4/decoder
$\overline{\text{AY4}}$	Current ratio measurement strobe	U13p11	U20p10
$\overline{\text{AY5}}$	Non-Volatile Memory chip select	U13p10	U26p11
$\overline{\text{AY6}}$	ROM chip select	U13p9	U4p20/ROM-program
$\overline{\text{AY7}}$	ROM chip select	U13p7	U3p20/ROM-program
$\overline{\text{BY0}}$	Digitizer prescaler clock	U21p15	U15p13/count logic
$\overline{\text{BY1}}$	Single/Slope enable	U21p14	U17p10/count logic
$\overline{\text{BY2}}$	Keyboard/Display strobe	U21p13	U2p9(display PCB) WRITE U33p9 and U1p15
$\overline{\text{BY3}}$	Prescaler clear, digitizer count	U21p12	U26p4 to U24p12
$\overline{\text{BY3}}$	FET and relay drive circuity clock	U21p12	U6p2 and U8p3
$\overline{\text{BY4}}$	FET and relay driver strobe	U21p11	U6p1 and U8p1
$\overline{\text{BY6}}$	Charge balance measurement control	U21p9	U19p3
$\overline{\text{BY7}}$	Hardware IRQ clear	U21p7	U20p13 to U25p2
CAL 1	Common reference point	1	Q15d, Isolator input
CAL 2	Reference voltages +2/+.2 or -4/-.4 volts	E15	Q18d, Isolator input
CAL 3	Ohms measurement signal	E14	Q17d, Isolator input
DIGITIZER 1	µP control signal to digitizer (ohms function)	U7p14	Q24g, FET switch control
FILSW	Analog filter on/off control	Q27d	C14
ISO X1	Isolator gain times one	U12p1	Q14g, FET switch control

Table 5.17 - 5001 Signal Description (Continued)

LABEL	DESCRIPTION	FROM	TO
ISO X 10	Isolator gain times 10	U12p13	Q19-G, FET switch control
INPUT DISABLE	Digitizer control signal	U19p8	U22p2, gm Amplifier On-Off Switch
$\overline{RST}$	Reset for signature analysis	U21p10	U19p1 and 13, Digitizer control logic, U26p1 to U18p2 and 3, U25p2 and 14 prescalers
R/$\overline{W}$	Read/Write control	U26p8	U9p16 RAM, CAL-SW
SCAL 1	CAL 1 FET switch control	U12p14	Q15g, Isolator input
SCAL 2	CAL 2 FET switch control	U12p2	Q18g, Isolator input
SCAL 3	CAL 3 FET switch control	U7p1	Q18g, Isolator input
SIG COUNT	Digitizer count input to prescaler	U17p11	U24p1, Digitizer count prescaler
[illegible]VSIG	VSIG FET switch control	U7p2	Q16g, Isolator input
V/F ENABLE	Digitizer charge balance enable	U20p8	U15p4, Charge balance comparator
VSIG	Analog measurement signal	E5	Q16d, Isolator input
Ø2	System clock, 1 MHz	U10p37	Propagates throughout system
62.5 kHz	Signature analysis test clock	U18p11	E17 Inputs SA system
500 kHz	Charge balance counting clock	U18p12	U14p11, Charge balance comparator
Ω REF	-7 Volt ohms reference and single slope reference	VR4-anode	AR1p3, Ohms voltage source
0.2 V REF	Q5 FET switch control	U11p1	Q5g
2 V REF	Q6 FET switch control	U11p14	Q6g
0.4 V REF	Q6 FET switch control	U11p13	Q3g
+ 7 V REF	+ 7 V DC reference	VR3p1	R15

Table 5.18 – 5001 Power Supply Voltage Checks

TESTS CIRCUIT	REQUIRED VOLTAGE DC±10%	PARTS LAYOUT REF.	METER PROBES: POS(ITIVE) NEG(ATIVE)	READING OK	MOVE PROBE TO →	MOVE PROBE TO →	AC READING
Digital Supply	+5 V	Fig. 5.14	Pos. J5-3 Neg. TP6	No, Next →	CR9-cathode No →		Terminals 7 and 9 Power Transformer
Non-Volatile Memory	+9 V (Unreg.)	Fig. 5.14	Pos. CR11-cathode Neg. TP6	No, Next →	CR9-cathode No →		Terminals 7 and 9 Power Transformer
Analog	+12 V	Fig. 5.14	Pos. CR6-cathode Neg. TP2	No, Next →	CR10-anode No →		Terminals 10 and 12 Power Transformer
Analog	-15 V	Fig. 5.14	Pos. CR7-anode Neg. TP2	No, Next →	CR10-cathode No →		Terminals 10 and 12 Power Transformer
Non-Volatile Memory: Battery	+3 V	Fig. 5.14	Pos. BT1-anode Neg. TP6	No, Replace Battery			
DC Supply	+5.6 V	Fig. 5.14	Pos. VR5-cathode Neg. TP6	No, Next →	Pos. CR11-cathode+9V,No →	CR9-cathode No →	Terminals 7 and 9 Power Transformer

Table 5.19 - 5001 Reference Voltages

COMPONENT	NAME	VOLTAGE LEVEL
AR9p3	Voltage REF amplifier	6.9 ± 0.4 VDC
VR4-anode	Zener regulator	-6.9 ± 0.4 VDC
AR1p3	Ohms voltage op amp	-4 ± 0.3 VDC (1 kΩ to 10 MΩ range). -0.4 ± 0.03 VDC (100Ω range).
Q6s	2 V REF	2 ± 0.15 VDC
Q5s	0.2 V REF	0.2 ± .02 VDC
CR1-anode	Over-voltage protector	4 ± 0.3 VDC (1 kΩ to 10 MΩ). 0.4 ± 0.03 VDC (100Ω).
R38	5 Volt divider	+10 ± 0.4 VDC at Q25s and +5 ± 0.4 VDC at AR8p2.
AR6p3	Integrator	+2 ± 0.2 VDC
U16p2	SS comparator	+2 ± 0.2 VDC

5.4.8 5001 Front Panel Fault Analysis

5.4.8.1 Many 5001 faults can be diagnosed from observing the status of the instrument's front panel. Abnormal conditions of indicators, annunciators and displays should assist in isolating 5001 malfunctions to specific operating sections of the 5001. First, refer to Table 5.20 which summarizes the possible 5001 Front Panel Faults and/or Error Numbers. Then, consult the appropriate INSTRUCTION number from this table for detailed troubleshooting procedure(s).

5.4.8.1.1 **INSTRUCTION 1**

a) Troubleshoot the AC power cord, fuse, and ON-OFF switch.

b) Troubleshoot the DC Power supplies - proceed to the next subsection (5.4.9) describing Analog Troubleshooting and refer to Figure 5.15 on page 5-40.

5.4.8.1.2 **INSTRUCTION 2**

a) The "Percent Constant" reference value is set at zero. Enter a "Percent Constant" in memory before proceeding with any Percent Function calculation. Refer to Subsection 3.4.10 of this manual.

5.4.8.1.3 **INSTRUCTION 3**

a) This fault display indicates an operator error caused by **simultaneously** depressing both the mA and KΩ function keys to their ON positions. Select the desired function key to remedy this problem.

Table 5.20 - 5001 Fault/Error Number Summary

Fault Description	Reference
No Front Panel Illumination; No power-On	Instruction 1 (Subsection 5.4.8.1.1)
ERROR 0	Instruction 2 (Subsection 5.4.8.1.2)
ERROR 2	Instruction 3 (Subsection 5.4.8.1.3)
ERROR 3/7	Instruction 4 (Subsection 5.4.8.1.4)
ERROR 4	Instruction 5 (Subsection 5.4.8.1.5)
READ-RATE indicator is OFF.	Instruction 6 (Subsection 5.4.8.1.6)
READ-RATE indicator is OFF; the LSD and Digit One "bounces around" excessively.	Instruction 7 (Subsection 5.4.8.1.7)
SA or DIAG Power-On is ineffective.	Instruction 8 (Subsection 5.4.8.1.8)
READ-RATE indicator erratic; relay clicks not audible when AUTO range key is depressed.	Instruction 9 (Subsection 5.4.8.1.9)
READ-RATE indicator operating properly; display stuck on "5001".	Instruction 10 (Subsection 5.4.8.1.10)

WARNING

Removal of the 5001's covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while the 5001 is connected to an AC power source.

5.4.8.1.4 INSTRUCTION 4

a) Remove the 5001 covers. Refer as required to Subsection 5.4.3 for disassembly instructions.

b) Execute the ERROR 3(7) Troubleshooting Procedure shown in Table 5.21 at the end of this subsection.

5.4.8.1.5 INSTRUCTION 5

a) This fault display alerts the user that the checksum calculated during 5001 power-on does not agree with the reference checksum stored in Non-Volatile Memory during the last calibration.

b) Primary causes for an ERROR 4 message include:

1. an altered Non-Volatile Memory.
2. a failed 6508 CMOS RAM (U27).
3. faulty inputs to the 6508 CMOS RAM (U27).

c) ERROR 4 display may also be caused by applying measurement signals in excess of 1,000 volts to the 5001.

d) Also, an ERROR 4 message may result at power-on following the storage of nominals. This fault requires that the user complete the entire calibration procedure, rather than simply correcting a Non-Volatile Memory failure in the 5001.

e) If an ERROR 4 message does occur, remove the 5001 covers, referring to Subsection 5.4.3 as required. Then, perform the following verification procedure before recalibrating the instrument.

WARNING

Removal of the 5001's covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while the 5001 is connected to an AC power source.

1. Verify the voltage of battery BT1. The required voltage should be 2.9 V ± 0.2 V.

2. Power-off the 5001 and wait approximately one minute. Verify that the voltage drop across R27 is ≤ 5 mV.

3. Place a Variac on the AC line. Verify the proper operation of U27's power-off protective circuit by checking the following reference data:

+5 V	U28p6
+5 ± 0.2 V	+5 V ± 0.2
3.6 V	≤ 0.8 V
≥ 4.5 V	+5 ± 0.2 V

4. Finally, setup the 5001 in the .1 VDC range and short the input terminals. Depress and hold the CAL SW (switch); then depress the LAH key. If the display decrements rapidly, recalibrate the instrument. Otherwise, proceed to the Preliminary SA Troubleshooting Procedure outlined in Subsection 5.5.

5.4.8.1.6 **INSTRUCTION 6**

a) This malfunction suggests a problem in the digital uP area. Refer to the SA Troubleshooting Procedure in Subsection 5.5.

5.4.8.1.7 **INSTRUCTION 7**

a) This malfunction suggests a problem in the digitizer. Refer to the DIAG Troubleshooting Procedure described in Subsection 5.4.10.

5.4.8.1.8 **INSTRUCTION 8**

a) Repeat the power-on procedure.

b) Exercise the keyboard to verify its operation.

c) Execute the Free Run Signature Analysis Procedure (SAFR) described in Subsection 5.5.

5.4.8.1.9 **INSTRUCTION 9**

a) The 5001's FET switches or relay drive is not operating properly.

b) Use the DIAG Troubleshooting Procedure described in Subsection 5.4.10.

5.4.8.1.10 **INSTRUCTION 10**

a) This display fault indicates a digitizer malfunction. Refer to the SA Troubleshooting Procedure in Subsection 5.5.

5.4.9 Analog Troubleshooting

5.4.9.1 Refer to the Analog Troubleshooting Chart in Figure 5.15 to verify the 5001's performance and provide servicing of the instrument's Analog Section. When using this chart for troubleshooting, evaluation of the check points should progress from one 5001 section to another. This procedure will permit verification of the operating status of entire 5001 sections at one time. In the chart, references made to other tables and figures in the Troubleshooting

Section should be consulted as required.

5.4.10 5001 Digitizer Diagnostics (DIAG) Mode

5.4.10.1 The DIAG Troubleshooting operating mode is a software program implemented in the 5001 which facilitates the diagnosis of most problems in the digitizer section of the 5001. DIAG may be used to either verify the proper performance or troubleshoot fault conditions in the isolator and digitizer.

5.4.10.2 DIAG Mode Entry - use the following simple front panel keyboard procedure:

a) Depress and hold the AUTO and .1 keys.

b) Power-on the 5001 until "DIAG" appears on display.

c) Release the AUTO and .1 key after "DIAG" display.

The 5001 is now in the DIAG operating mode.

5.4.10.3 After entering the DIAG mode, the five front panel compute keys are redefined as follows:

a) LAH: VSIG (input signal) selected via FET Q16.

b) △ %: CAL 1 (ground) selected via FET Q15.

c) NULL: CAL 2 (+2 V reference) selected via FET Q18.

d) RECALL: CAL 3 (ohms reference) selected via FET Q17.

e) STORE: I_{CB}/I_{SS} ratio selected.

NOTE

The annunciator LED immediately above each of the front panel compute keys will illuminate indicating the selected signal; disregard the AUTO range annunciator which is not active.

5.4.10.4 Upon entering the DIAG mode, its program modifies the input switching sequence of FETs Q15-Q18 so that one FET is always ON and the remaining three OFF. This condition enables the digitizer to continually convert one of the four input function signals (VSIG, CAL 1, CAL 2. or CAL 3).

5.4.10.5 When in the DIAG mode, the following conditions will prevail:

a) Power-on condition in the DIAG mode has the 5001 in the 1 range with the VSIG signal being continuously measured ON.

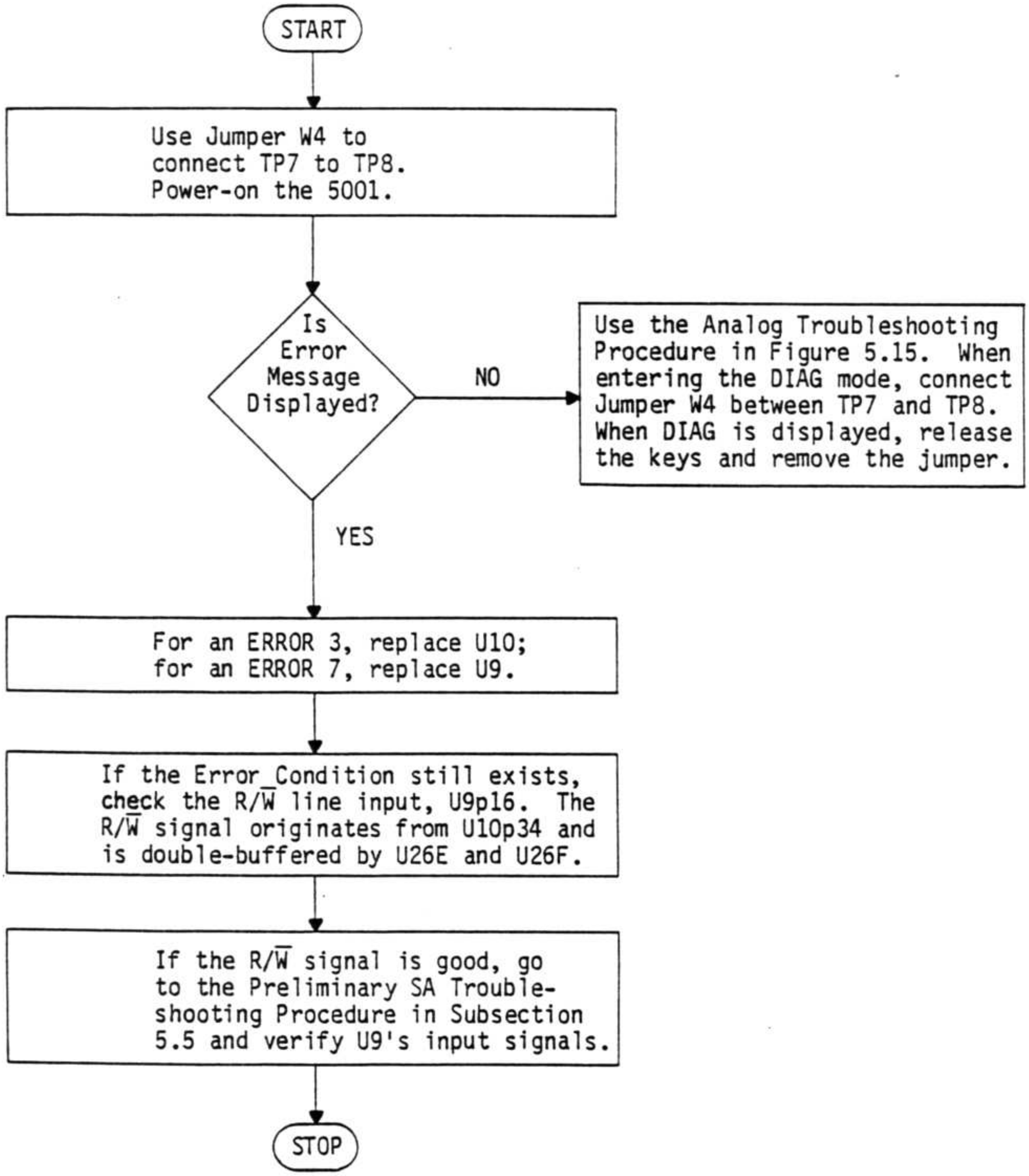
b) Use the range keys to select the desired measurement range; use the function keys to select the desired function.

c) The front panel display shows the number equal to the combined charge balance (CB) and single slope (SS) counts accumulated during digitization.

d) The I_{CB}/I_{SS} ratio of 225 nominal (2×2 mA $\div$ 18 µA) verifies the proper operation of the digitizer's current sources and transistor switches (U22 and U23), along with the following other hardware: U14, U15, U16, U17, VR3, VR4, AR6, AR8, and AR9.

e) The DIAG program scans the 5001's keyboard to check which of the four input function signals should be measured or whether the I_{CB}/I_{SS} ratio should be displayed.

Table 5.21 - 5001 ERROR 3(7) Troubleshooting Procedure
(ERROR 3(7) Message is displayed following Power-On)



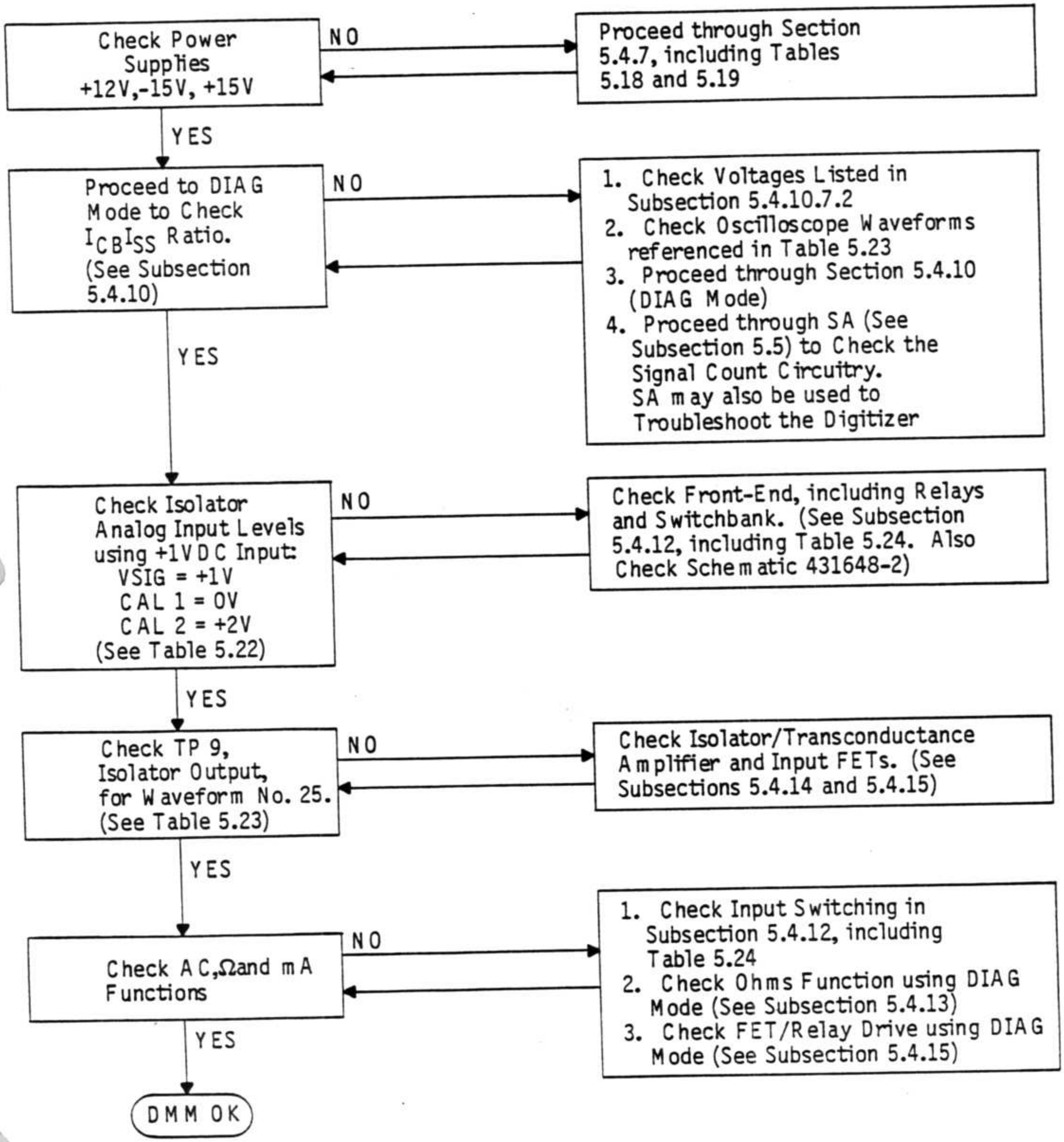


Figure 5.15 - 5001 Analog Troubleshooting Chart

5.4.10.6 DIAG Troubleshooting Procedure - refer to Table 5.22 which shows the correct number of displayed counts, indicating proper operation for the various functions, ranges, or input switching FET selections. Then, perform the DIAG troubleshooting operation as described in the next several paragraphs.

NOTE

In the 5001, the I_{CB}/I_{SS} ratio is independent of function or range selections.

5.4.10.6.1 Depress the DC function, "1" range, and the **LAH** keys to select Q16's VSIG input signal. Apply the voltages listed in the "INPUT" column to the 5001's HI and LO input terminals and check the count number displayed.

5.4.10.6.2 Depress the △% key to select Q15's ground signal, CAL 1. Check the display to verify that 11000.0 to 14000.0 counts are shown.

5.4.10.6.3 Depress the **NULL** key to select Q18's reference signal, CAL 2. Check the display to verify that 2000.00 to 3000.00 counts are shown.

5.4.10.6.4 Depress the **STORE** key to select the I_{CB}/I_{SS} ratio. Check the display to verify that 200.000 to 260.000 counts are shown.

5.4.10.7 DIAG Service Suggestions - the following instructions should be carried out as required.

5.4.10.7.1 If the I_{CB}/I_{SS} ratio is correct, the proper operation of U14, U15, U16, U17, U22, U23, AR6, AR8, AR9, VR3, and VR4 is verified. However, if this ratio is incorrect, the resultant counts from VSIG, CAL 1, CAL 2, and CAL 3 are probably erroneous also.

5.4.10.7.2 To troubleshoot I_{CB}/I_{SS} ratio errors, proceed as follows:

a) Verify that VR4 anode reads -6.9 ± 0.4 VDC. If not, replace VR4.

Table 5.22 - Signal and Reference Display Count

LAST DIAG KEY PRESSED	SIGNAL AND REFERENCE	FET	RANGE	INPUT	UNITS	DISPLAYED COUNTS
LAH	VSIG	Q16	1	+2	VDC	2000.00 - 3000.00
			1	+1	VDC	6700.00 - 8400.00
			1	0	VDC	11000.0 - 14000.0
			1	-1	VDC	15600.0 - 19600.0
			1	-2	VDC	20000.0 - 25200.0
△%	CAL 1	Q15	1	0	VDC	11000.0 - 14000.0
NULL	CAL 2	Q18	1	2	VDC	2000.00 - 3000.00
STORE	I_{CB}/I_{SS}		1	2	VDC	200.000 - 260.000

b) Verify that AR9p3 reads +6.9 ± 0.4 VDC. If not, replace VR4.

c) Verify the following voltages:
1. Q25s = +10 ± 0.5 VDC.
2. AR9p2 = + 6.9 ± 0.4 VDC.
3. AR8p3 = + 5.0 ± 0.3 VDC.
4. AR6p3 = + 2 ± 0.2 VDC.
5. U16p2 = +2 ± 0.2 VDC.

5.4.11 Input Switching and Attenuator Troubleshooting

5.4.11.1 If the Input Switching and Attenuator Circuitry's performance becomes questionable, refer to Table 5.23. This table provides the necessary voltage inputs, test locations and test values for properly troubleshooting this 5001 section. Also given are the 5001 function and range parameters for troubleshooting the instrument. Refer to Figure 5.16 for the required test locations.

5.4.12 5001 Digitizer Section Performance Tests

5.4.12.1 To verify the proper operation of the digitizer's circuitry, a series of digitizer performance tests is provided for reference in Table 5.24. The table provides setup instructions for the 5001 and oscilloscope, signal nomenclature, reference designations, test points, illustration references and calibrated waveforms.

NOTE

The waveforms are numbered and refer to the entries indicated in the Performance Standard column of the table.

5.4.13 Ohms Troubleshooting

5.4.13.1 Use the following procedure to troubleshoot the ohms function:

a) Power-on in the DIAG mode; then depress the AUTO and .1 keys.

b) Depress the kΩ function key; then depress the 10 (kΩ) range key.

c) Depress the STORE key to select the I_{CB}/I_{SS} ratio. Check the display for 200.00 to 260.000 counts.

d) Depress the NULL key to select CAL 2. Check the display for 20000.0 to 25200.0 counts.

e) Depress the △% key to select CAL 1. Check the display for 2000.00 to 3000.00 counts.

5.4.14 Isolator/Transconductance Amplifier Troubleshooting

5.4.14.1 Use the following procedure to troubleshoot the Isolator and Transconductance Amplifier sections:

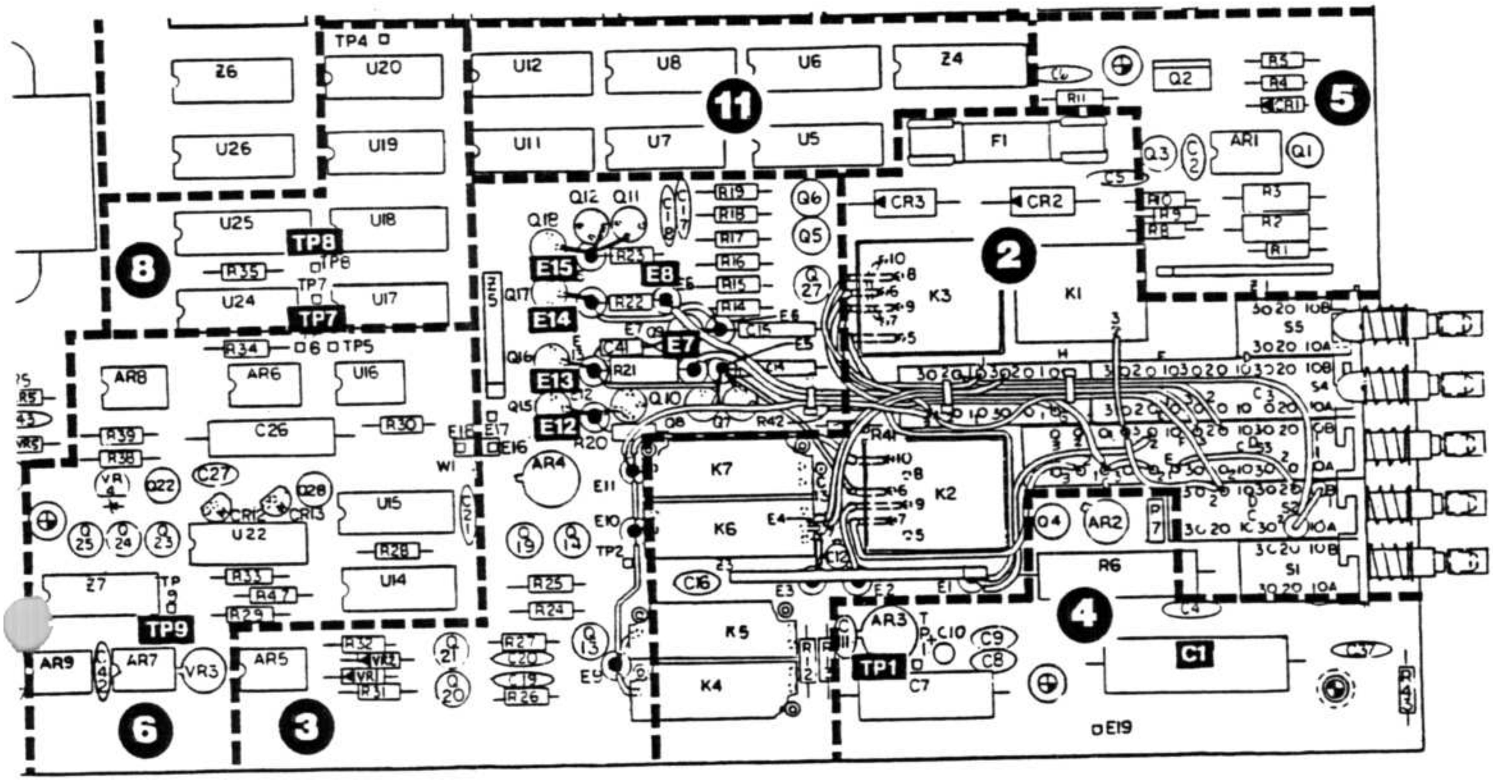
a) Power-on in the DIAG mode; depress the DC volts and 1 keys; finally, depress the △% key to select CAL 1 (Q15's ground signal). Apply 0.0 VDC to the front panel INPUT terminals.

b) Then verify the following voltages:

1. Q15g = -15 VDC
2. Q17g = -15 VDC
3. Q16g = -15 VDC
4. Q15g = OV + .1 VDC
5. Q15d, Q15s = OV + 100 uV
6. TP9 - Isolator Output = OV ± 2 mV
7. AR5p2,3,6 = OV ± 10 mV
8. AR4p7 = 5.6 V ± 0.8 V
9. AR4p4 = -6.25 V ± 0.85 V

Table 5.23 – Input Switching and Attenuator Troubleshooting

ITEM	FUNCTION	RANGE	INPUT	TEST LOCATION	TEST VALUE
1.	DC	ANY	ANY	R20/E12	0 ± 100 μVDC
2.	DC	1	+ 1 VDC	R21/E7	+ 1.00 VDC
3.	DC	1,10,100,1 K	ANY	R23/E15	+ 2.0 VDC ± .15 VDC
4.	DC	.1	ANY	R23/E15	+ .2 VDC ± .02 VDC
5.	DC	10	+ 10 VDC	R21/E7	+ 1.00 VDC
6.	DC	100	+ 100 VDC	R21/E7	+ 1.00 VDC
7.	AC	1	1 VAC/1 kHz	C 1	1 VAC
8.	AC	1	1 VAC/1 kHz	TP 1	1 VAC
9.	AC	1	1 VAC/1 kHz	R21/E7	+ 1.0 VDC
10.	AC	10	10 VAC/1 kHz	TP 1	1 VAC
11.	AC	100	100 VAC/1 kHz	TP 1	1 VAC
12.	OHMS	ANY	ANY	R20/E12	0 ± 100 μVDC
13.	OHMS	1-10,000	ANY	R23/E15	- 4 VDC ± .3 VDC
14.	OHMS	.1	ANY	R23/E15	- .4 VDC ± .03 VDC
15.	OHMS	10	10 kΩ	R21/E7	- 2 VDC ± .2 VDC
16.	OHMS	10	10 kΩ	R22/E8	- 2 VDC ± .2 VDC
17.	OHMS	.1	100Ω	R21/E7	- .2 VDC ± .02 VDC
18.	OHMS	.1	100Ω	R22/E8	- .2 VDC ± .02 VDC
19.	OHMS	1	1 kΩ	R21/E7	- 2 VDC ± .2 VDC
20.	OHMS	100	100 kΩ	R21/E7	- 2 VDC ± .2 VDC
21.	OHMS	1000	1 MEGΩ	R21/E7	- 2 VDC ± .2 VDC
22.	OHMS	10000	10 MEGΩ	R21/E7	- 2 VDC ± .2 VDC
23.	DC mA	1	+ 1 mA DC	R21/E7	+ .1 VDC
24.	DC mA	10	+ 10 mA DC	R21/E7	+ .1 VDC
25.	DC mA	100	+ 100 mA DC	R21/E7	+ .1 VDC
26.	DC mA	1000	+ 1000 mA DC	R21/E7	+ .1 VDC
27.	DC mA	ANY	ANY	R23/E15	+ .2 VDC ± .02 VDC
28.	AC mA	1	1 mA AC/200 Hz	C 1	.1 VAC
29.	AC mA	1	1 mA AC/200 Hz	TP 1	1.0 VAC
30.	AC mA	1	1 mA AC/200 Hz	R21/E7	1.0 VAC
31.	AC mA	10	10 mA AC/200 Hz	C 1	.1 VAC
32.	AC mA	10	10 mA AC/200 Hz	TP 1	1.0 VAC
33.	AC mA	100	100 mA AC/200 Hz	C 1	.1 VAC
34.	AC mA	1000	1 Amp AC/200 Hz	C 1	.1 VAC
35.	AC mA	ANY	ANY	R23/E15	+ 2.0 VDC ± .2 VDC



LEGEND - 5001 PCB Assy. Section

2. FUNCTION and RANGE SWITCHING
3. ISOLATOR
4. AC CONVERTER
5. OHMS VOLTAGE SOURCE
6. DIGITIZER
8. CLOCK CIRCUITRY
11. RELAY and FET SWITCH DRIVE

Figure 5.16 - 5001 Test Point Locator - Input Switching and Attenuator Circuitry

c) If steps 1, 2, 3 or 4 fail, check U7, U11 and U12 and/or Q15, Q16, Q17 and Q18.

d) If steps 5, 6, 7, 8 or 9 fail, check the isolator input buffer AR4 or bootstrap amplifier AR5 and associated components Q13, Q14, Q19, Q20 and Q21.

5.4.15 FET/Relay Drive Troubleshooting

5.4.15.1 Troubleshooting Set-up - ensure that the 5001 is in any DIAG mode. Refer to schematic 431648, sheet 4 (Section 6 of this manual). The relay chart on this schematic indicates by crosshatching which relays and FET switches are energized for each function and range. While completing the following troubleshooting procedure, alternately press two different function or range keys to permit different data to be latched into the FET/relay drive circuitry. Carefully alternating between the two selected functions or ranges allows both logic high and low levels to be seen at all nodes in the FET/relay drive circuitry.

5.4.15.2 Use the following procedure to troubleshoot the FET switches and relay driver:

a) Verify that U5's outputs are active low (pins 10-16 = + 0.7 VDC).

b) Verify that U6 and U8's outputs are active high: 5.0 VDC.

c) Verify that U6 and U8 are 16-bit shift registers with pins 1, 2 and 3 being those for the strobe input, data input, and clock input signals, respectively.

d) Verify, finally, the following:

1. After clocking in 16 bits, the new bit pattern is transferred and latched at the output by the strobe line (pin 1).

2. New data is clocked in only after a range or function change. This requires the depressing of a new range or function key or operation in the AUTO range.

e) Verify that quad comparators U7, U11 and U12 meet the following conditions:

1. A reference level of + 2.5 VDC exists at Z4p4,5; U7p4,6,8,10; U11p6,9,10; U12p4,7,8,10.

2. Comparator outputs are open collectors with -15 VDC being OFF.

5.4.16 Battery Replacement For Non-Vol Circuit

5.4.16.1 During power off periods when the 5001 is not AC line powered, a lithium battery (BT1) maintains the required voltage to the Non-Volatile Memory circuit, which includes the CMOS RAM U27. When the voltage drops below 2.3 V, the RAM will lose its CAL constants. This causes the "ERROR 4" message to be displayed the next time the 5001 is powered on.

5.4.16.2 It is important to recognize that the displayed error message indicates that the contents of the Non-Vol Memory were disrupted and most often indicates a discharged battery. If the battery voltage to U27p16 during power off exceeds 2.3 V, other components in the circuit may be at fault.

5.4.16.3 Steps to replace the BT1 battery include:

a) Apply power to the 5001. Verify that it completes the power on sequence listed in paragraph 3.2.2.

Table 5.24 - Digitizer Section Performance Tests

INPUT AND CONTROL SETTING	SIGNAL NOMENCLATURE	REFERENCE DESIGNATION	TEST POINT	ILLUSTRATION REFERENCE	PERFORMANCE STANDARD
Set scope to CH1, AC coupled Norm. Trig., (-) slope 5001: DIAG, DC, CAL 1	SS Comparator	U16p7	TP5	Figure 5.14	Waveform #1
Set scope to CH1, AC coupled Auto Trig., (+) slope	Integrator Output	C26/R29	U23p10	Figure 5.14	Waveform #2
Set scope to CH1, AC coupled Auto Trig., (+) slope, Input Disable, EXT. 5001: DIAG, DC, △%	Integrator Output	C26/R29	U23p10	Figure 5.14	Waveform #3
Set scope to CH1, AC coupled Auto Trig., (+) slope. 5001: DIAG, DC, △% (CAL 1, GND)	Integrator Output	C26/R29	U23p10	Figure 5.14	Waveform #4
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001: DIAG, DC, △%	CB Charge Dispenser	Charge Switch	U22p8	Figure 5.14	Waveform #5
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001: DIAG, DC, LAH, + 2 VDC In	CB Charge Dispenser	Charge Switch	U22p8	Figure 5.14	Waveform #6

Table 5.24 - Digitizer Section Performance Tests (Continued)

INPUT AND CONTROL SETTING	SIGNAL NOMENCLATURE	REFERENCE DESIGNATION	TEST POINT	ILLUSTRATION REFERENCE	PERFORMANCE STANDARD
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001: DIAG, DC, LAH, -2 VDC In	CB Charge Dispenser	Charge Switch	U22p8	Figure 5.14	Waveform #7
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001:	CB Comparator 500 kHz	U14p11	U14p11	Figure 5.14	Waveform #8
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001:	1 MHz Clock	U15p9	U15p9	Figure 5.14	Waveform #9
Set scope to CH1, AC coupled Norm. Trig., (-) slope 5001: DIAG, DC Δ%	V/F Enable	U15p4	U15p4	Figure 5.14	Waveform #10
Set scope to CH1, AC coupled Norm Trig., (+) slope 5001:	Input Disable Clock	U22p1	U22p1	Figure 5.14	Waveform #11
Set scope to CH1, AC coupled Norm Trig., (-) slope High intensity 5001: DIAG, DC, Δ%, "1" Range	$\overline{BY1}$ SS Enable	U17p10	U17p10	Figure 5.14	Waveform #12

Table 5.24 - Digitizer Section Performance Tests (Continued)

INPUT AND CONTROL SETTING	SIGNAL NOMENCLATURE	REFERENCE DESIGNATION	TEST POINT	ILLUSTRATION REFERENCE	PERFORMANCE STANDARD
Set scope to CH1, AC coupled Norm Trig., (-) slope 5001: DIAG, DC, △%	$\overline{BY0}$ clears Prescaler	U15p13	U15p13	Figure 5.14	Waveform #13
Set scope to CH1, AC coupled Norm Trig., (-) slope 5001:	$\overline{BY0}$ clears Prescaler	U15p13	U15p13	Figure 5.14	Waveform #14
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001:	$\overline{NMI}$ Interrupt	U10p6	TP8	Figure 5.14	Waveform #15
Set scope to CH1, AC coupled Norm Trig., (-) slope 5001: DIAG, DC, △%	SS Comparator Buffer	U23p2	U23p2	Figure 5.14	Waveform #16
Set scope to CH1, AC coupled Norm Trig., (-) slope 5001: DIAG, DC, △%	SS Comparator Buffer	U23p2	U23p2	Figure 5.14	Waveform #17
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001:	62.5 kHz Clock	U18p11	U18p11	Figure 5.14	Waveform #18
Set scope to CH1, AC coupled Norm Trig., (+) slope 5001:	1.25 kHz Clock	U25p9	U25p9	Figure 5.14	Waveform #19

Table 5.24 - Digitizer Section Performance Tests (Continued)

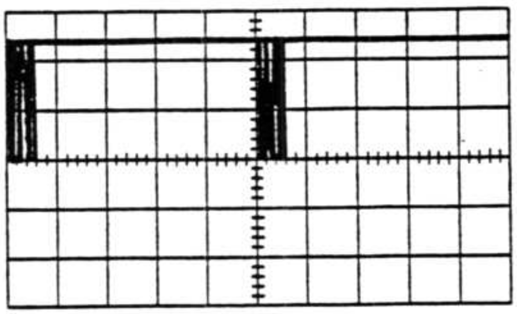
INPUT AND CONTROL SETTING	SIGNAL NOMENCLATURE	REFERENCE DESIGNATION	TEST POINT	ILLUSTRATION REFERENCE	PERFORMANCE STANDARD
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001:	0.8 mSec Interrupt	U25p13	U25p13	Figure 5.14	Waveform #20
Set scope to CH1, AC coupled Auto Trig., (+) slope 5001:	Divider Sequence	U25p7,12	U25p7,12	Figure 5.14	Waveform #21
Set scope to CH1, AC coupled Auto Trig., (+) slope 5001:	31.25 kHz Divider	U25p3,4	U25p3,4	Figure 5.14	Waveform #22
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001:	$\overline{BY6}$ Address Decoder	U21p9	U21p9	Figure 5.14	Waveform #23
Set scope to CH1, AC coupled Auto Trig., (-) slope 5001: OHMS 1 K, 1 M Input unfiltered	OHMS Signal	Isolator Buffer	TP9	Figure 5.14	Waveform #24
Set scope to CH1, AC coupled Auto Trig., (+) slope 5001: DC, "1" Range, +1 VDC unfiltered	VSIG	Isolator Buffer	TP9	Figure 5.14	Waveform #25

Table 5.24 - Digitizer Section Performance Tests (Continued)

1
(No.)

CH. 1, AC coup.
Norm trig.
(-) slope

2
(v/div)

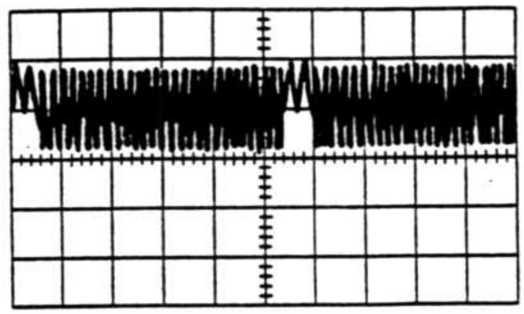


20m
(s/div)

2
(No.)

CH. 1, AC coup.
Auto trig.

1
(v/div)

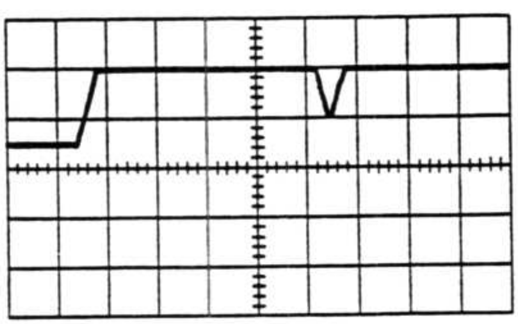


20m
(s/div)

3
(No.)

CH. 1, AC coup. In-put Dis-able,Ext., (+) slope
Norm trig.

1
(v/div)

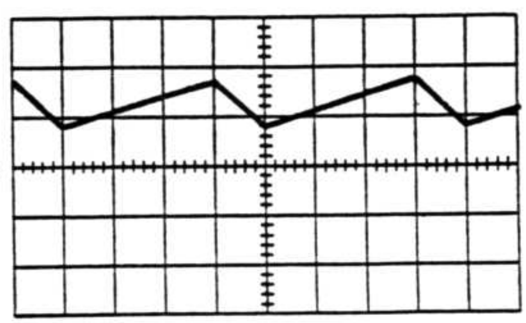


1m
(s/div)

4
(No.)

CH. 1, AC coup.
Auto trig.

1
(v/div)



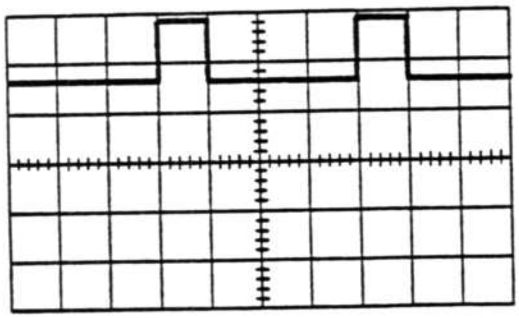
2u
(s/div)

Table 5.24 - Digitizer Section Performance Tests (Continued)

5
(No.)

CH. 1, AC
Auto trig.
(-) slope

1
(v/div)

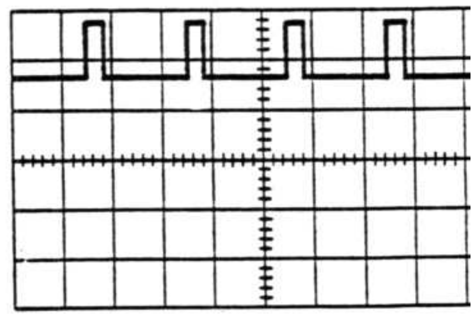


20u
(s/div)

6
(No.)

CH. 1, AC
coup.
Auto trig.
(-) slope

1
(v/div)

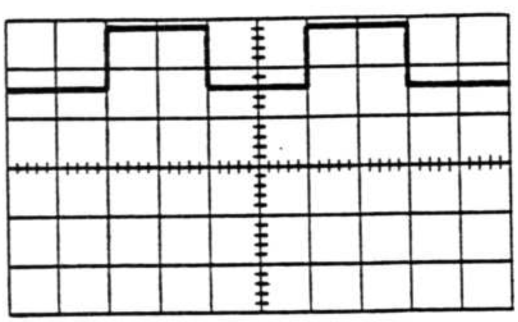


20u
(s/div)

7
(No.)

CH. 1, AC
coup.
Auto trig.
(-) slope

1
(v/div)

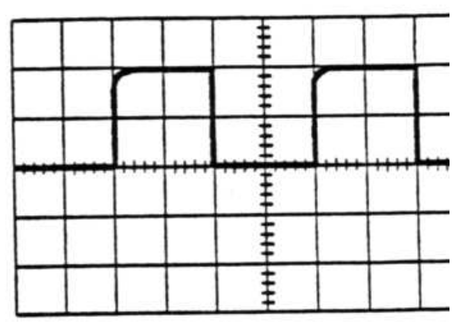


1u
(s/div)

8
(No.)

CH. 1, AC
coup.
Auto trig.
(-) slope

2
(v/div)

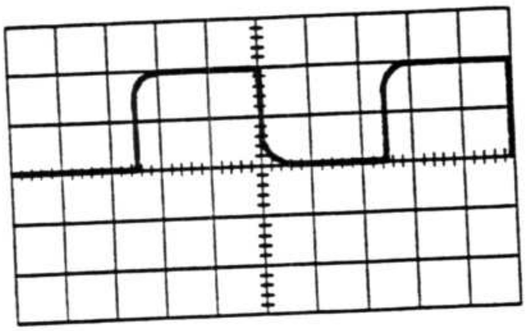


.5u
(s/div)

Table 5.24 - Digitizer Section Performance Tests (Continued)

9
(No.)

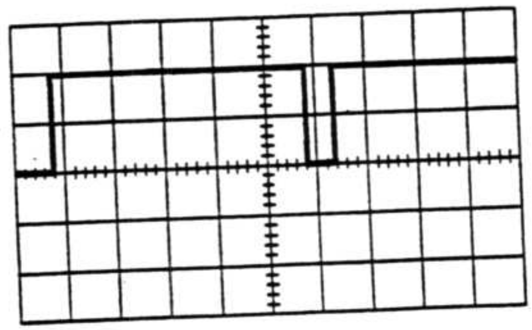
CH. 1, AC
coup.
Auto trig.
(-) slope
2
(v/div)



.2u
(s/div)

10
(No.)

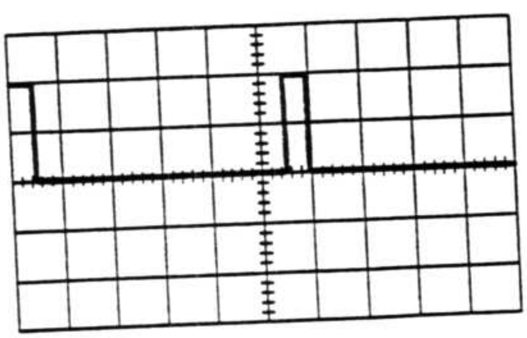
CH. 1, AC
Norm trig.
(-) slope
2
(v/div)



20m
(s/div)

11
(No.)

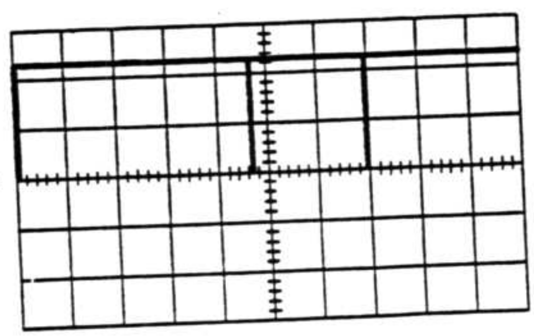
CH. 1, AC
coup.
Norm trig.
(+) slope
2
(v/div)



20m
(s/div)

12
(No.)

CH. 1, AC
coup.
Norm trig.
(-) slope
High in-
tensity
2
(v/div)

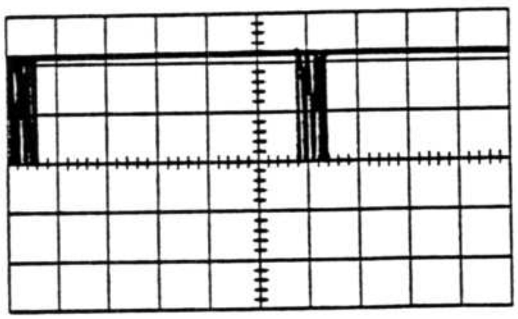


1m
(s/div)

Table 5.24 - Digitizer Section Performance Tests (Continued)

13
(No.)

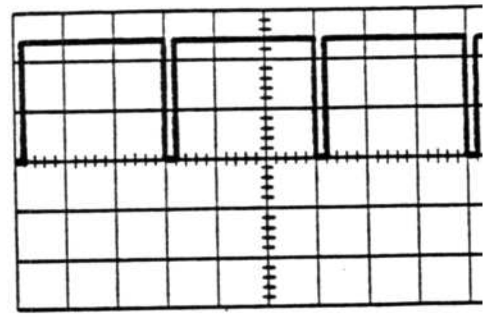
CH. 1, AC
coup.
Norm trig.
(-) slope
2
(v/div)



20m
(s/div)

14
(No.)

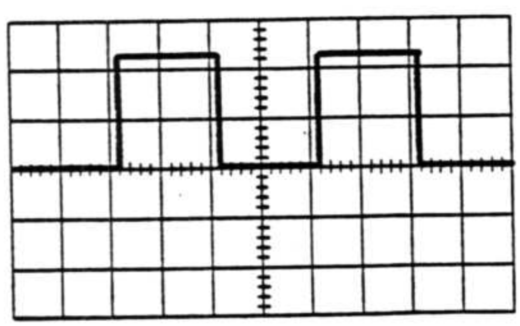
CH. 1, AC
coup.
Norm trig.
(-) slope
2
(v/div)



5u
(s/div)

15
(No.)

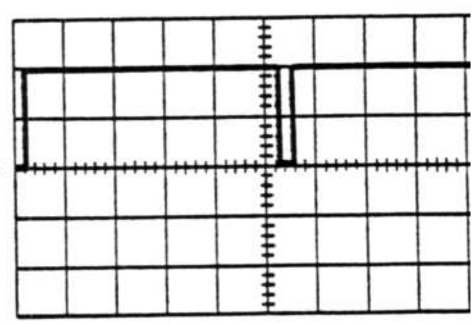
CH. 1, AC
coup.
Auto trig.
(-) slope
2
(v/div)



.5m
(s/div)

16
(No.)

CH. 1, AC
coup.
Norm trig.
(-) slope
2
(v/div)

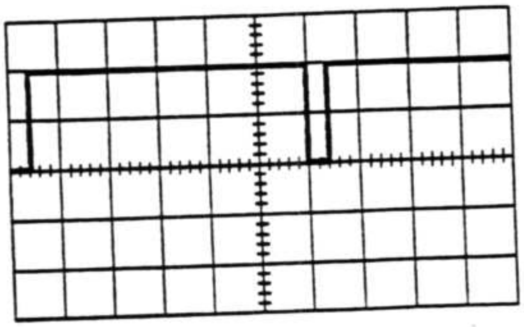


20m
(s/div)

Table 5.24 - Digitizer Section Performance Tests (Continued)

17
(No.)

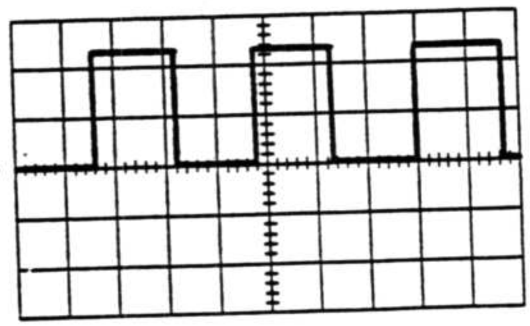
CH. 1, AC
coup.
Norm trig.
(-) slope
2
(v/div)



.5m
(s/div)

18
(No.)

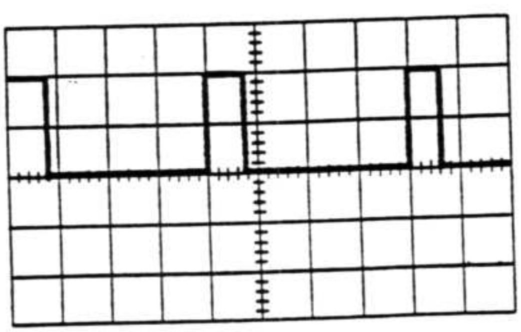
CH. 1, AC
coup.
Auto trig.
(-) slope
2
(v/div)



5u
(s/div)

19
(No.)

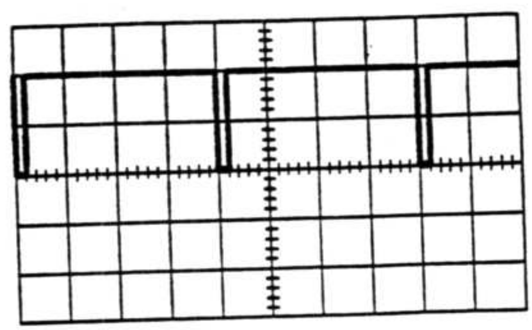
CH. 1, AC
coup.
Norm trig.
(+) slope
2
(v/div)



.2m
(s/div)

20
(No.)

CH. 1, AC
coup.
Auto trig.
(-) slope
2
(v/div)

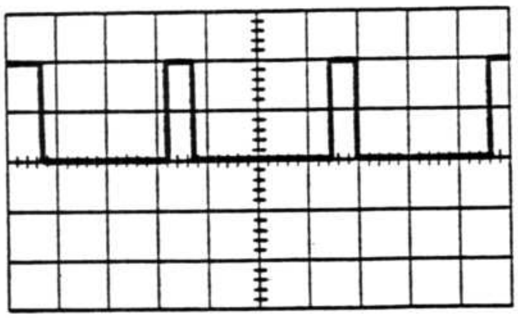


.2m
(s/div)

Table 5.24 - Digitizer Section Performance Tests (Continued)

21
(No.)

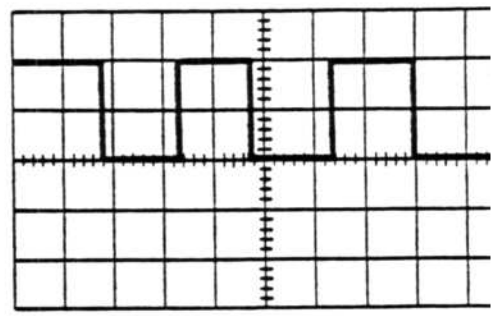
CH. 1, AC
coup.
Auto trig.
(+) slope
2
(v/div)



50u
(s/div)

22
(No.)

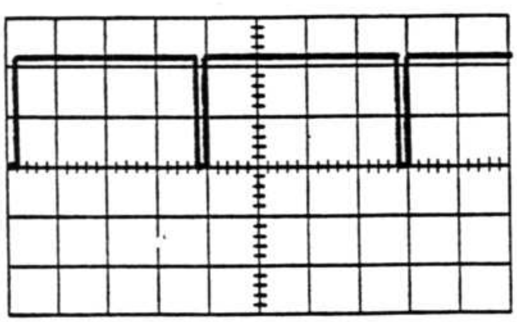
CH. 1, AC
coup.
Auto trig.
(+) slope
2
(v/div)



10u
(s/div)

23
(No.)

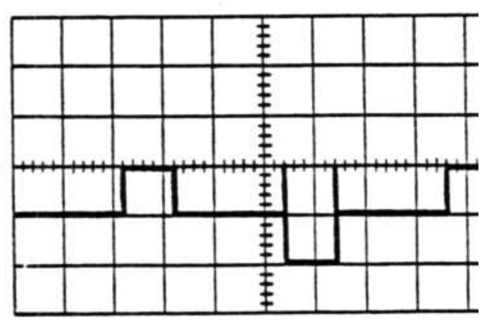
CH. 1, AC
coup.
Auto trig.
(-) slope
2
(v/div)



.2m
(s/div)

24
(No.)

CH. 1, AC
coup.
Auto trig.
(-) slope
2
(v/div)



.1m
(s/div)

Table 5.24 - Digitizer Section Performance Tests (Continued)

25

(No.)

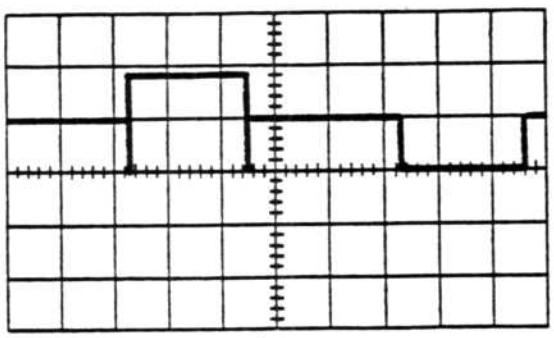
CH. 1, AC coup.

Auto trig.

(+) slope

1

(v/div)



50m

(s/div)

CAUTION

The 5001 is still powered on. Use an ungrounded soldering iron to unsolder the battery tabs from the motherboard and remove the old battery.

b) Observe polarity and install the new battery in the same position.

WARNING

Lithium batteries may explode if short-circuited, recharged, disassembled, heated or disposed of in fire. Battery leakage may forewarn the problem.

5.4.16.4 Preventative Maintenance: Use the following procedure to check the battery condition:

a) Turn off the AC power to the 5001.

b) Wait 30 seconds.

c) Measure the voltage drop with a one millivolt resolutional digital voltmeter across R37, the 1 kΩ resistor in series with the battery.

d) The voltage drop across R37 should measure between 0 and 20 mV; otherwise the battery should be replaced (battery drain is 0μA - 20 mA).

5.4.16.5 The suggested battery replacement interval can be determined from Figure 5.17. It is supplied as an aid to determine how often the lithium battery BT1 should be replaced. Notice that the worst case battery drain occurs if the instrument is stored at high temperatures with the power off (3-year replacement interval). For most applications, a 4-year replacement interval is suggested.

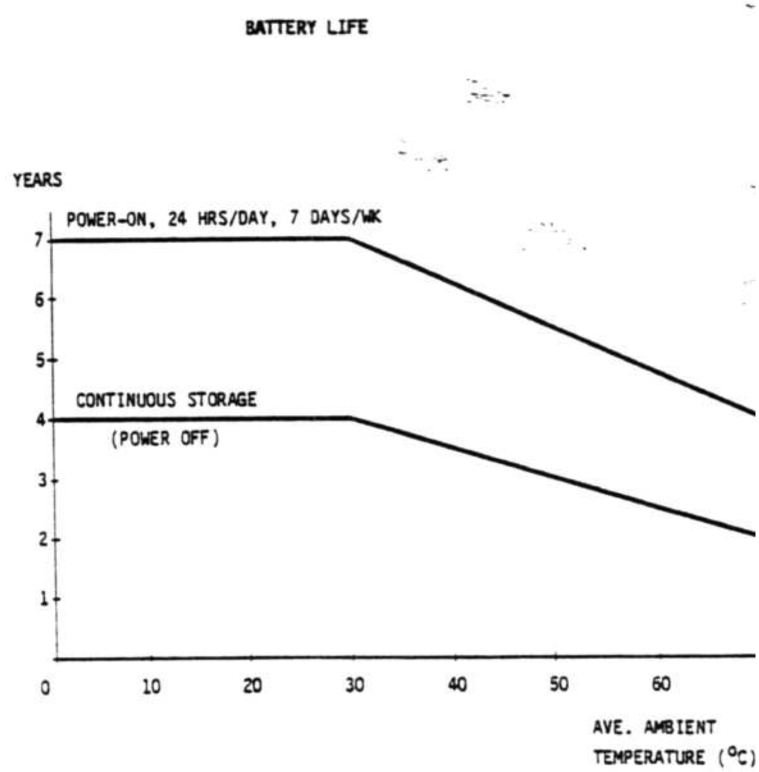


Figure 5.17 - Suggested 5001 Lithium Battery Replacement

5.5 SIGNATURE ANALYSIS

5.5.1 Introduction

5.5.1.1 Signature Analysis (SA) is a unique capability and method for troubleshooting the digital circuitry of the Model 5001 DMM. Advantages gained using SA techniques result from significantly reducing the following three problems, usually encountered when employing conventional test equipment for troubleshooting:

a) Difficulty in characterizing instrument circuitry because the operation of microprocessor firmware may be hidden from the user.

b) Problem in detecting the very dynamic operation of microcomputer circuitry in which signals appear for only a few microseconds before disappearing.

c) Difficulty in interpreting address and data information because of the parallel structure and bidirectional operation of the microcomputer-based bus system.

5.5.2 SA Description

5.5.2.1 SA techniques used during 5001 troubleshooting force the DMM's microprocessor to constantly execute designated test routines, making repetitive data patterns always available at selected data nodes in the 5001's logic section. By using a signature analyzer (for example, the Hewlett-Packard Model 5004A), these data nodes may be probe-tested and continuous data patterns identified by the resulting display of unique four-digit, alphanumeric codes called "signatures." These signatures characterize the cumulative data patterns occurring over specified time intervals.

5.5.2.2 Test signatures obtained from the data nodes are then compared to reference signatures included at the back of this section of the manual - those produced by a 5001 DMM known to be operating properly. If the test and reference signatures correspond, the proper operation of that particular section of the 5001's logic circuitry is verified. If the test and reference signatures do not correspond, then that particular part of the logic circuitry is malfunctioning. When a bad test signature is obtained, service procedures as outlined in the SA troubleshooting flowcharts should then be implemented.

5.5.3 SA Operation

5.5.3.1 The signal that stimulates a 5001 data node to generate a signature during SA is generated by the 5001's own microprocessor. Using the Unit-Under-Test (UUT) itself in this way during SA creates a controlled test environment which permits (1) independent testing of selected circuitry, while (2) still maintaining full dynamic operation. Also, the UUT now controls both the synchronization and measurement intervals for the signature analyzer being used for SA.

5.5.3.2 In operation, signals supplied to the signature analyzer start and stop a measurement time period. A clock input synchronizes and controls the data sampling rate of the probe input so that data is input for processing to the signature analyzer every clock cycle within a start and stop interval. The start and stop inputs are individually selectable for logic "1" or "0" levels. The clock input is edge-triggered and selectable for either rising or falling edges.

5.5.3.3 The 5001's microprocessor generates the stimulus for SA in the following two ways:

a) Free Run SA Mode (SAFR)

b) Self-Test Program SA Mode (SASTP)

5.5.3.4 Free-Run SA Mode

5.5.3.4.1 This operating mode becomes necessary whenever sufficient evidence indicates that the 5001's CPU cannot execute the Self-Test routines stored in ROM. SAFR Mode is easily achieved by removing the 5001's microprocessor and replacing it with the SAFR microprocessor socket adaptor (Racal-Dana P/N 404269). The microprocessor is then installed in the socket adaptor which enables the SAFR Mode by (1) disabling interrupts, (2) disconnecting the data bus, and (3) forcing an (No Operation) NOP instruction onto the data input lines of the microprocessor.

5.5.3.4.2 SAFR Mode is characterized by continuous cycling through the entire address or control field by the CPU circuitry (often called the Master Controller or "kernel") of the 5001's microprocessor-based system. If this part of the 5001's circuitry doesn't operate properly, or at all, neither will the rest of the instrument's circuitry.

5.5.3.4.3 When operating in the SAFR Mode, obtaining signatures permits verification of the status of (1) the kernel, (2) much of the combinational circuitry on the address or control lines (especially the address decoders and ROM data), and (3) the operation of the data bus. However, the SAFR Mode alone generally is not sufficient to exercise all devices and circuit nodes. For example, RAM's, most sequential and LSI circuits, and microprocessors are not adequately tested by SAFR. To test these latter components, the Self-Test Program SA (SASTP) Mode is employed.

5.5.3.5 Self-Test Program SA Mode

5.5.3.5.1 This capability of the 5001 utilizes a set of test stimulus algorithms which are stored in ROM and generated when the instrument is placed in the SASTP operating mode. To properly perform the SASTP Mode, the 5001's main controller must be able to execute a stored program. SASTP along with SAFR and microcomputer-assisted analog troubleshooting all permit excellent serviceability of the 5001.

5.5.4 SA Troubleshooting Procedures

5.5.4.1 Troubleshooting procedures for the 5001 using SA techniques are described in this subsection. The accompanying decision flowcharts (see Tables 5.25 - 5.28 and 5.30) permit a fault in the 5001's digital circuitry to be isolated to a specific section and, then, traced to the component level.

5.5.4.2 The following general guidelines and procedures will assist the user when applying the SA flowcharts during troubleshooting:

a) **Half-Splitting** - a useful technique in troubleshooting digital circuitry that has straightforward signal flow and minimal feedback. This method can often provide the user with the shortest path to the fault. Similar to tracing a signal in analog circuitry, half-splitting traces the source of a bad signature by selecting a test point approximately midway through the circuit, where there is an equal probability that the fault exists before as after the chosen point. A good signature indicates that all the circuitry up to the test point is probably good (depending on how much of the circuit is exercised) and that the fault is located further down the circuit beyond the test point. A bad signature, however, signifies just the opposite. Once identified, the bad half of the circuit can also be half-split, with this procedure repeated until the fault is located.

b) **Vcc Signature** - every different signature analyzer setup exhibits a characteristic signature when the analyzer probe is applied to the + 5 V reference point. This distinctive signature is termed the "Stuck-at-Logic 1" signature for that analyzer setup and each Vcc signature can be used to identify that condition elsewhere in the digital circuitry. The Vcc Signature results from shifting logic 1's into every clock cycle that occurs when the window to analyzer is open. Each Vcc Signature verifies that the analyzer's inputs are properly connected and the test loop operating. "Stuck-at-Logic 0" is 0000, regardless of the signature analyzer setup.

c) **Bad Signatures** - these result at a test node for many reasons, some of which are not mentioned in the flowcharts. Therefore, the following possible causes for bad signatures should be remembered when working through these charts:

   1) Chip not powered or grounded.

   2) Bad chip that is loading the output of another chip.

   3) Discontinuous signal lines resulting in signals not reaching their proper circuit locations.

   4) Short-circuited signal lines providing like signatures.

   5) Excessive settling times of analyzer test probes.

5.5.4.3 Effective SA Troubleshooting of the 5001 digital circuitry requires use of the three following references described in the next three subsections.

a) SA Flowcharts.

b) Signature Sets for the logic nodes.

c) Instructions for connecting the 5001 to the signature analyzer.

5.5.4.3.1 **SA Flowcharts** - these are detailed instructions required by the user to trace a particular fault to its source. The five flowcharts used in 5001 SA Troubleshooting are provided in subsection 5.5.4.4 to which the user is referred. As the user performs the various instructions in these decision flowcharts, it is recommended that every fault encountered be corrected before proceeding to the next instruction.

5.5.4.3.2 **Signature Sets** - there are eight signature sets referenced in the flowchart procedures. These sets are listed in Table 5.31, located immediately after the last flowchart. Each set provides (1) Probe TP (2) Signature and (3) Special Conditions. Procedurally, the analyzer probe is applied to the logic node specified in the signature set and the signature displayed on the analyzer readout is then compared to the correct reference signature noted in the set. Any lack of correspondence between the test and reference signatures indicates a circuitry problem.

NOTE

Signature sets are identified by the two ROMs, U3 (P/N 230617A) and U4 (P/N 230618B), that store the signature data. Verify that the ROM numbers listed in the signature sets correspond to the ROM designations marked on these two components inside the unit. If the ROM numbers listed in the signature sets do not correspond to the ROM designations on U3 and U4, contact Racal-Dana for the correct signature set.

5.5.4.3.3 **5001 Analyzer Connection Instructions** - the signature analyzer is connected to the 5001 by first removing the instrument's top cover. Jumpers W1 through W4 are then installed at the locations described in the flowchart instructions. Refer to Table 5.25 for these jumper locations on the Motherboard PCB. Placement of these jumpers shift the 5001 to the SA Mode. Next, attach the analyzer pod connectors to the 5001 logic nodes specified in the SA flow-charts, signature sets and digital section schematics.

5.5.4.4 SA Troubleshooting Flow-charts

5.5.4.4.1 Figure 5.18 presents a simplified digital section block diagram. Use Figure 5.18 along with fold-out Figure 4.21 (previous section) - the main digital schematic block diagram - when proceeding through the SA flow-charts and using the signature sets.

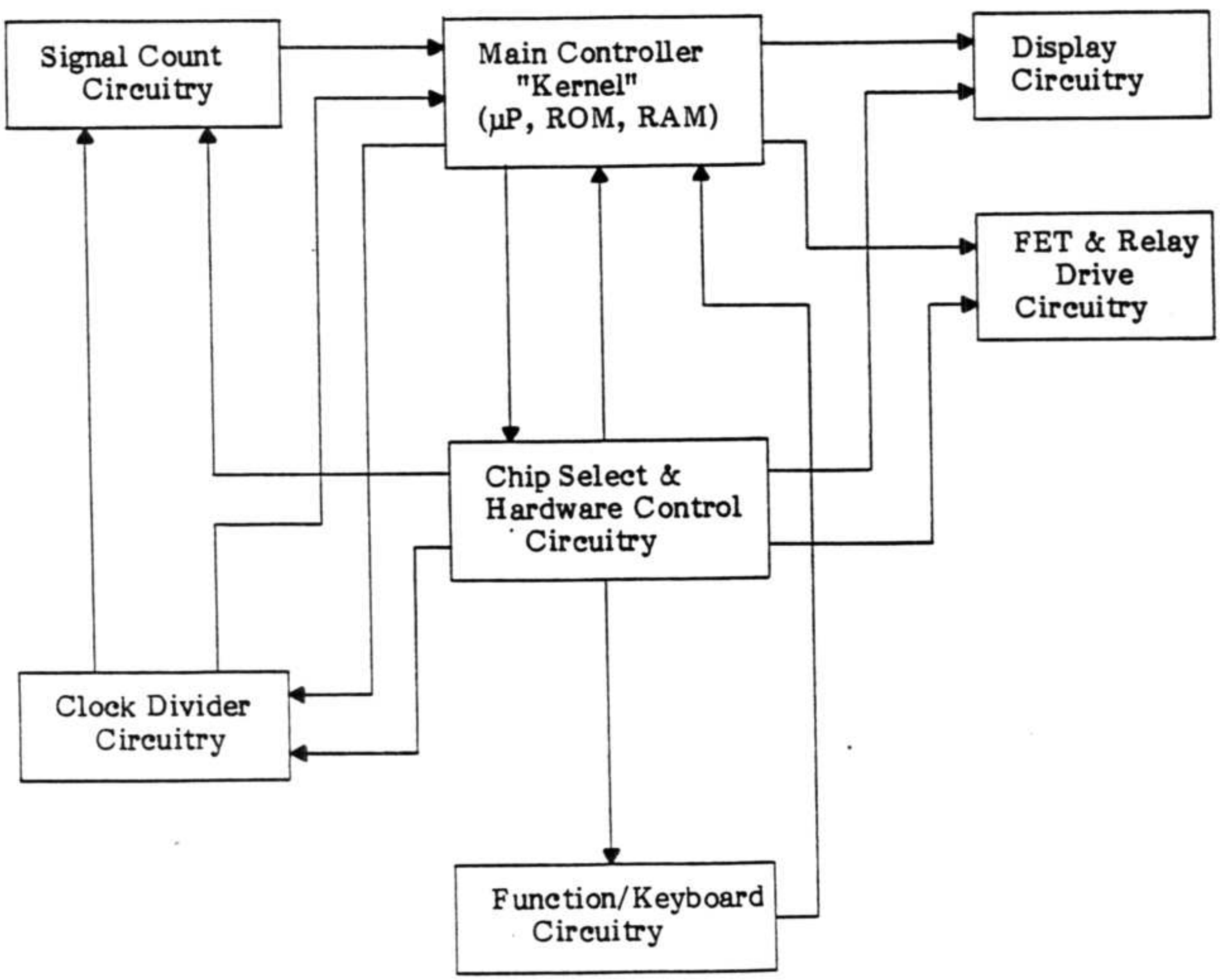


Figure 5.18 - Simplified Digital Section Block Diagram

Table 5.25 - Preliminary SA Troubleshooting Procedure

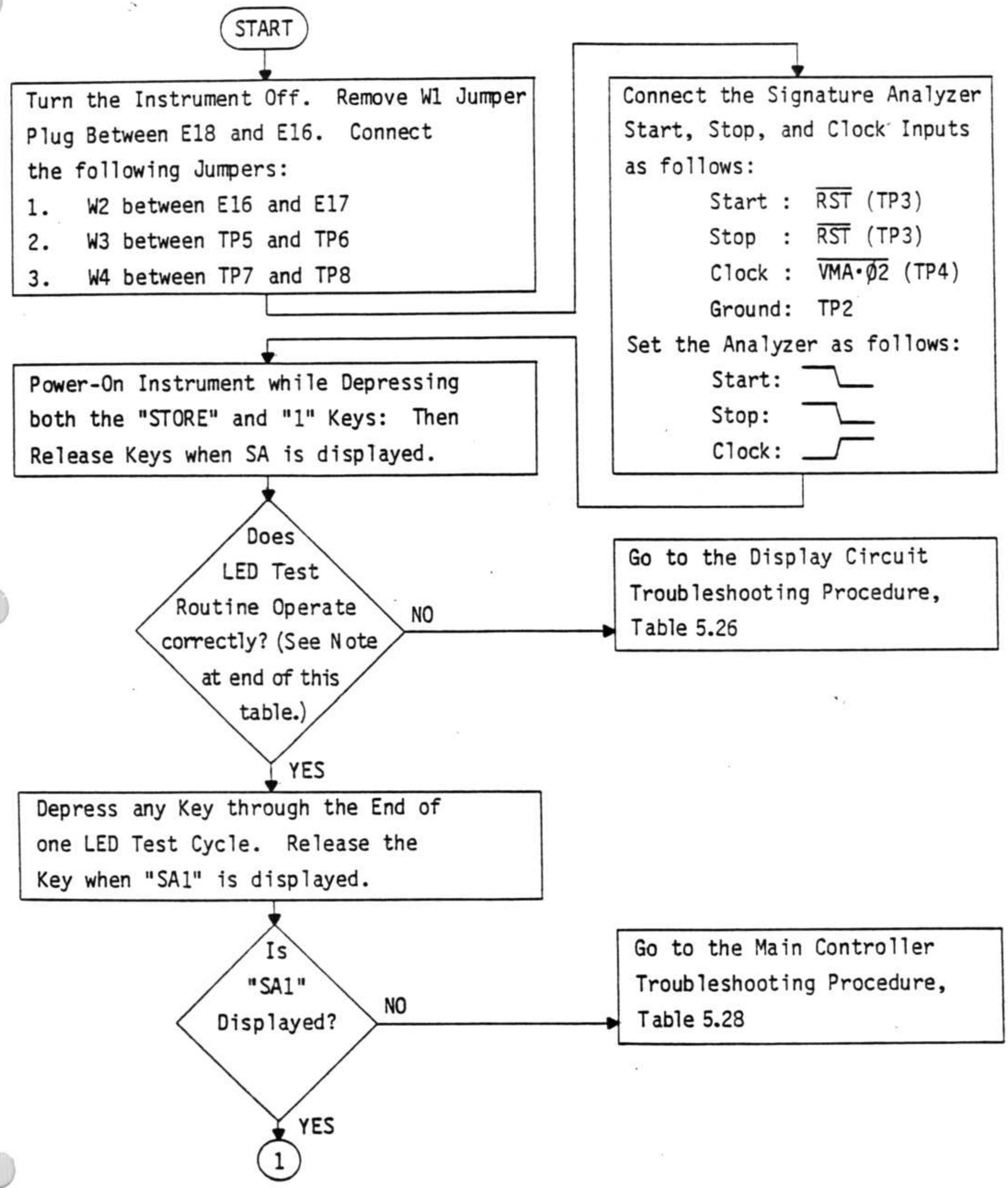


Table 5.25 - Preliminary SA Troubleshooting Procedure (Continued)

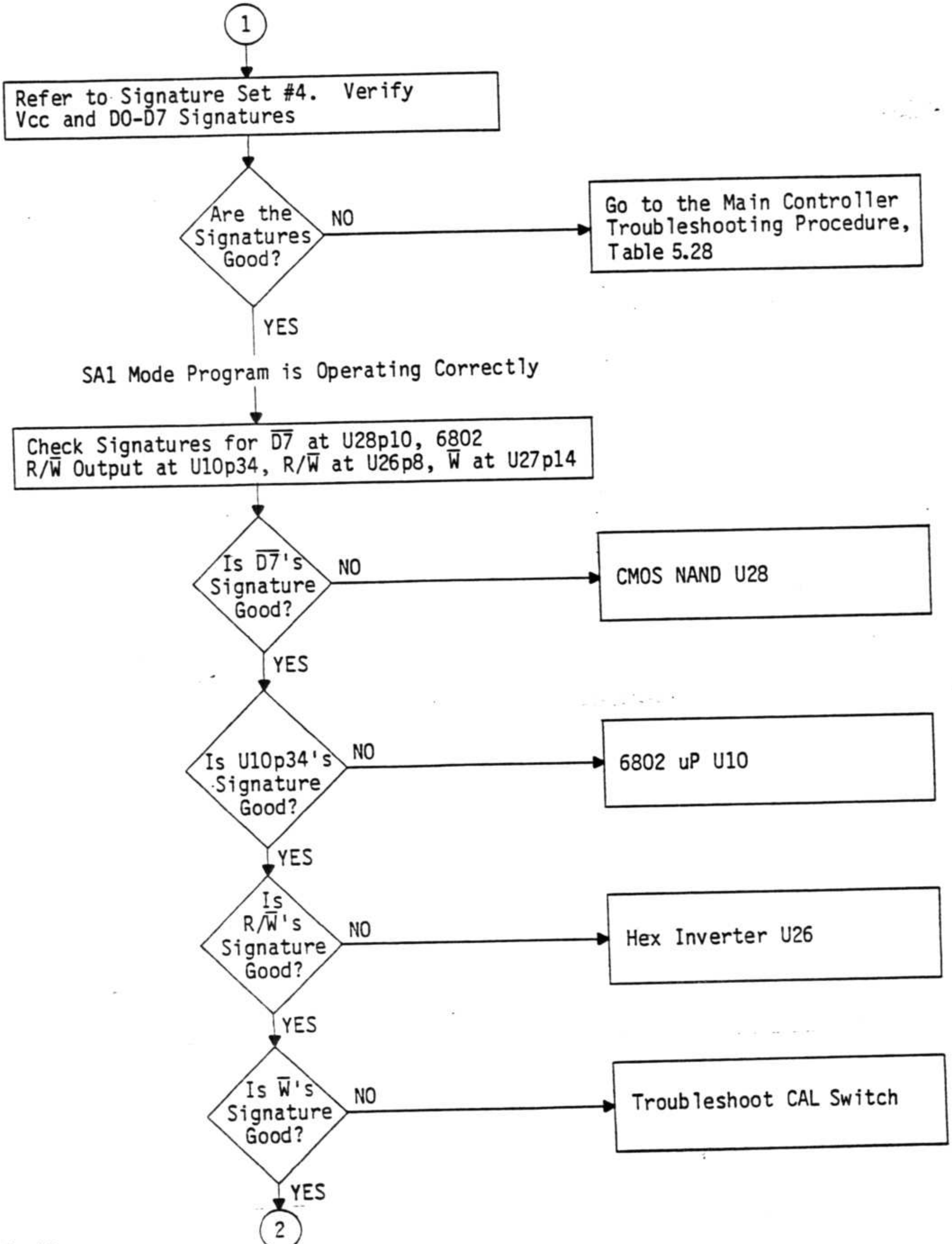


Table 5.25 - Preliminary SA Troubleshooting Procedure (Continued)

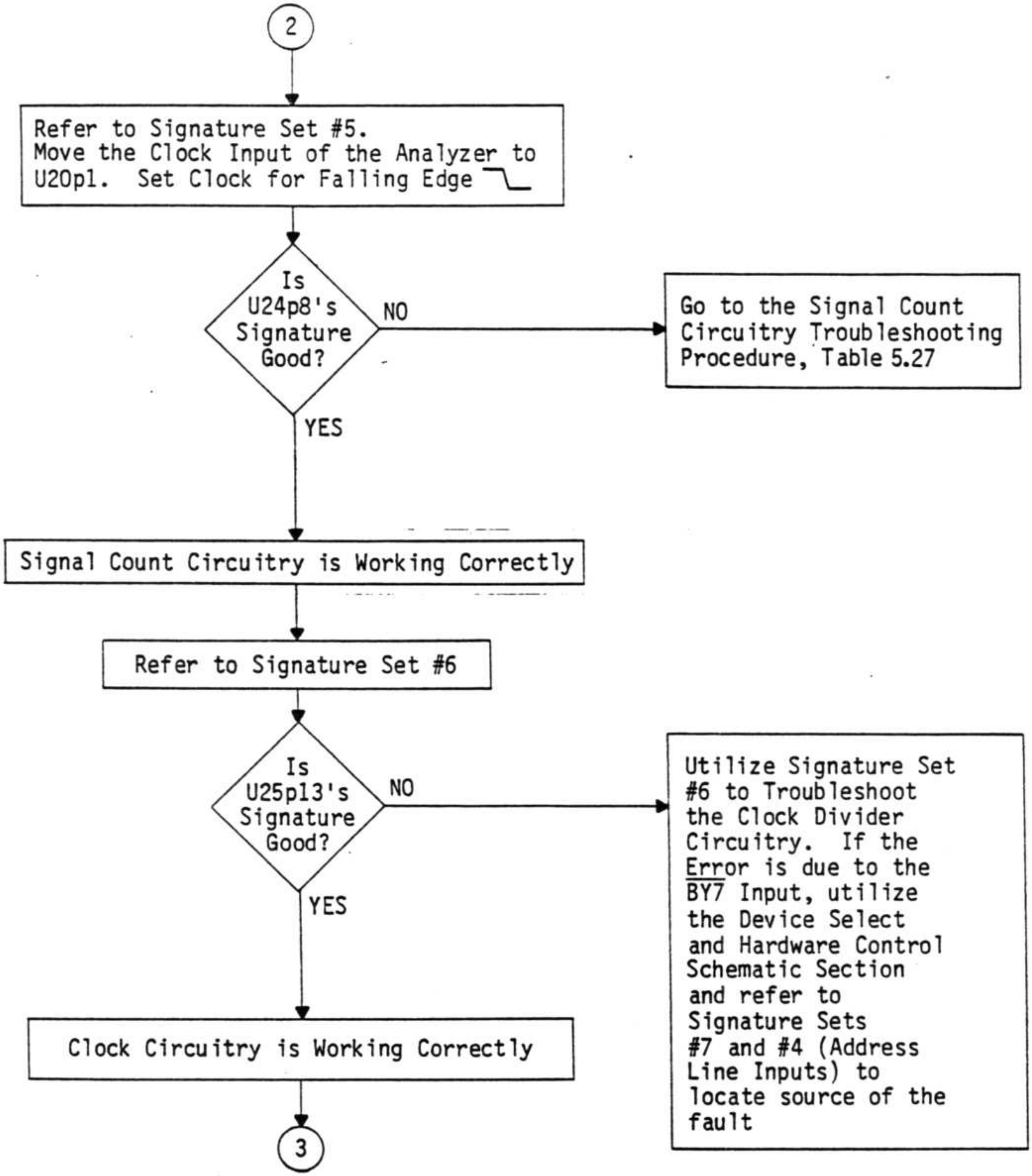
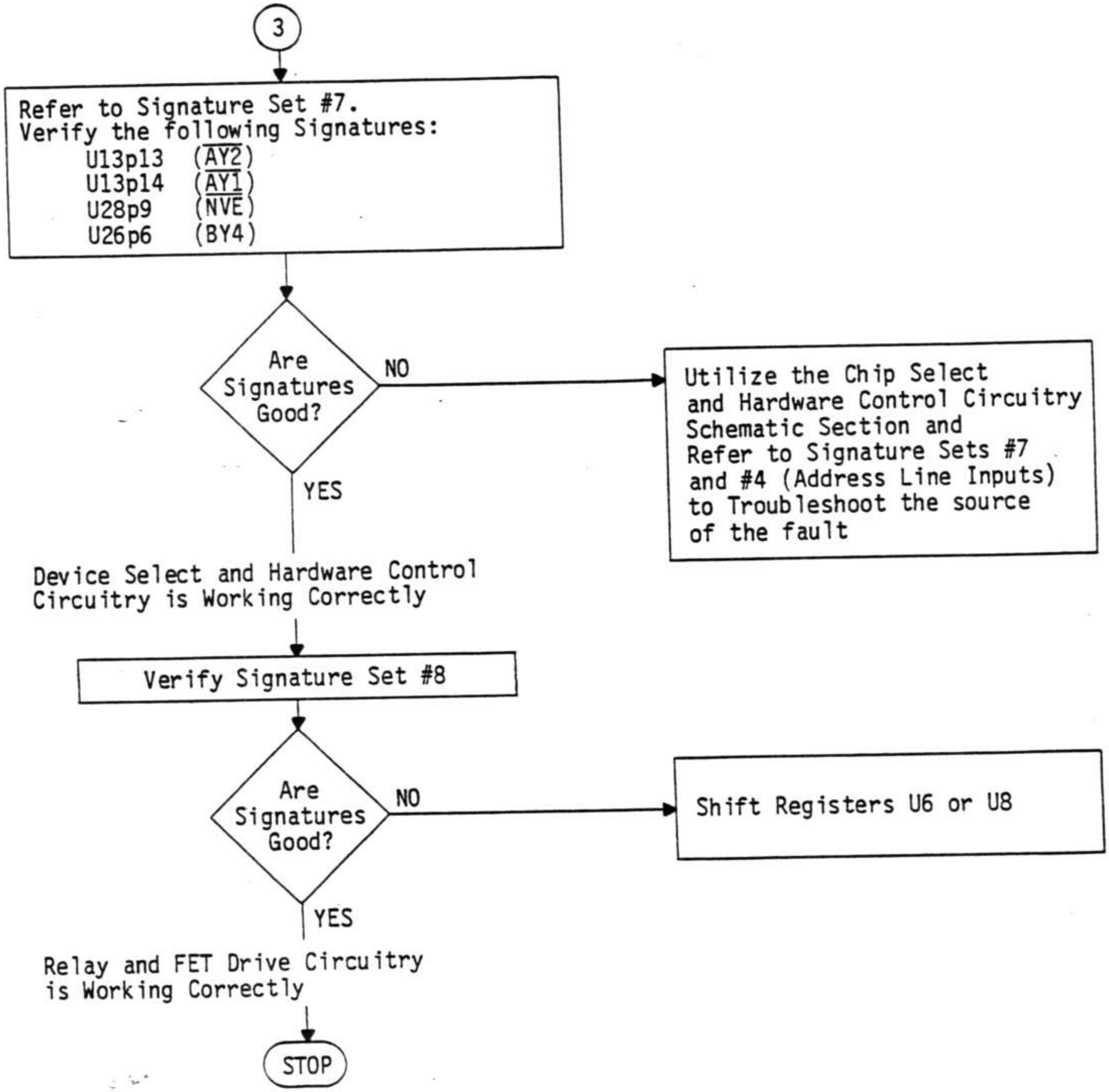


Table 5.25 – Preliminary SA Troubleshooting Procedure (Continued)



NOTE

Proper operation of the LED test routine is indicated by an "8" being strobed across the display, from left to right, followed by successive illumination of the individual segments of the 7-element displays. The front panel enunciators, minus sign and signal light are alternately lit with each display change. This cycle repeats until a key closure transfers 5001 operation to the SA2 mode.

Table 5.26 - Display Circuitry SA Troubleshooting Procedure

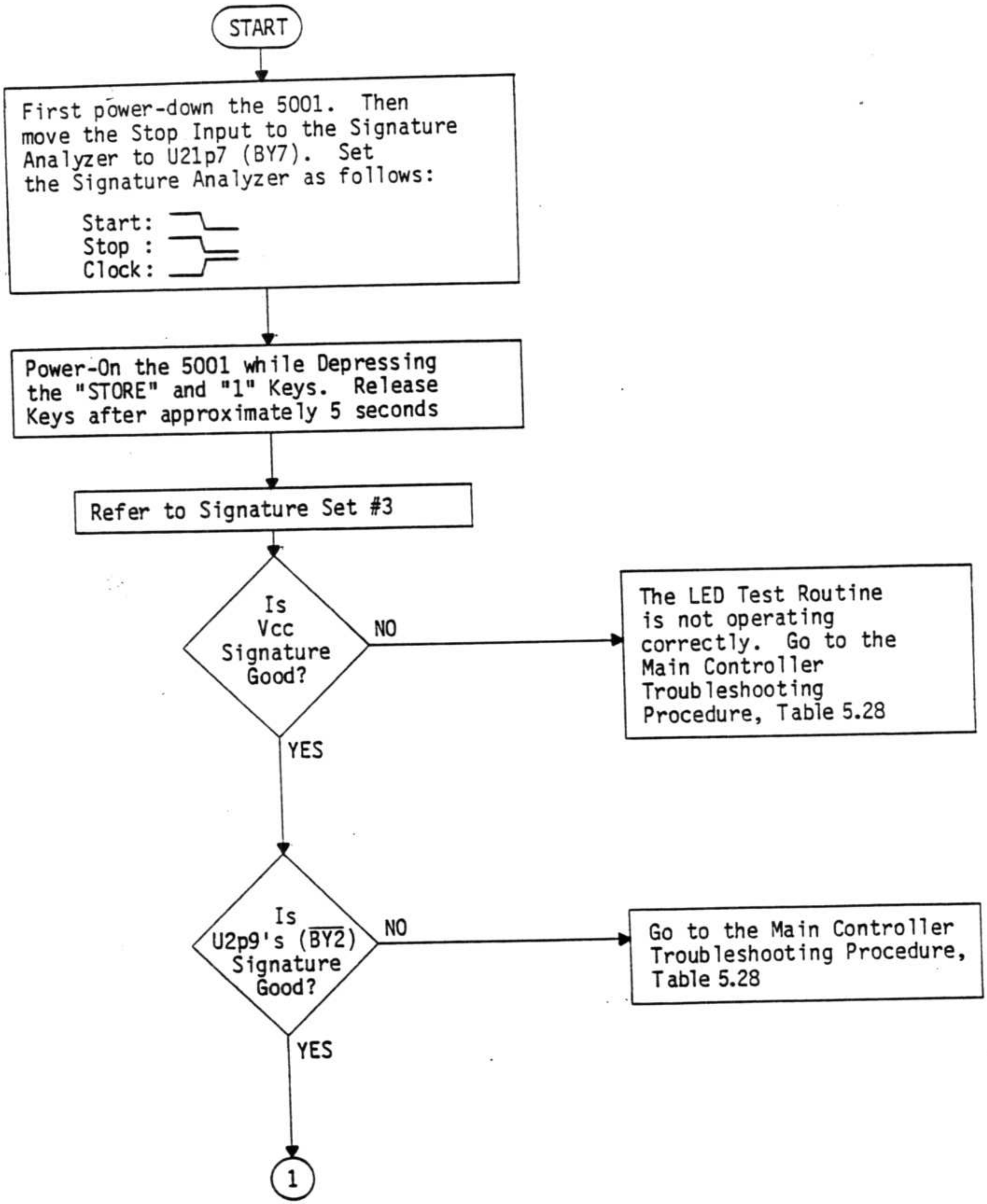


Table 5.26 - Display Circuitry SA Troubleshooting Procedure (Continued)

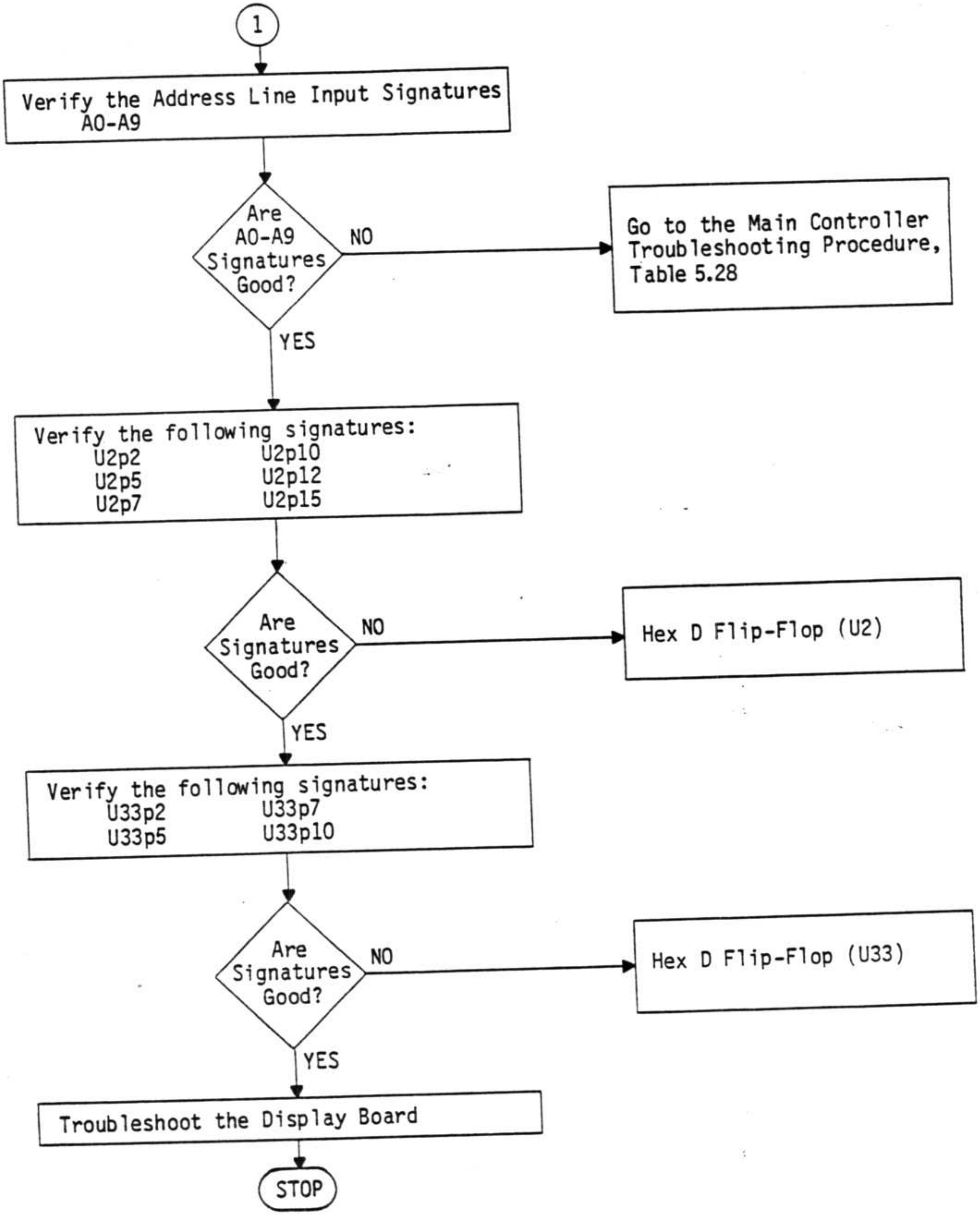


Table 5.27 - Signal Count Circuitry SA Troubleshooting Procedure

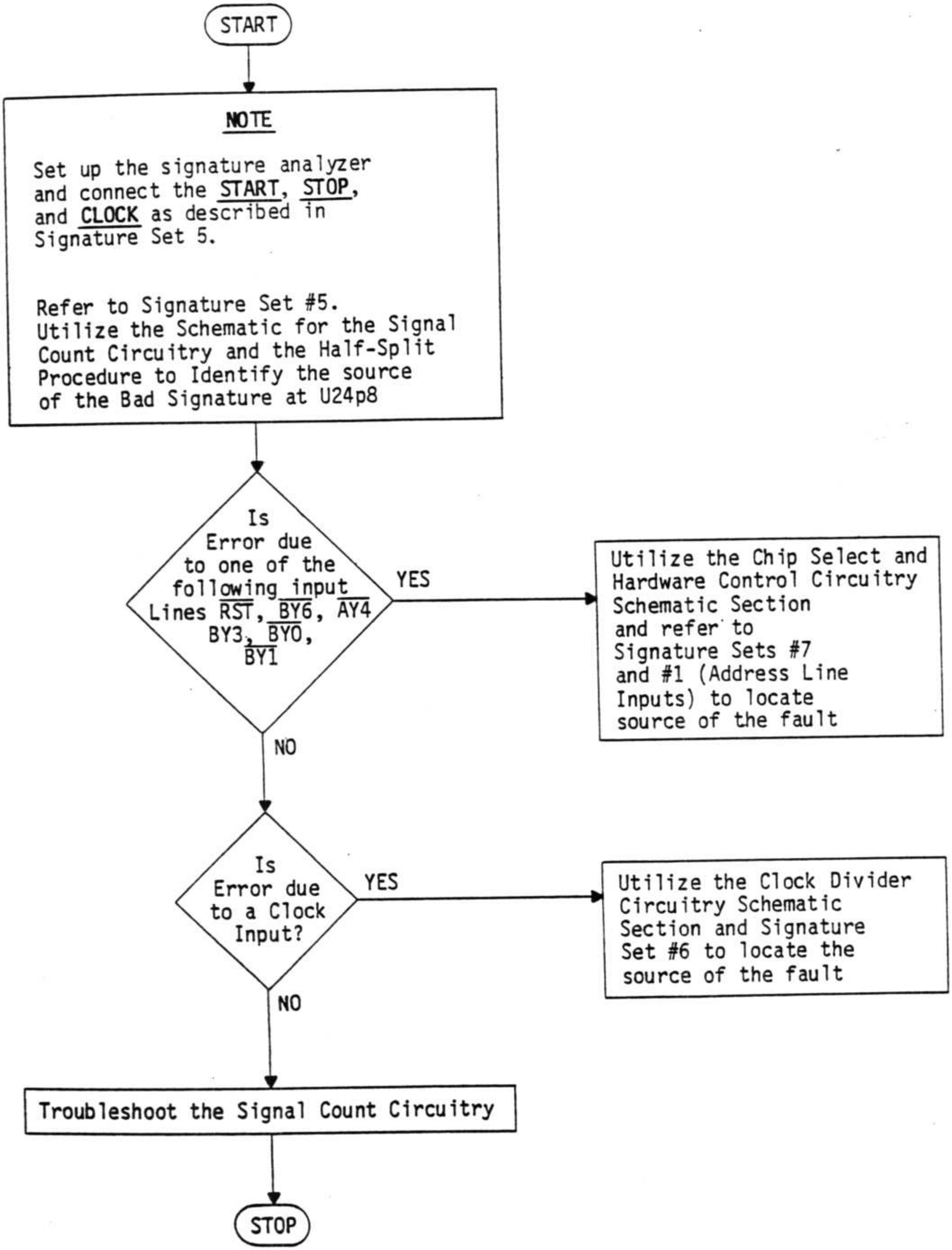
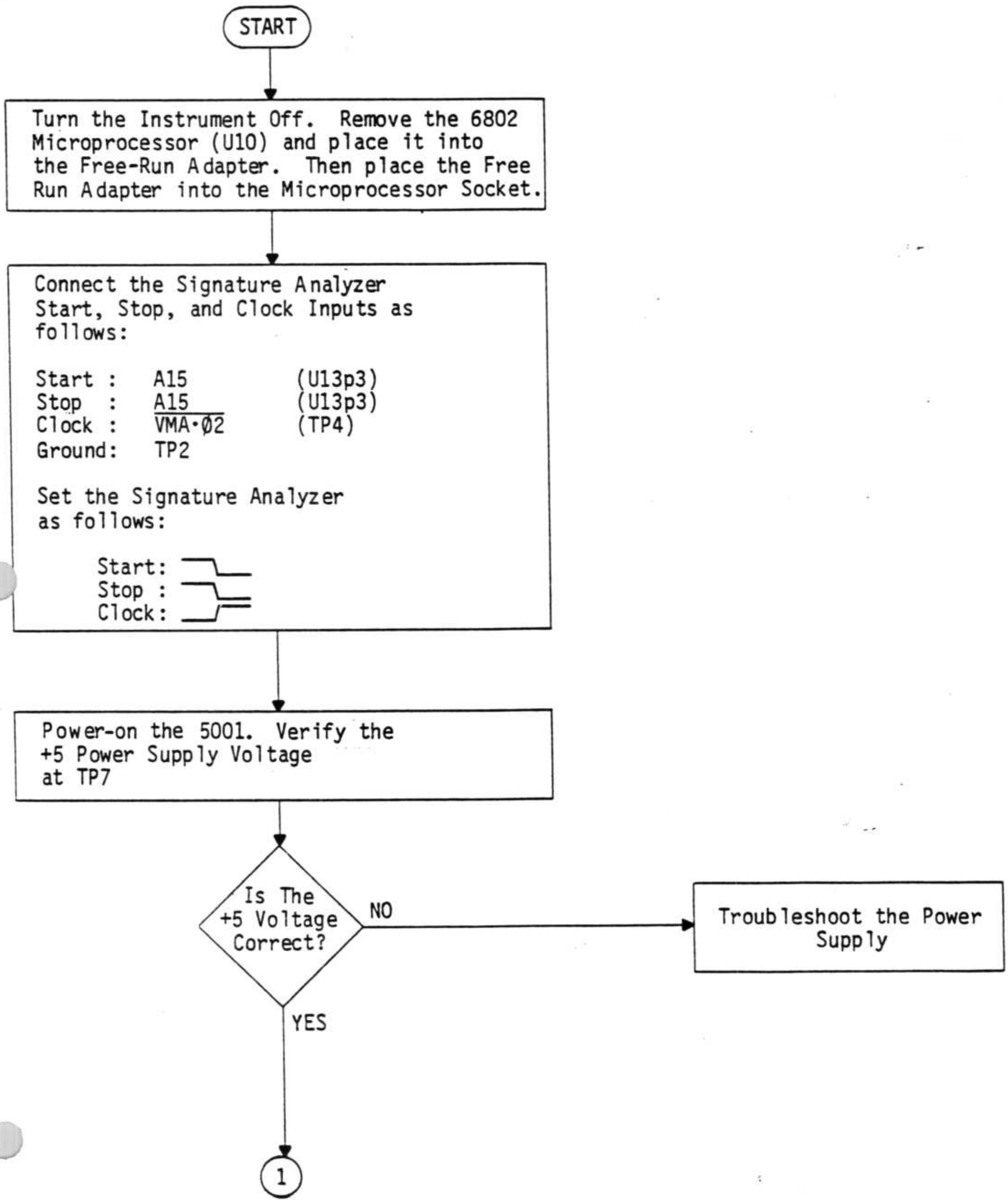
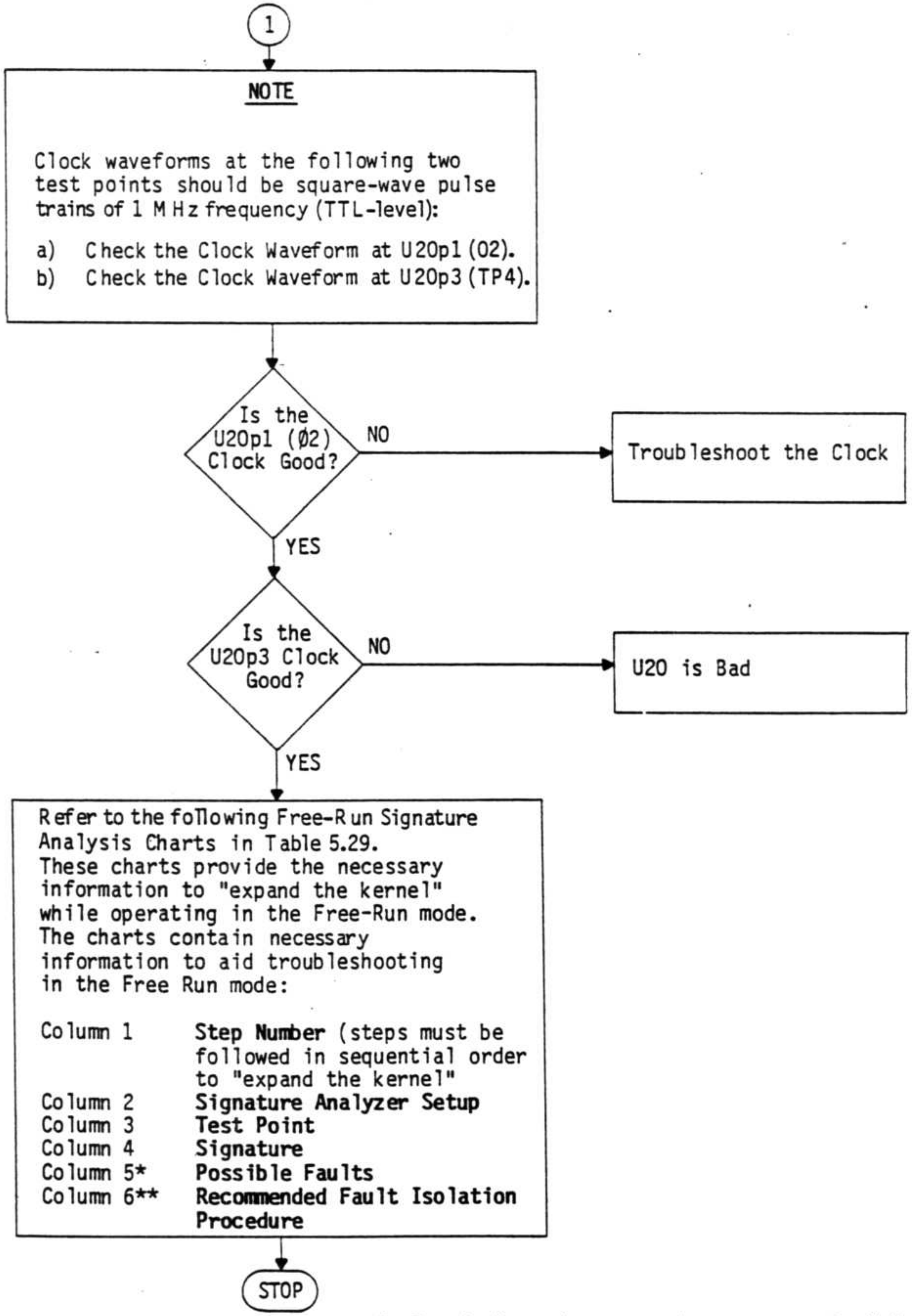


Table 5.28 - Main Controller SA Troubleshooting Procedure





* Faults indicated assume signatures up to this point are good.

** Additional information to isolate source of fault.

Table 5.29 - Free-Run SA Chart

Step No.	Signature Analyzer Setup	Test Point	Signature	Possible Faults	Recommended Fault Isolation Procedure
1	Start A15 U13p3 Stop A15 U13p3 Clock $\overline{VMA \cdot \phi 2}$ TP4 Start ↓ IN Stop ↓ IN Clock ↑ OUT Hold OUT Self Test OUT	Vcc	0003	1) Analyzer and/or Free-Run Setup is Incorrect 2) Start/Stop Input (A15) is Bad 3) Microprocessor is Inoperative	Verify A15's Operation (A15 should be a 50% Duty-Cycle Square Wave with a Period of approximately 131 mSec). Isolate A15 from the Address Bus to Identify any possible Bus Problem. If such a problem is identified, Troubleshoot the Bus using its own Troubleshooting Procedure (See Table 5.30)
		U10p9 A0 U10p10 A1 U10p11 A2 U10p12 A3 U10p13 A4 U10p14 A5 U10p15 A6 U10p16 A7 U10p17 A8 U10p18 A9 U10p19 A10 U10p20 A11 U10p22 A12 U10p23 A13 U10p24 A14 U10p25 A15	UUUU FFFF 8484 P763 1U5P 0356 U759 6F9A 7791 6321 37C5 6U28 4FCA 4868 9UP1 0001	1) Microprocessor is Bad 2) Faulty Address Bus 3) Address Pullups (Z6 & Z7) are Bad	Isolate the Microprocessor's Address Pins from the Address Bus to Identify any possible Bus Problem. If such a problem is identified, Troubleshoot the Bus using its own Troubleshooting Procedure (See Table 5.30)

Table 5.29 - Free-Run SA Chart (Continued)

Step No.	Signature Analyzer Setup	Test Point	Signature	Possible Faults	Recommended Fault Isolation Procedure
2	Same as Step 1	U13p15 $\overline{AY0}$ U13p14 $\overline{AY1}$ U13p13 $\overline{AY2}$ U13p12 $\overline{AY3}$ U13p11 $\overline{AY4}$ U13p10 $\overline{AY5}$ U13p9 $\overline{AY6}$ U13p7 $\overline{AY7}$	C9U1 534H F9CF 2302 5FUA 29A4 64HF 1183	1) U13 is Bad 2) U13's Chip Enable Inputs (G1,G2A,G2B) and/or Address Line Inputs (A13-A15) are Not Valid	Replace U13. If the problem still exists, Verify U13's Inputs: U13p1 A13 U13p2 A14 U13p3 A15 U13p4 GND U13p5 GND U13p6 VMA
		U26p10 AY5 U28p9 $\overline{NVE}$	29A7 29A4	1) U26 is Bad 2) U28 is Bad or U32's Enable Signal is Not Valid (Vcc SIG)	
3	Same as Step 1	U21p15 $\overline{BY0}$ U21p14 $\overline{BY1}$ U21p13 $\overline{BY2}$ U21p12 $\overline{BY3}$ U21p11 $\overline{BY4}$ U21p10 $\overline{BY5}$ U21p9 $\overline{BY6}$ U21p7 $\overline{BY7}$	P3A9 AH89 U00P 5987 H85H 1829 U03U U4P3	1) U21 is Bad 2) U21's Chip Enable Inputs (G1,G2A,G2B) and/or Address Line Inputs (A10-A12) are Not Valid	Replace U21. If the problem still exists, Verify U21's Inputs: U21p1 A10 U21p2 A11 U21p3 $\overline{A12}$ U21p4 $\overline{AY3}$ U21p5 U21p6 +5V
		U26p4 BY3 U26p6 BY4 U26p2 RST	5984 H85P 182A	1) U26 is Bad	

Table 5.29 - Free-Run SA Chart (Continued)

Step No.	Signature Analyzer Setup	Test Point	Signature	Possible Faults	Recommended Fault Isolation Procedure
4	Start $\overline{AY7}$ U13p7 Stop $\overline{AY7}$ U13p7 Clock $\overline{VMA \cdot \phi 2}$ TP4	Vcc	1180	1) Analyzer and/or the Free Run Setup is Incorrect 2) Start/Stop Input ($\overline{AY7}$) is Bad	Check Setup and $\overline{AY7}$'s continuity
	Start IN Stop OUT Clock OUT Hold OUT Self Test OUT	U3p9 D0 U3p10 D1 U3p11 D2 U3p13 D3 U3p14 D4 U3p15 D5 U3p16 D6 U3p17 D7	See Signature Set #1	1) U3 is Bad 2) Data Bus is Faulty 3) Chip Select Inputs ($\overline{CS1}$,$\overline{CS2}$) are Not Valid	Isolate the ROM's Data Pins from the Data Bus to Identify any possible Bus Problem. If such a problem is identified, Troubleshoot the Bus using its Troubleshooting Procedure (See Table 5.30)
5	Start $\overline{AY6}$ U13p9 Stop $\overline{AY6}$ U13p9 Clock $\overline{VMA \cdot \phi 2}$ TP4	Vcc	1180	1) Analyzer and/or the Free Run Setup is Incorrect 2) Start/Stop Input ($\overline{AY6}$) is Bad	Check Setup and $\overline{AY6}$'s continuity
	Start IN Stop OUT Clock OUT Hold OUT Self Test OUT	U4p9 D0 U4p10 D1 U4p11 D2 U4p13 D3 U4p14 D4 U4p15 D5 U4p16 D6 U4p17 D7	See Signature Set #2	1) U4 is Bad 2) Chip Select Inputs ($\overline{CS1}$,$\overline{CS2}$,CS3) are Not Valid	Isolate the ROM's Data Pins from the Data Bus to Identify any possible Bus Problem. If such a problem is identified, Troubleshoot the Bus using its Troubleshooting Procedure (See Table 5.30)

Table 5.29 - Free-Run SA Chart (Continued)

Step No.	Signature Analyzer Setup			Test Point		Signature	Possible Faults	Recommended Fault Isolation Procedure
6*	Start	A15	U13p3	U1p2	(None)	0003	1) Display Board (U1) is Bad	
	Stop	A15	U13p3	U1p2	(LAH)	0355	2) Z2 Pullup is Bad	
	Clock	$\overline{VMA \cdot Ø2}$	TP4	U1p2	(△%)	1U5H	3) Keyboard is Bad	
				U1p2	(NULL)	P760		
	Start	↓	IN	U1p2	(RECALL)	8487		
	Stop	↓	IN	U1p2	(STORE)	FFFU		
	Clock	↑	OUT	U1p2	(AUTO)	UUUF		
	Hold		OUT	U1p2	(.1)	0003		
	Self Test		OUT	U1p2	(1)	0003		
				U1p2	(10)	0003		
				U1p2	(100)	0003		
				U1p2	(1K)	0003		
				U1p2	(10K)	0003		
				U1p4	(None)	0003		
				U1p4	(LAH)	0003		
				U1p4	(△%)	0003		
				U1p4	(NULL)	0003		
				U1p4	(RECALL)	0003		
				U1p4	(STORE)	0003		
				U1p4	(AUTO)	0003		
				U1p4	(.1)	UUUF		
				U1p4	(1)	FFFU		
				U1p4	(10)	8487		
				U1p4	(100)	P760		
				U1p4	(1K)	1U5H		
				U1p4	(10K)	0355		

*Signature taken when the key indicated in parenthesis is pressed

Table 5.29 - Free-Run SA Chart (Continued)

Step No.	Signature Analyzer Setup	Test Point	Signature	Possible Faults	Recommended Fault Isolation Procedure
7*	Start $\overline{BY2}$ U21p13 Stop $\overline{BY2}$ U21p13 Clock $\overline{VMA\cdot\emptyset2}$ TP4	Vcc	7A70	1) Analyzer and/or the Free Run Setup is Incorrect 2) Start/Stop Input ($\overline{BY2}$) is Bad	Check Setup and $\overline{BY2}$'s continuity
	Start IN Stop OUT Clock OUT Hold OUT Self Test OUT	U1p3 (None)	7A70	1) U1 is bad	
		U1p3 (LAH)	355A		
		U1p3 (△%)	3P32		
		U1p3 (NULL)	9A40		
		U1p3 (RECALL)	AAHA		
		U1p3 (STORE)	A077		
		U1p3 (AUTO)	F86A		
		U1p3 (.1)	7A70		
		U1p3 (1)	7A70		
		U1p3 (10)	7A70		
		U1p3 (100)	7A70		
		U1p3 (1K)	7A70		
		U1p3 (10K)	7A70		
		U1p5 (None)	7A70		
		U1p5 (LAH)	7A70		
		U1p5 (△%)	7A70		
		U1p5 (NULL)	7A70		
		U1p5 (RECALL)	7A70		
		U1p5 (STORE)	7A70		
		U1p5 (AUTO)	7A70		
		U1p5 (.1)	F86A		
		U1p5 (1)	A077		
		U1p5 (10)	AAHA		
		U1p5 (100)	9A40		
		U1p5 (1K)	3P32		
		U1p5 (10K)	355A		

* Signature taken when the key indicated in parenthesis is pressed

Table 5.29 - Free-Run SA Chart (Continued)

Step No.	Signature Analyzer Setup	Test Point	Signature	Possible Faults	Recommended Fault Isolation Procedure
8	Same as Step 7	U1p7 D5	DC Switch: IN 7A70 OUT 0000	1) U1 is bad	
		U1p9 D7	Ω Switch: IN 7A70 OUT 0000		
		U1p11 D4	mA Switch: IN 7A70 OUT 0000		
		U1p13 D3	FIL Switch: IN 7A70 OUT 0000		

Table 5.30 - Bus Circuitry SA Troubleshooting Procedure

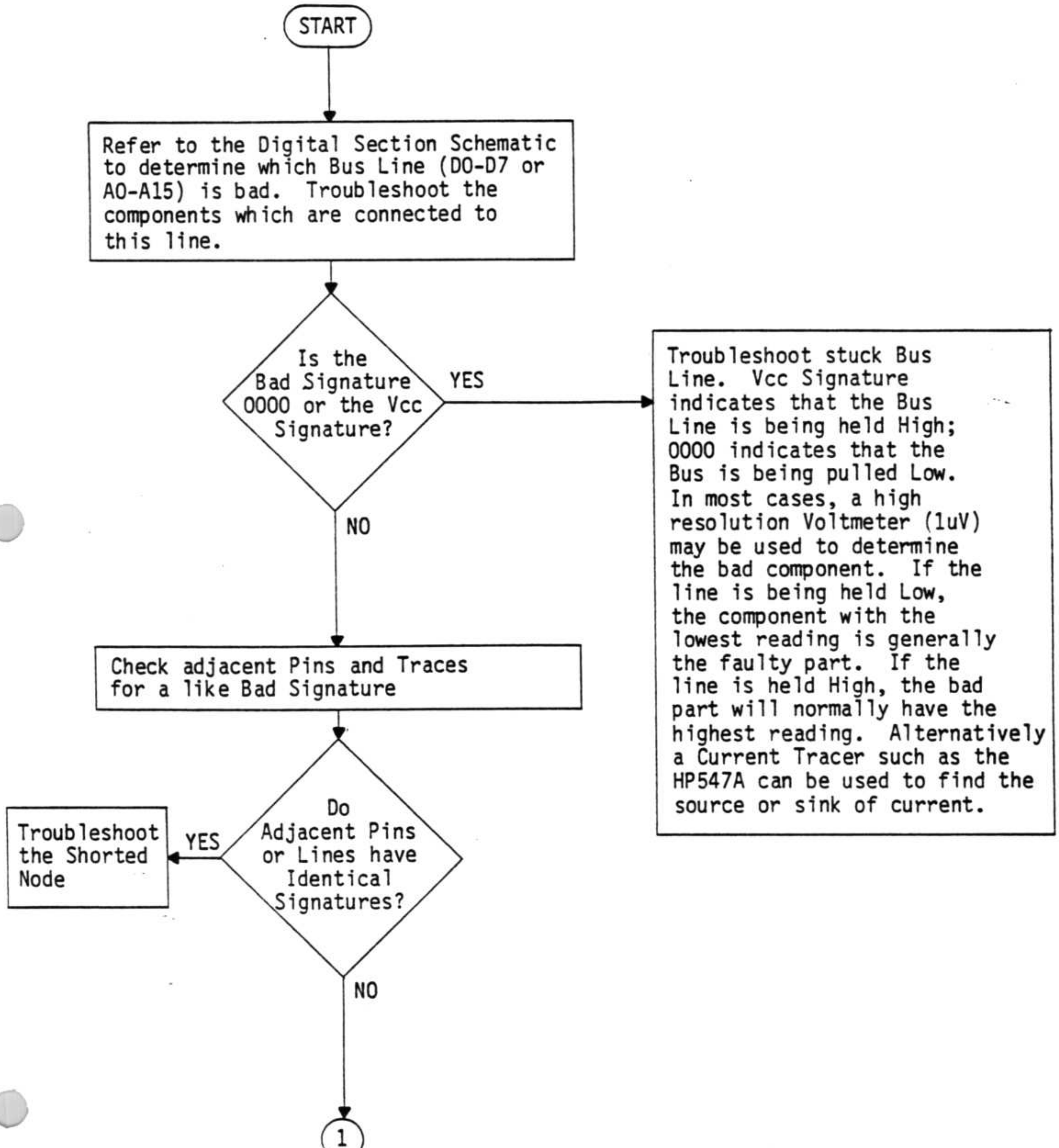
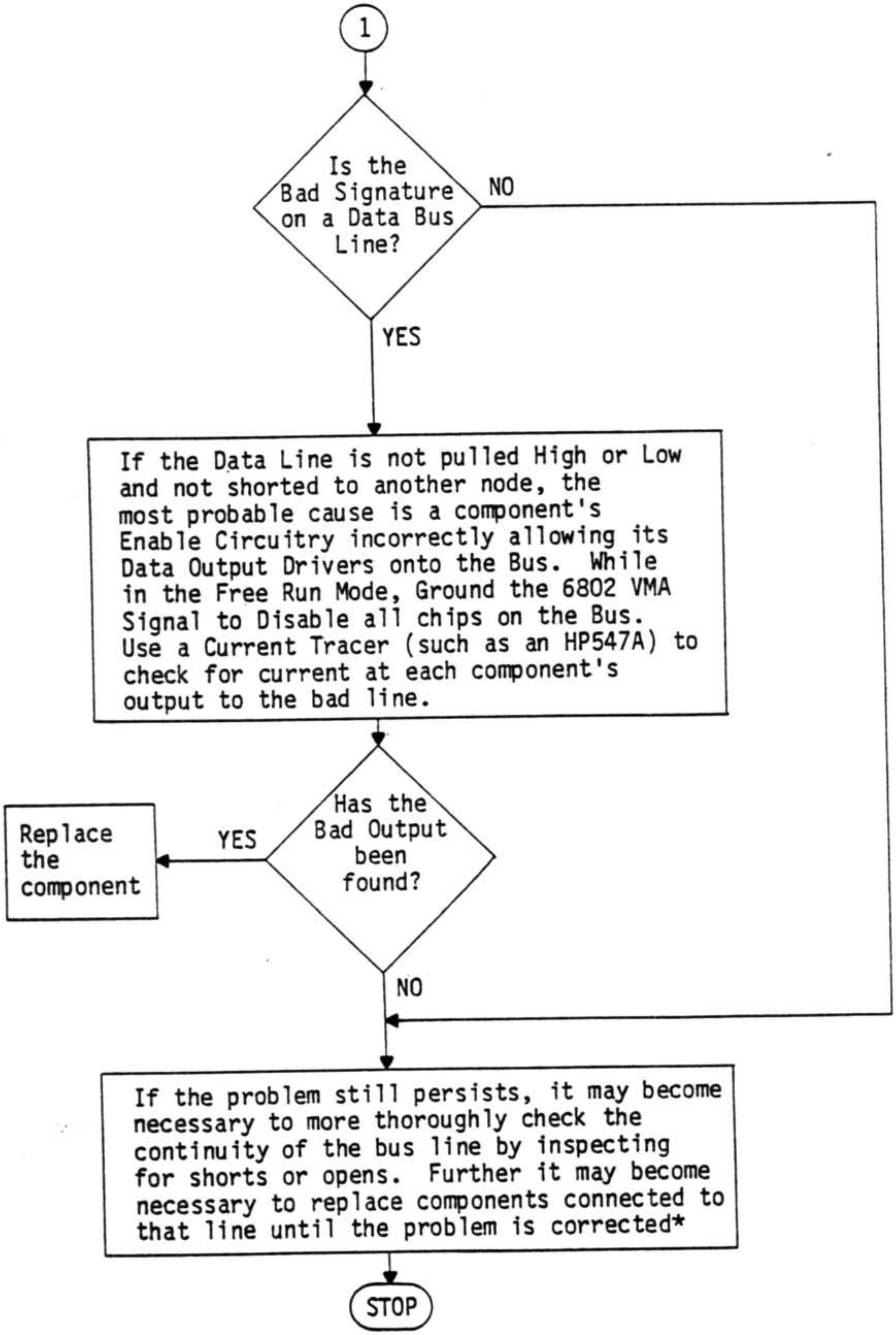


Table 5.30 – Bus Circuitry SA Troubleshooting Procedure (Continued)



*Don't remove the 6508 CMOS RAM (U27), the Non-Volatile Memory microcircuit, unless it's absolutely essential.

Table 5.31 – 5001 Signature Sets

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 1

MODE: FREE-RUN
(Adapter Socket in U10)
ROM NUMBER: 230617A

START: U13p7 ($\overline{AY7}$) IN
STOP: U13p7 ($\overline{AY7}$) OUT
CLOCK: TP4 ($\overline{VMA\cdot Ø2}$) OUT

Probe Test Point		Signature
Vcc		1180
U3p9	D0	HA94
U3p10	D1	96H7
U3p11	D2	F22C
U3p13	D3	FP98
U3p14	D4	OFF1
U3p15	D5	2A25
U3p16	D6	5U47
U3p17	D7	F979

Table 5.31 - 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 2

MODE: FREE-RUN		**START:**	U13p9	($\overline{AY6}$)	IN
(Adapter Socket in U10)		**STOP:**	U13p9	($\overline{AY6}$)	OUT
ROM NUMBER: 230618B		**CLOCK:**	TP4	($\overline{VMA \cdot \phi 2}$)	OUT

Probe Test Point		Signature
Vcc		1180
U4p9	D0	6590
U4p10	D1	117A
U4p11	D2	U44F
U4p13	D3	1000
U4p14	D4	91U8
U4p15	D5	P973
U4p16	D6	9HH9
U4p17	D7	0756

Table 5.31 - 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 3

MODE: SA
1. W2 - (E16-E17)
2. W3 - (TP5-TP6)
3. W4 - (TP7-TP8)

ROM NUMBERS: 230617A and 230618B

START: TP3 ($\overline{RST}$) IN
STOP: U21p7 ($\overline{BY7}$) IN
CLOCK: TP4 ($\overline{VMA \cdot \emptyset 2}$) OUT

Probe Test Point		Signature
Vcc		F5P3
U2p2	ID6	6765
U2p3	A6	H6A4
U2p4	A7	5CA2
U2p5	ID7	813C
U2p6	A5	0336
U2p7	ID5	36PA
U2p9	BY2	FU54
U2p10	ID4	37HA
U2p11	A4	0982
U2p12	ID3	7293
U2p13	A3	3075
U2p14	A2	PP06
U2p15	ID2	425A

Table 5.31 – 5001 Signature Sets (Continued)

Probe Test Point		Signature
U33p2	ID1	713P
U33p3	A1	H197
U33p4	A0	2C65
U33p5	ID0	92U1
U33p6	A9	17F1
U33p7	$\overline{\text{WRITE}}$	3F71
U33p9	$\overline{\text{BY2}}$	FU54
U33p10	MODE	45HH
U33p11	A8	H1F4

Table 5.31 - 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 4

MODE: SA1
1. W2 - (E16-E17)
2. W3 - (TP5-TP6)
3. W4 - (TP7-TP8)

ROM NUMBERS: 230617A and 230618B

START: TP3 ($\overline{RST}$) IN
STOP: TP3 ($\overline{RST}$) IN
CLOCK: TP4 ($\overline{VMA \cdot \emptyset 2}$) OUT

Probe Test Point		Signature
Vcc		4A20
U9p2	D0	8PCF
U9p3	D1	159P
U9p4	D2	9PO2
U9p5	D3	HP31
U9p6	D4	1895
U9p7	D5	66UO
U9p8	D6	A594
U9p9	D7	C78F
U28p10	D7	UHAF
U10p9	A0	1P12
U10p10	A1	PU3A

Table 5.31 - 5001 Signature Sets (Continued)

Probe Test Point		Signature
U10p11	A2	C79P
U10p12	A3	H79U
U10p13	A4	OPPP
U10p14	A5	P991
U10p15	A6	F651
U10p16	A7	7HHU
U10p17	A8	1F8U
U10p18	A9	PUUF
U10p19	A10	3600
U10p20	A11	OPH2
U10p22	A12	32H6
U10p23	A13	6U73
U10p24	A14	C3PF
U10p25	A15	49HF
U10p34	(6802 R/$\overline{W}$ OUTPUT)	23H9
U26p8	R/$\overline{W}$	23H9
U27p14	$\overline{W}$	23H9 Cal Switch Depressed
U27p14	$\overline{W}$	4A20 Cal Switch Not Depressed

Table 5.31 – 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 5

MODE: SA1
1. W2 - (E16-E17)
2. W3 - (TP5-TP6)
3. W4 - (TP7-TP8)

ROM NUMBERS: 230617A and 230618B

START: TP3 (RST) ⏋⎽ IN
STOP: TP4 (RST) ⏋⎽ IN
CLOCK: U20p1 (Ø2) ⏋⎽ IN

Probe Test Point		Signature
Vcc		9P8U
U24p1	SIG COUNT	HP4U
U24p2	BY3	1A21
U24p6		72HH
U24p8		P5P7
U24p12	BY3	1A21
U24p13		72HH
U17p1		0000
U17p2		4U27
U17p3		9P8U
U17p4		9P8U
U17p5	500 kHz	453H
U17p6		HCC2

Table 5.31 - 5001 Signature Sets (Continued)

Probe Test Point		Signature
U17p8		4U27
U17p9		9P8U
U17p10	$\overline{BY1}$	H1A8
U17p11	SIG COUNT	HP4U
U17p12		40F0
U17p13		40F0
U15p1		H1A8
U15p2		7584
U15p3		9P8U
U15p4		82FC
U15p5		H1CC
U15p6		PUOH
U15p8		H1A8
U15p9	Ø2	9P8U
U15p10		9P8U
U15p11		4U27
U15p12		40F0
U15p13	$\overline{BY0}$	7A63
U20p8		82FC
U20p9		C8A3

Table 5.31 - 5001 Signature Sets (Continued)

Probe Test Point		Signature
U20p10	$\overline{AY4}$	3A68
U14p1	$\overline{RST}$	FU47
U14p2		PU0H
U14p3		HCC2
U14p5		7584
U14p6		PC0C
U14p9		H1CC
U14p11	500 kHz	453H
U14p12	62.5 kHz	F609
U14p13		7584
U19p1	$\overline{RST}$	FU47
U19p2	D7	7U1P
U19p3	$\overline{BY6}$	9505
U19p5		0686
U19p8		C8A3
U19p11	1.25 kHz	OP89
U19p12		0686
U19p13	$\overline{RST}$	FU47

Table 5.31 - 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 6

MODE: SA1
1. W2 - (E16-E17)
2. W3 - (TP5-TP6)
3. W4 - (TP7-TP8)

ROM NUMBERS: 230617A and 230618B

START: TP3 ($\overline{RST}$) ⌝⎽ IN
STOP: TP3 ($\overline{RST}$) ⌝⎽ IN
CLOCK: U20p1 (Ø2) ⌝⎽ IN

Probe Test Point		Signature
Vcc		9P8U
U18p1	500 kHz	453H
U18p2		51F8
U18p3		51F8
U18p11	62.5 kHz	F609
U18p12	500 kHz	453H
U20p11		7178
U20p12	1.25 kHz	OP89
U20p13	$\overline{BY7}$	4FU6
U25p1	62.5 kHz	F609
U25p2		51F8
U25p3		9H5C

Table 5.31 – 5001 Signature Sets (Continued)

Probe Test Point		Signature
U25p4		9H5C
U25p7		5187
U25p9	1.25 kHz	OP89
U25p12		5187
U25p13	$\overline{IRQ}$	C786
U25p14		51F8
U25p15		7178
U26p1	$\overline{RST}$	FU47
U26p2		51F8

Table 5.31 - 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 7

MODE: SA1
1. W2 - (E16-E17)
2. W3 - (TP5-TP6)
3. W4 - (TP7-TP8)

ROM NUMBERS: 230617A and 230618B

START: TP3 ($\overline{RST}$) IN
STOP: TP3 ($\overline{RST}$) IN
CLOCK: U20p1 (Ø2) IN

Probe Test Point		Signature
Vcc		9P8U
U13p7	$\overline{AY7}$	9P8U
U13p9	$\overline{AY6}$	U2U9
U13p10	$\overline{AY5}$	16HC
U13p11	$\overline{AY4}$	3A68
U13p12	$\overline{AY3}$	1H29
U13p13	$\overline{AY2}$	1CF7
U13p14	$\overline{AY1}$	3793
U13p15	$\overline{AY0}$	7CF2
U21p4	$\overline{AY3}$	1H29
U21p7	$\overline{BY7}$	4FU6
U21p9	$\overline{BY6}$	9505
U21p10	$\overline{RST}$	FU47

Table 5.31 - 5001 Signature Sets (Continued)

Probe Test Point		Signature
U21p11	$\overline{BY7}$	78U6
U21p12	$\overline{BY3}$	84AP
U21p13	$\overline{BY2}$	F281
U21p14	$\overline{BY1}$	H1A8
U21p15	$\overline{BY0}$	7A63
U26p3	$\overline{BY3}$	84AP
U26p4	$\overline{BY3}$	1A21
U26p5	$\overline{BY4}$	78U6
U26p6	BY4	P679
U26p10	AY5	8854
U26p11	$\overline{AY5}$	16HC
U28p1	Ø2	9P8U
U28p2		9P8U
U28p6		9P8U
U28p8	AY5	8854
U28p9	$\overline{NYE}$	16HC

Table 5.31 - 5001 Signature Sets (Continued)

NOTE

Unless otherwise indicated, all of the following signatures are obtained with the DMM in the DC Function.

Signature Set 8

MODE: SA1
1. W2 - (E16-E17)
2. W3 - (TP5-TP6)
3. W4 - (TP7-TP8)

ROM NUMBERS: 230617A and 230618B

START: TP3 ($\overline{RST}$) ⏋⎽ IN
STOP: TP3 ($\overline{RST}$) ⏋⎽ IN
CLOCK: U20p1 (Ø2) ⏋⎽ IN

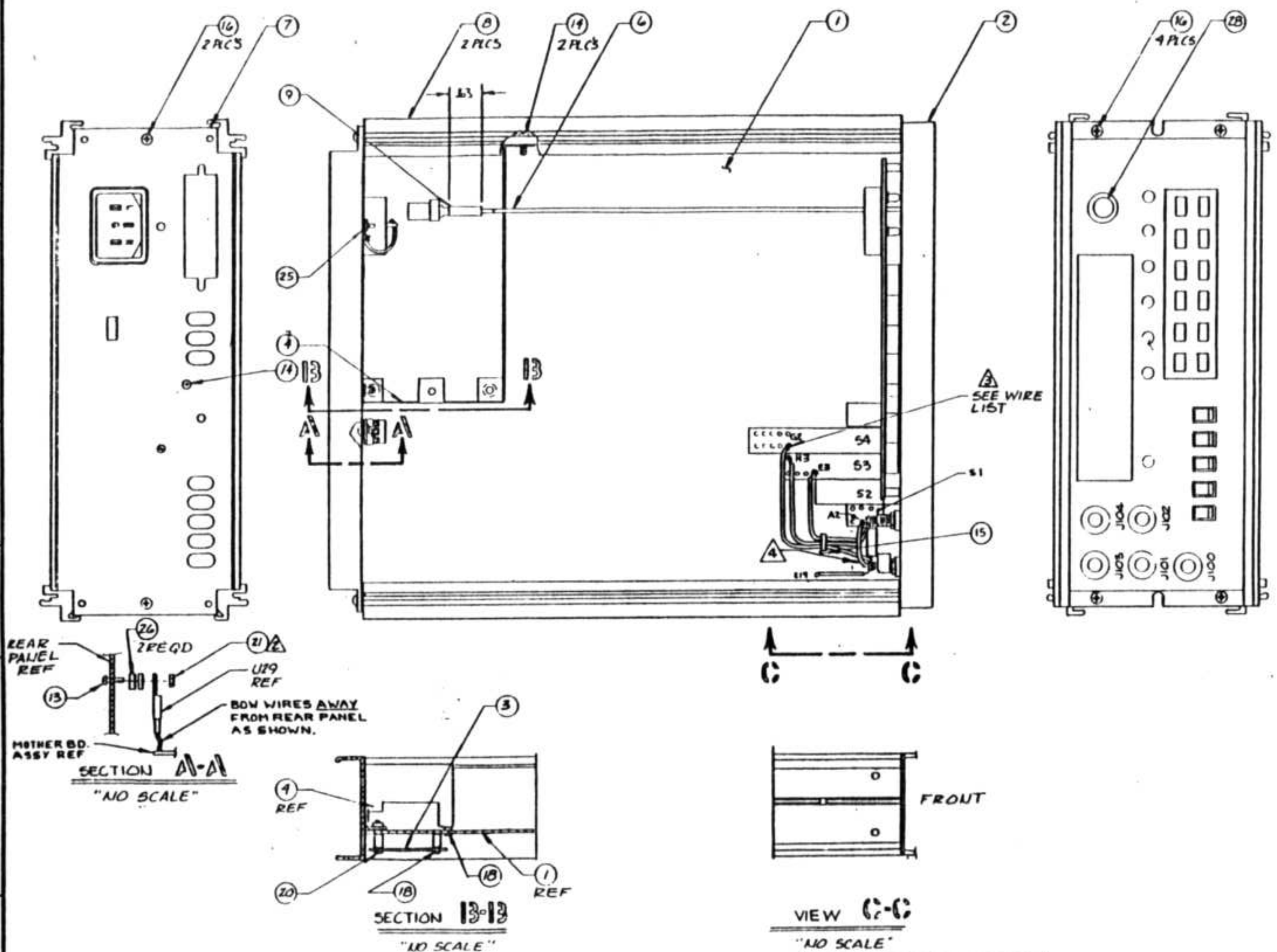
Probe Test Point		Signature
Vcc		9P8U
U6p1	BY4	P679
U6p2		40A6
U6p3	$\overline{BY3}$	84AP
U6p4		H4PF
U6p5		FF95
U6p6		F680
U6p7		24AF
U6p11		1198
U6p12		APH4
U6p13		U487
U6p14		04PU
U8p1	BY4	P679

Table 5.31 – 5001 Signature Sets (Continued)

Probe Test Point		Signature
U8p2	D7	7U1P
U8p3	$\overline{BY3}$	84AP
U8p4		H4PF
U8p5		FF95
U8p6		F680
U8p7		24AF
U8p9		40A6
U8p11		1198
U8p12		APH4
U8p13		U487
U8p14		04PU

Title	Page

USED ON EARLIER MODELS with Serial Numbers before 500500

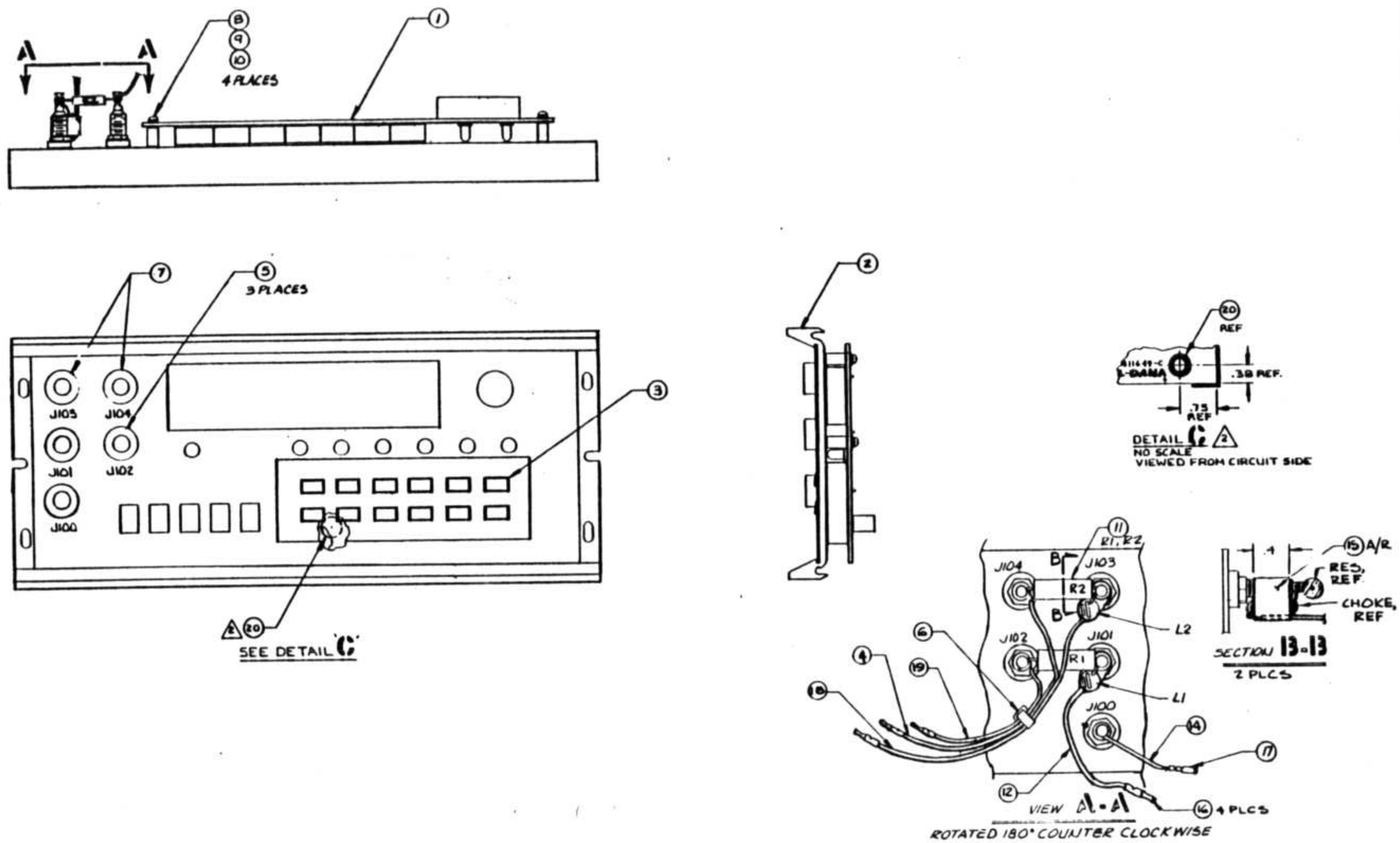


4. LOOP RED WIRE OVER THE TOP OF YELLOW, GREEN + BLUE WIRES.
3. FORM TIE-WRAPPED WIRES (YEL, GRN & BLU) TO RUN AT SAME HEIGHT AS INSTALLED PUSH-ON RECEPTACLES.
2. TORQUE ITEM 21 TO ITEM 13 USING 4 IN-LB FORCE.
1. ASSEMBLY PROCESSES & PROCEDURES TO CONFORM TO RACAL-DANA WORKMANSHIP STANDARD.

NOTES: UNLESS OTHERWISE SPECIFIED

CHASSIS ASSY

SIZE	CODE IDENT NO	DWG NO	REV
D	21793	404100	E
SCALE NONE		SHEET 1 OF 4	

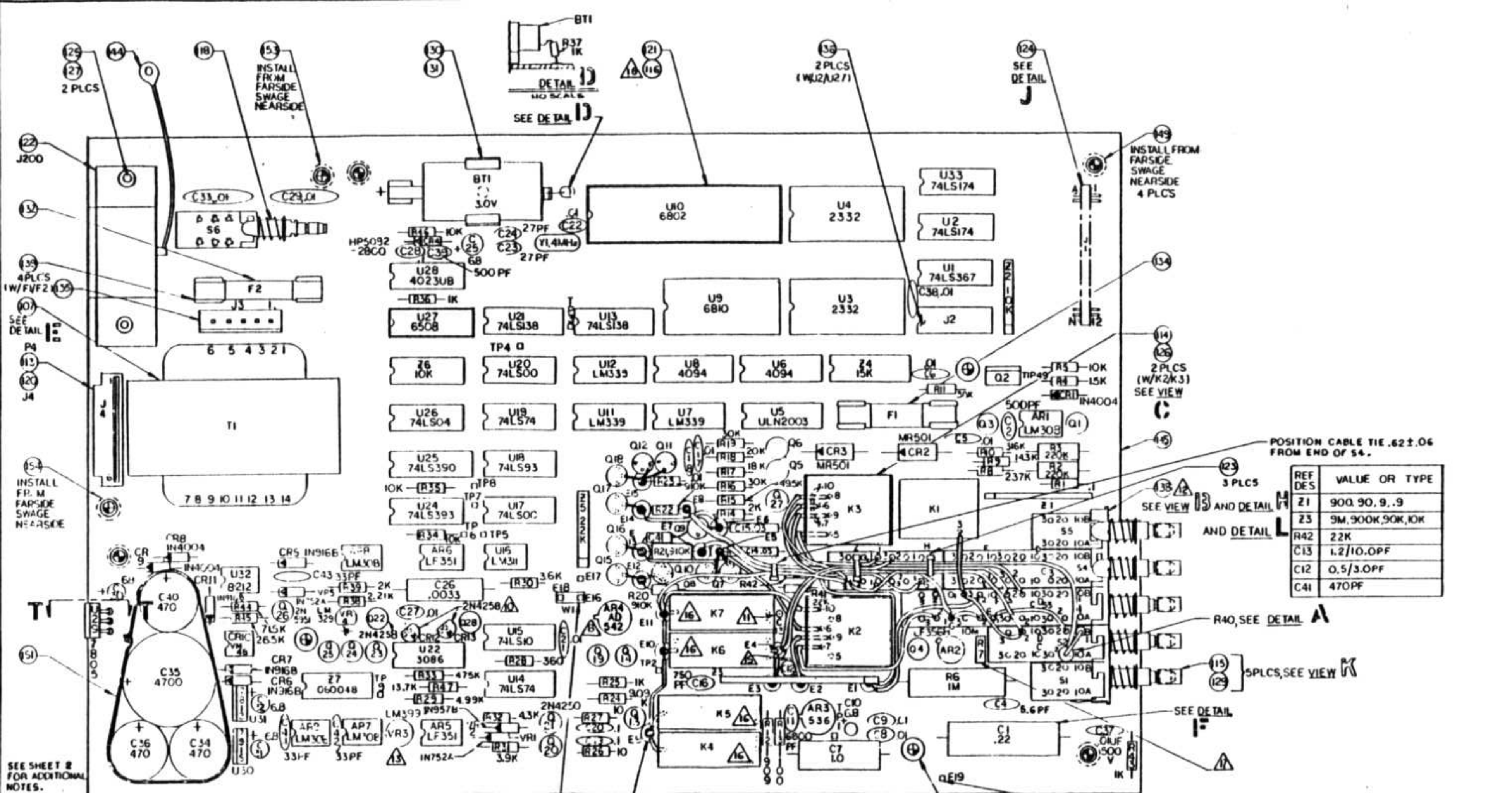


NOTES: UNLESS OTHERWISE SPECIFIED

1. ASSEMBLY PROCESSES & PROCEDURES TO CONFORM TO RACAL-DANA WORKMANSHIP STANDARD.
2. POSITION BUMPER ITEM 20 ON CIRCUIT SIDE OF DISPLAY BOARD OVER THE LOCATING TARGET.

FRONT PANEL, ASSY

SIZE	CODE IDENT NO	DWG NO.	REV
D	21793	404101	D
SCALE NONE		SHEET 1 OF 3	



REF DES	VALUE OR TYPE
Z1	900, 90, 9, .9
Z3	9M, 900K, 90K, 10K
R42	22K
C13	1.2/10.0PF
C12	0.5/3.0PF
C41	470PF

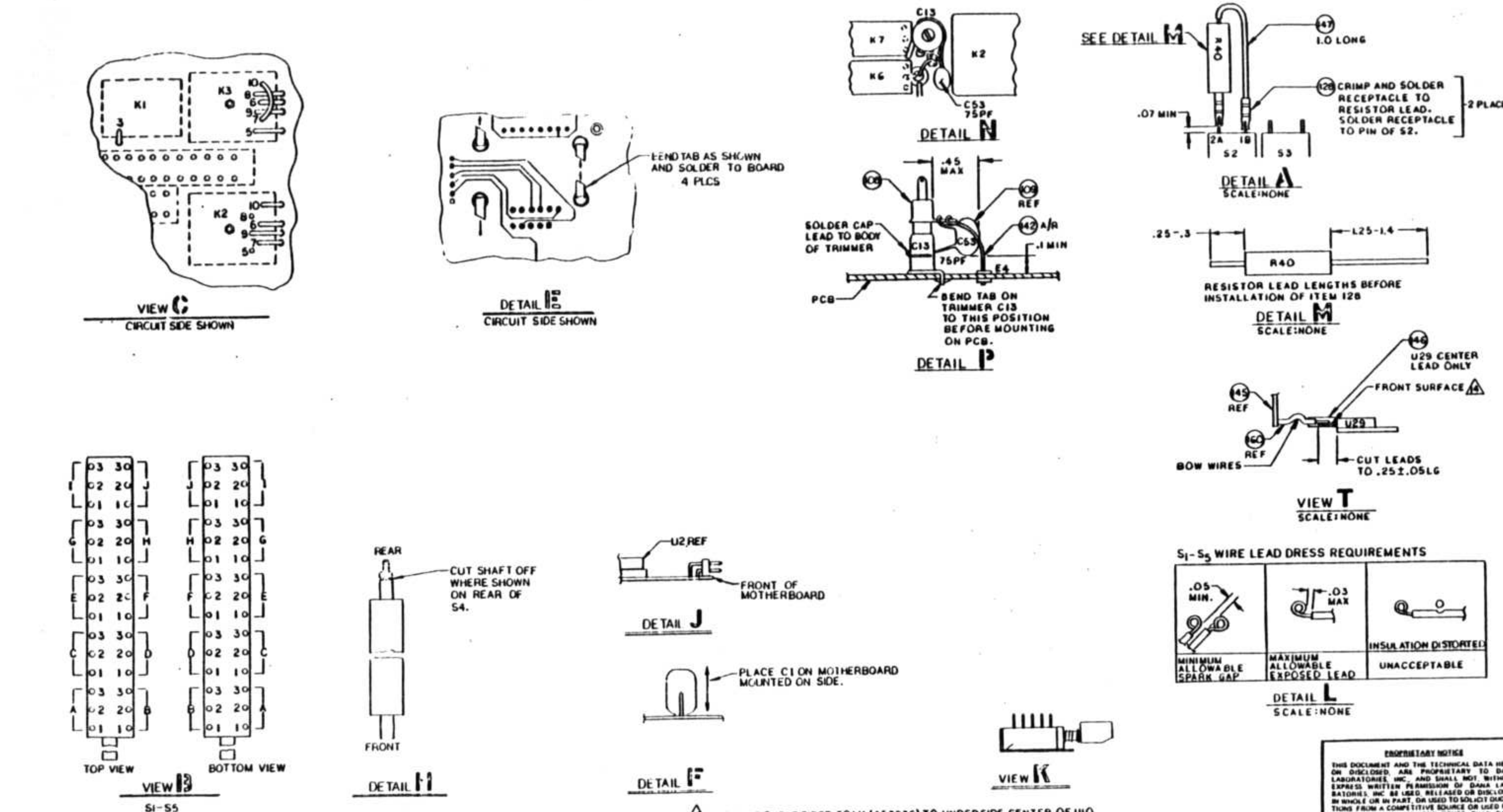
SEE SHEET 2 FOR ADDITIONAL NOTES.

10. TRIM EMITTER LEAD FLUSH TO BOTTOM OF CASE ON CR12 AND CR13.
9. UNLESS OTHERWISE SPECIFIED, RESISTORS, CAPACITORS, AND DIODES SHOULD NOT BE ELEVATED ABOVE PCB PRIOR TO SOLDERING.
8. INSTALL AR4, .25 OFF PC BOARD.
7. TRANSISTORS 200279 ARE Q7,8,11,12,15-19,27
6. TRANSISTORS 200275 ARE Q3,5,6,14,10,23,24,25.
5. TRANSISTORS 200200 ARE Q1,4,9,10,13,20,28.
4. CAPACITORS ARE IN UF.
3. RESISTORS ARE IN OHMS.
2. REFERENCE SCHEMATIC NO. 431648.
1. ASSEMBLY PROCESSES & PROCEDURES TO CONFORM TO RACAL-DANA WORKMANSHIP STANDARD.

NOTES UNLESS OTHERWISE SPECIFIED

PCB ASSY
MOTHERBOARD

SIZE	CODE IDENT NO	DWG NO	REV
D	21793	401648	S
SCALE 2/1		SHEET 1 OF 3	



NOTES: UNLESS OTHERWISE SPECIFIED

11. C13 + C53 NOT SHOWN FOR CLARITY. SEE DETAIL N + DETAIL P. ROUTE WIRES TO E4 + K2 AS CLOSE AS POSSIBLE TO K2 TO MAKE ROOM FOR C13 + C53.

12. REMOVE + DISCARD RETAINER FROM S4 BEFORE WIRING BEGINS.

13. LEADS OF VR3 NOT TO BE BENT PRIOR TO OR AFTER INSTALLATION.

14. SOLDER WIRES TO FRONT SURFACE OF REGULATOR PINS + HEAT SHRINK A/R.

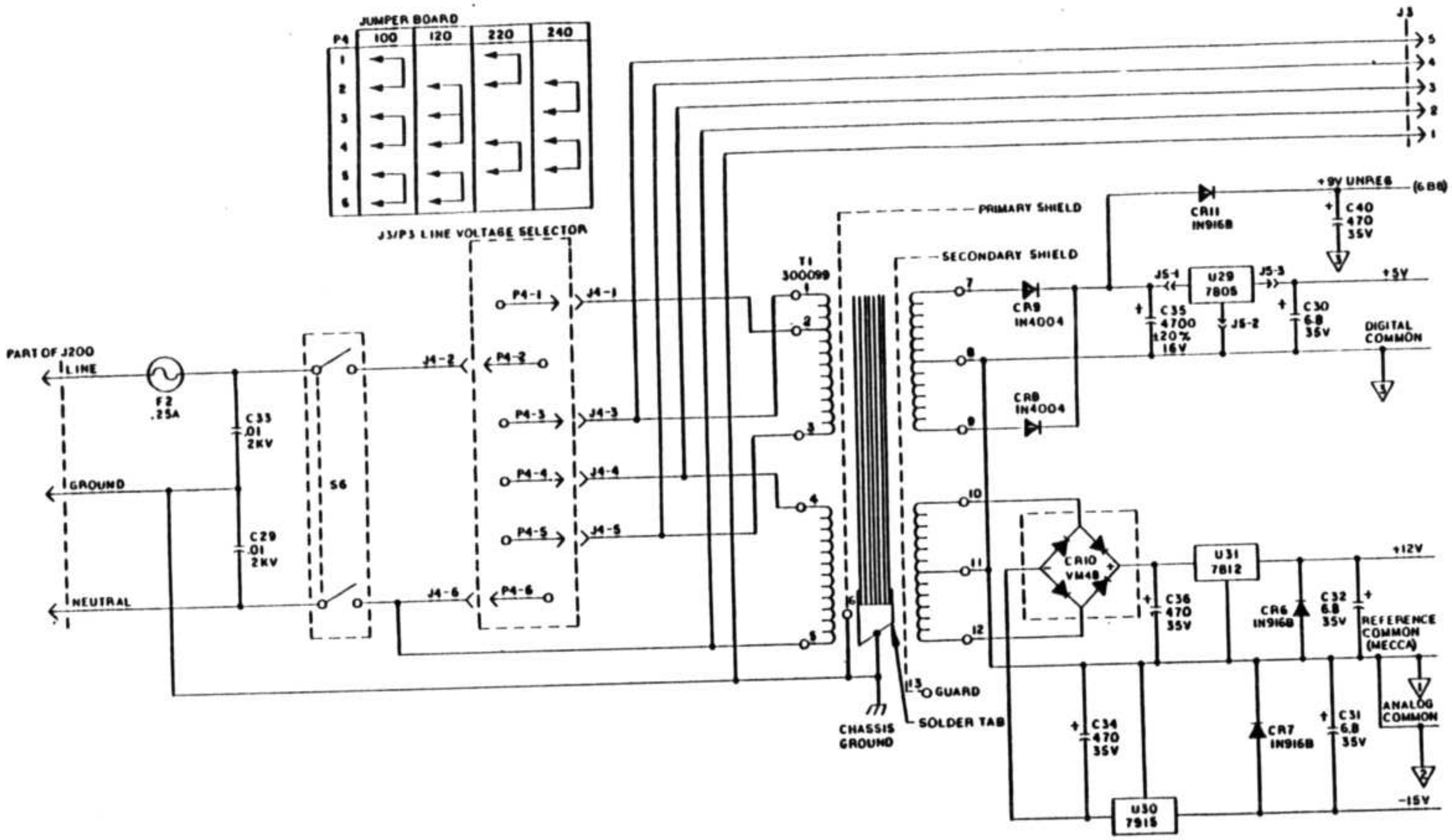
15. ON C12 CLIP OFF END OF UNUSED LEAD.

16. INSTALL K4, K5, K6 & K7 .05" OFF BOARD, ONE END ONLY.

17. R7 TO BE INSTALLED .37± .05 OFF PC BOARD.

18. ATTACH DOUBLE-SIDED FOAM (453936) TO UNDERSIDE CENTER OF U10 BEFORE INSTALLING INTO RESPECTIVE SOCKET, AFTER ASSY HAS PASSED ZEHNTEL TEST.

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	401648	S
SCALE 2/1		SHEET 2 OF 13	



3 S	15K	8
U22	3086	12,13,14
U20	74LS00	4,5,6
DES	TYPE	PINS

UNUSED LOGIC & NETWORKS

U28	CD4023	———	7
U26	74LS04	14	7
U17,20	74LS00	14	7
U15	74LS10	14	7
U14,19	74LS74	14	7
REF DES	IC TYPE	+5V PIN NO	GND PIN NO

IC POWER CONNECTIONS

Z7	
Y1	
W4	
VR5	
U33	U29
TP9	
T1	
S6	
R47	
Q28	
P3	
K7	
J200	J6 - 199
J5	
F2	
E19	
CR13	
C44	C3
BT1	
AR9	
HIGHEST USED	NOT USED

REFERENCE DESIGNATION

7. W2,3,4,USED FOLLOWING POWER UP TEST MODE; W1 USED DURING NORMAL OPERATION.

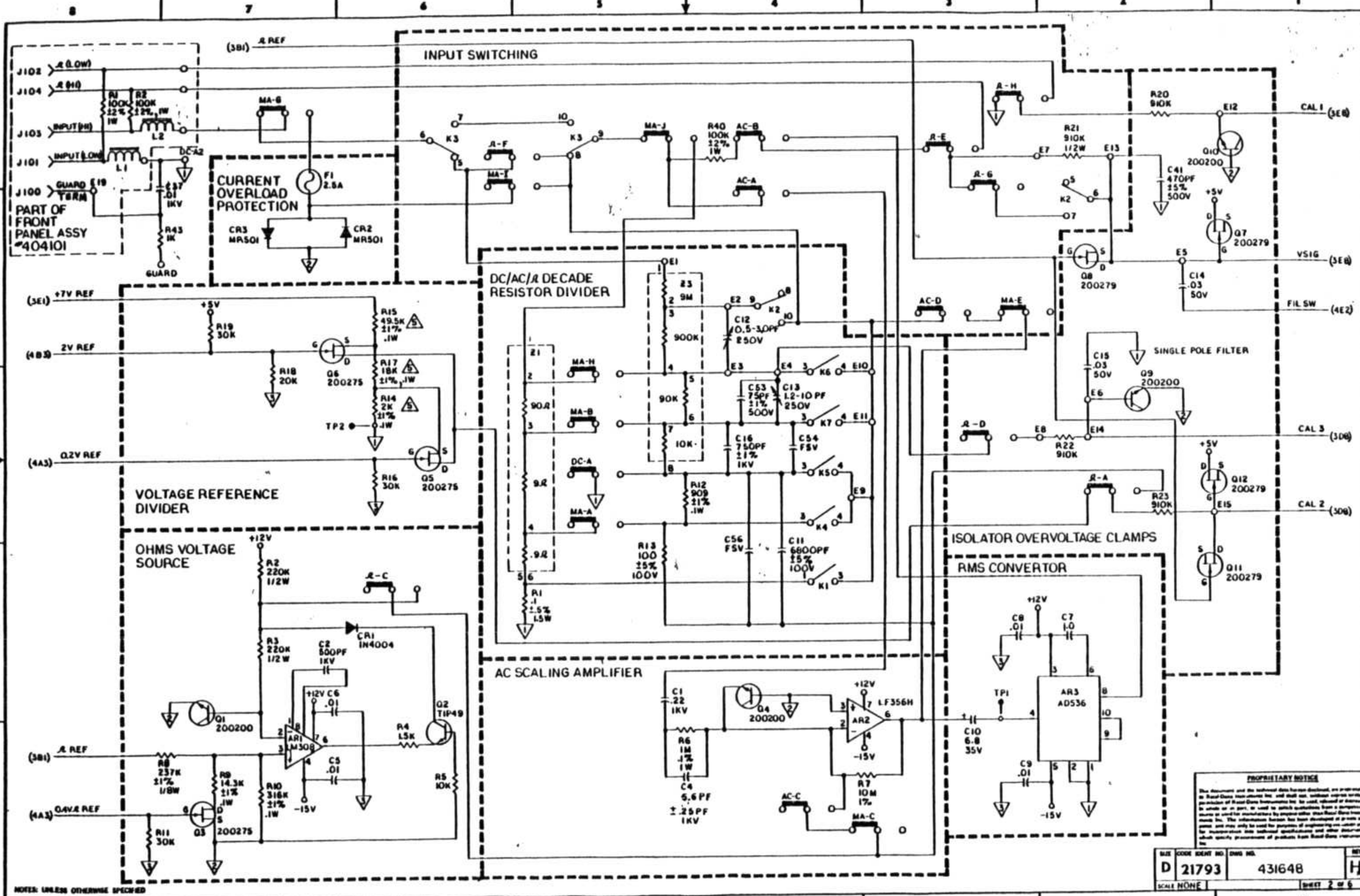
6. PINOUT FOR S1-S5 ARE AS FOLLOWS: 1 2 3
THE SWITCHBANK DESIGNATIONS ARE AS FOLLOWS:
S1=DC, S2=AC, S3=Ω, S4=MA, S5=FILTER.

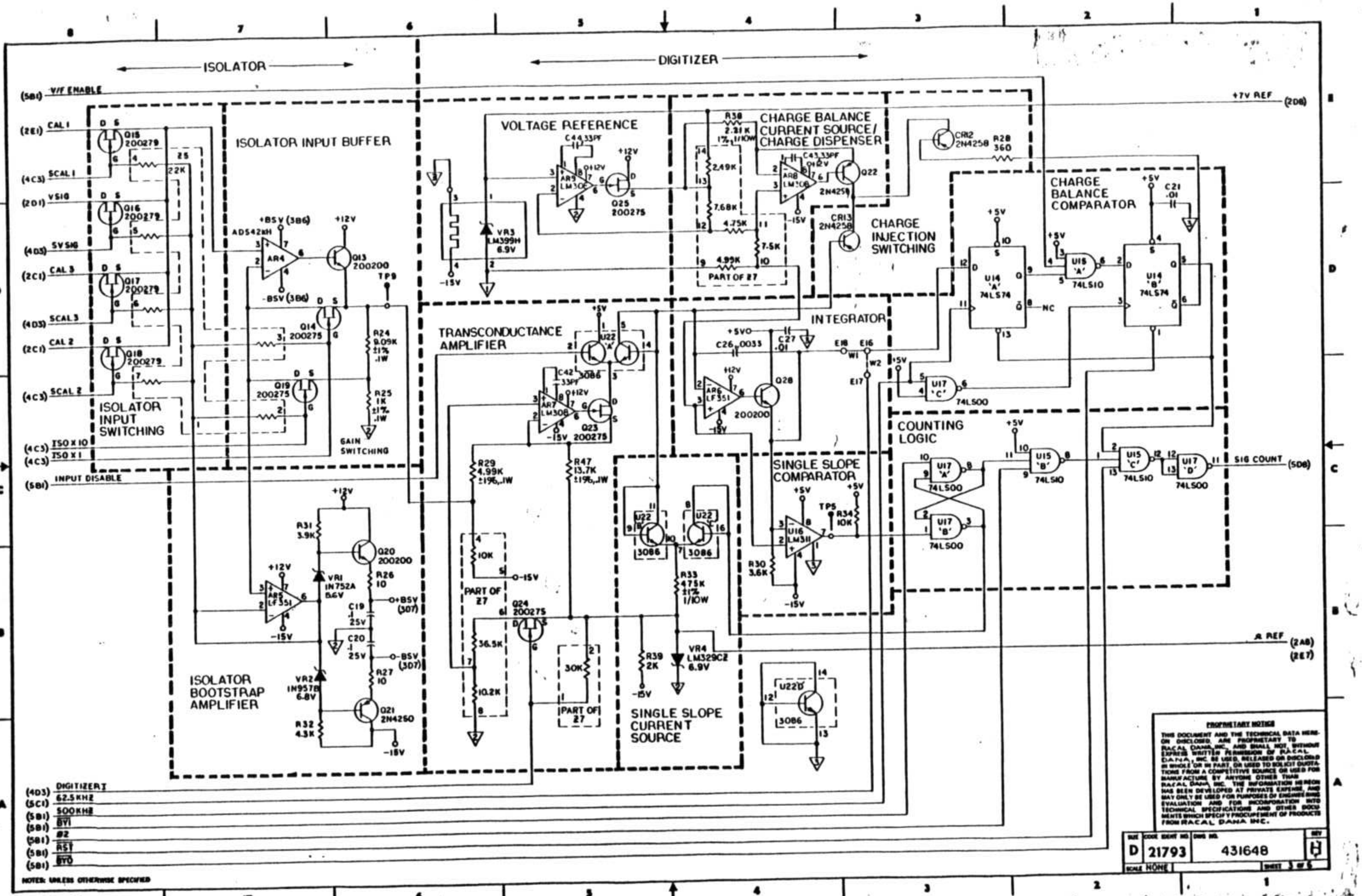
5. (△) R14, R15, R17 ARE MATCHED SET.
4. CAPACITORS C42,43,44 ARE 10%, 500V.
3. RESISTOR NETWORKS ±2%.
2. CAPACITOR VALUES ARE IN MICROFARADS, ±20%, 100VOLTS.
1. RESISTANCE VALUES ARE IN OHMS, ±5%, 1/4 WATT.

NOTES: UNLESS OTHERWISE SPECIFIED

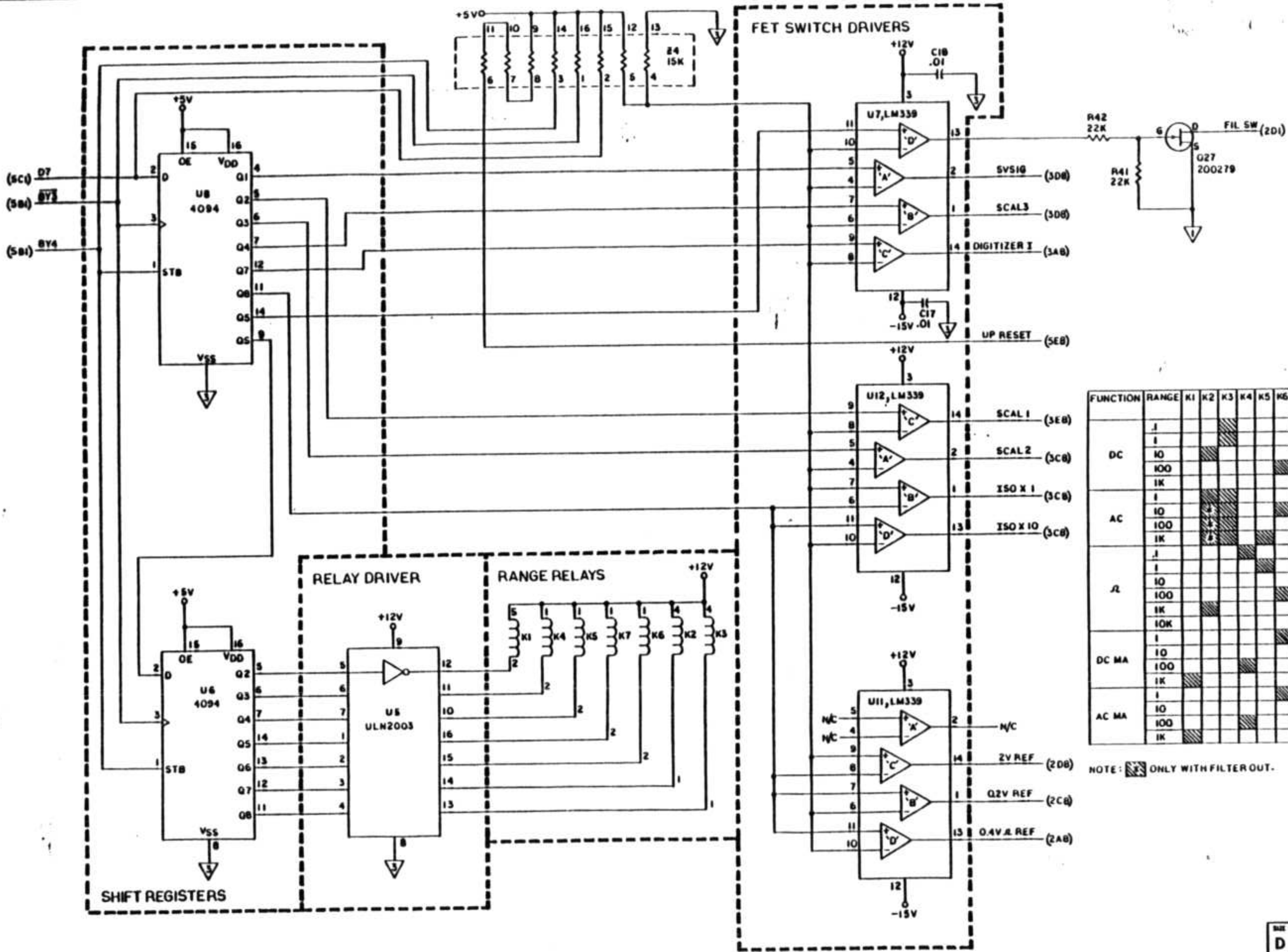
SCHEM, MOTHER BOARD

SIZE	CODE IDENT NO	DWG NO.	REV
D	21793	431648	H
SCALE NONE		SHEET 1 OF 6	


INPUT SWITCHING
CURRENT OVERLOAD PROTECTION
PART OF FRONT PANEL ASSY #404101
DC/AC/Ω DECADE RESISTOR DIVIDER
VOLTAGE REFERENCE DIVIDER
OHMS VOLTAGE SOURCE
AC SCALING AMPLIFIER
ISOLATOR OVERVOLTAGE CLAMPS
RMS CONVERTOR
SINGLE POLE FILTER
CAL 1
VSIG
FIL SW
CAL 3
CAL 2
+7V REF
2V REF
0.2V REF
Ω REF
0.4V Ω REF
GUARD
NOTES: UNLESS OTHERWISE SPECIFIED
PROPRIETARY NOTICE
D 21793 431648 H
SCALE NONE SHEET 2 OF 6



ISOLATOR
DIGITIZER
V/F ENABLE
+7V REF
ISOLATOR INPUT BUFFER
VOLTAGE REFERENCE
CHARGE BALANCE CURRENT SOURCE/ CHARGE DISPENSER
CHARGE BALANCE COMPARATOR
CHARGE INJECTION SWITCHING
INTEGRATOR
TRANSCONDUCTANCE AMPLIFIER
ISOLATOR INPUT SWITCHING
COUNTING LOGIC
SINGLE SLOPE COMPARATOR
SIG COUNT
ISOLATOR BOOTSTRAP AMPLIFIER
SINGLE SLOPE CURRENT SOURCE
GAIN SWITCHING
CAL 1
SCAL 1
VSIG
SVSIG
CAL 3
SCAL 3
CAL 2
SCAL 2
ISO X 10
ISO X 1
INPUT DISABLE
DIGITIZER I
62.5KHZ
500KHZ
NOTES: UNLESS OTHERWISE SPECIFIED
PROPRIETARY NOTICE
THIS DOCUMENT AND THE TECHNICAL DATA HEREON DISCLOSED, ARE PROPRIETARY TO RACAL DANA, INC. AND SHALL NOT, WITHOUT EXPRESS WRITTEN PERMISSION OF RACAL-DANA, INC. BE USED, RELEASED OR DISCLOSED IN WHOLE OR IN PART, OR USED TO SOLICIT QUOTATIONS FROM A COMPETITIVE SOURCE OR USED FOR MANUFACTURE BY ANYONE OTHER THAN RACAL DANA INC. THE INFORMATION HEREON HAS BEEN DEVELOPED AT PRIVATE EXPENSE, AND MAY ONLY BE USED FOR PURPOSES OF ENGINEERING EVALUATION AND FOR INCORPORATION INTO TECHNICAL SPECIFICATIONS AND OTHER DOCUMENTS WHICH SPECIFY PROCUREMENT OF PRODUCTS FROM RACAL DANA INC.
D
21793
431648
H
SCALE NONE



FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	ISO X10	.2V REF	2V REF	.4V REF	DIGITIZER I
DC	.1			X						X	X			
	1			X					X			X		
	10		X						X			X		
	100						X		X			X		
	1K							X	X			X		
AC	1		X	X					X			X		
	10		X*	X			X		X			X		
	100		X*	X				X	X			X		
	1K		X*	X		X			X			X		
Ω	.1				X					X			X	X
	1					X			X					X
	10							X	X					X
	100						X		X					X
	1K		X						X					X
	10K								X					X
DC MA	1						X			X	X			
	10							X		X	X			
	100				X					X	X			
	1K	X								X	X			
AC MA	1						X		X			X		
	10							X	X			X		
	100				X				X			X		
	1K	X							X			X		

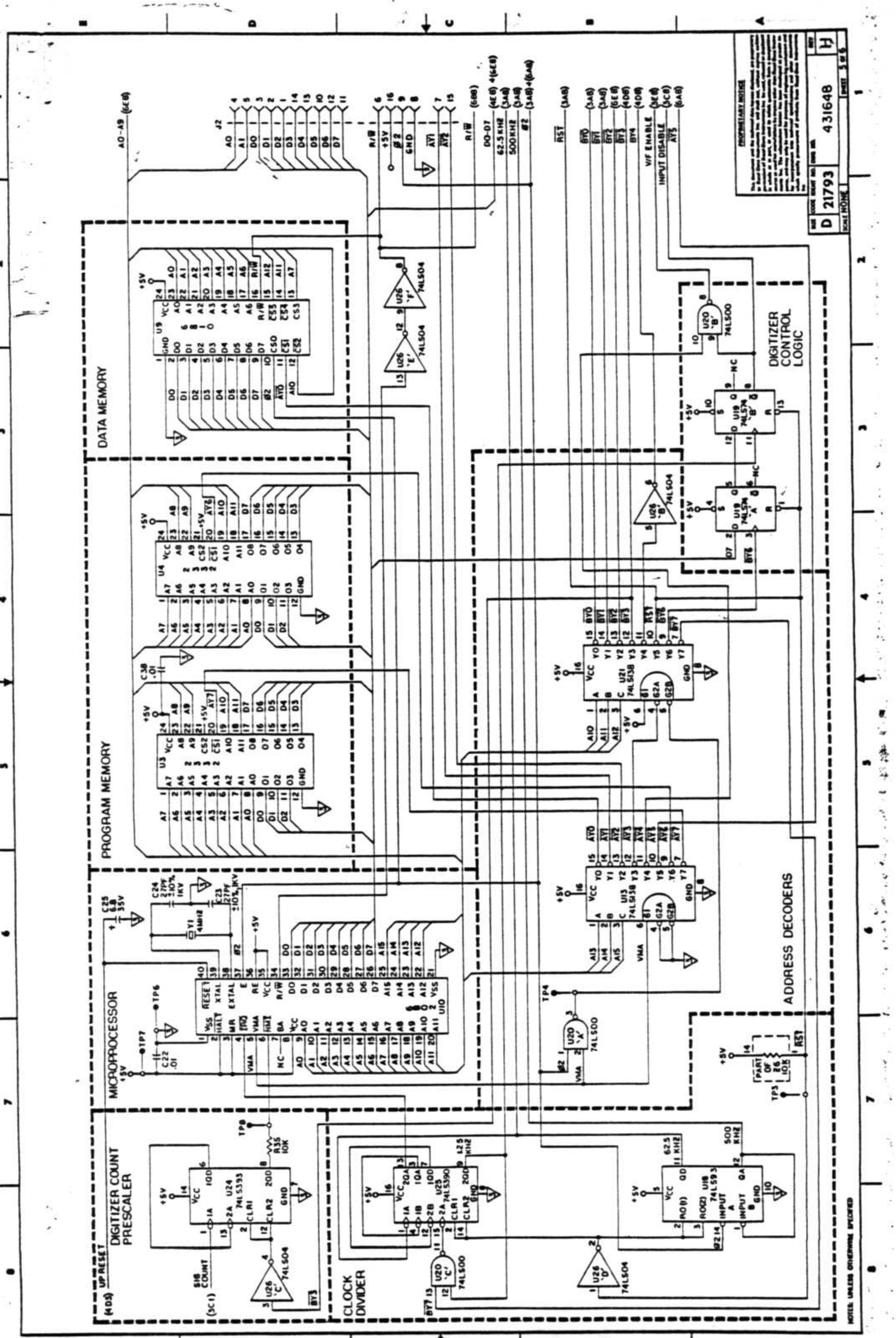
NOTE: X* ONLY WITH FILTER OUT.

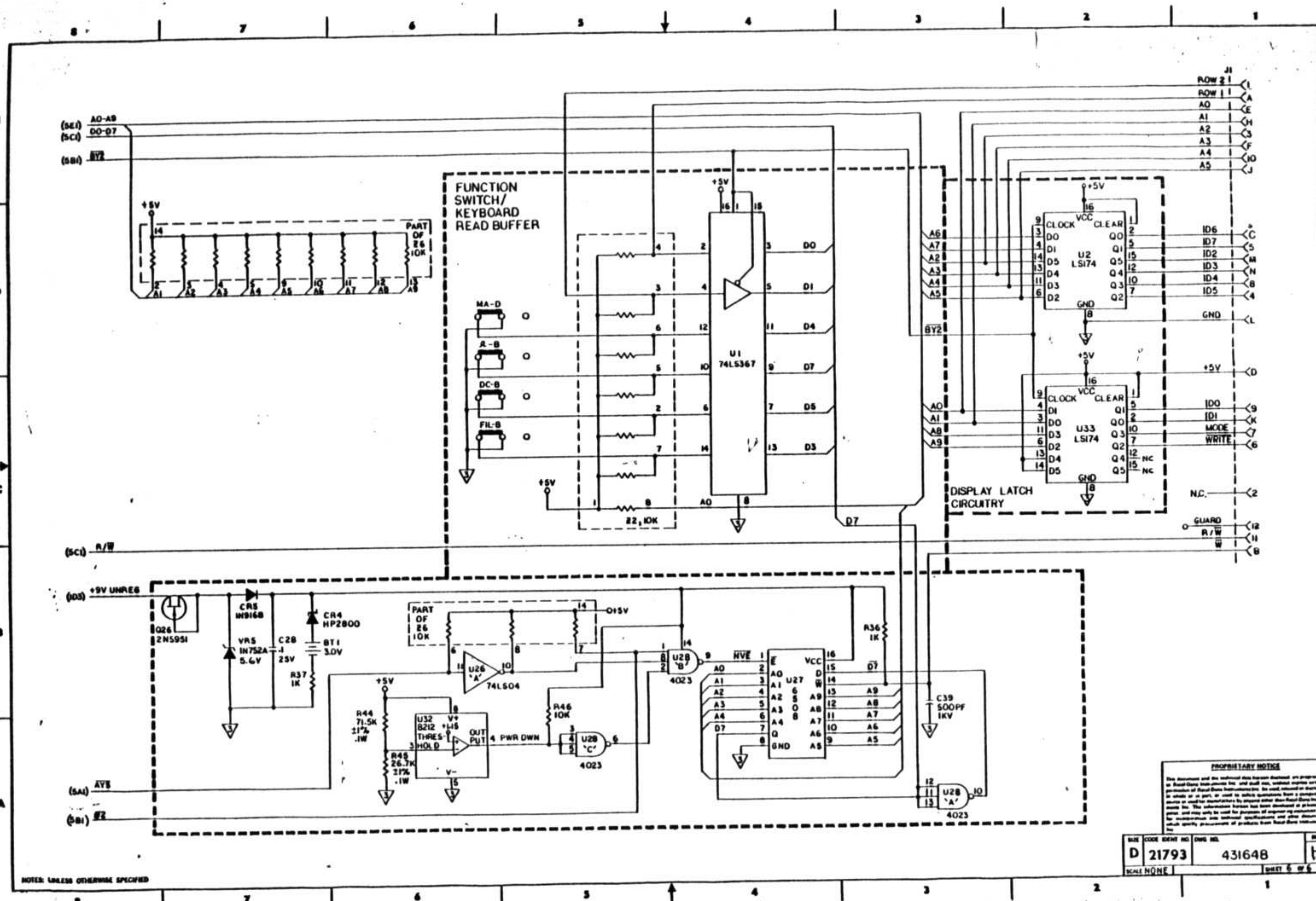
PROPRIETARY NOTICE

SIZE D | CODE IDENT NO. 21793 | DWG NO. 431648 | REV F

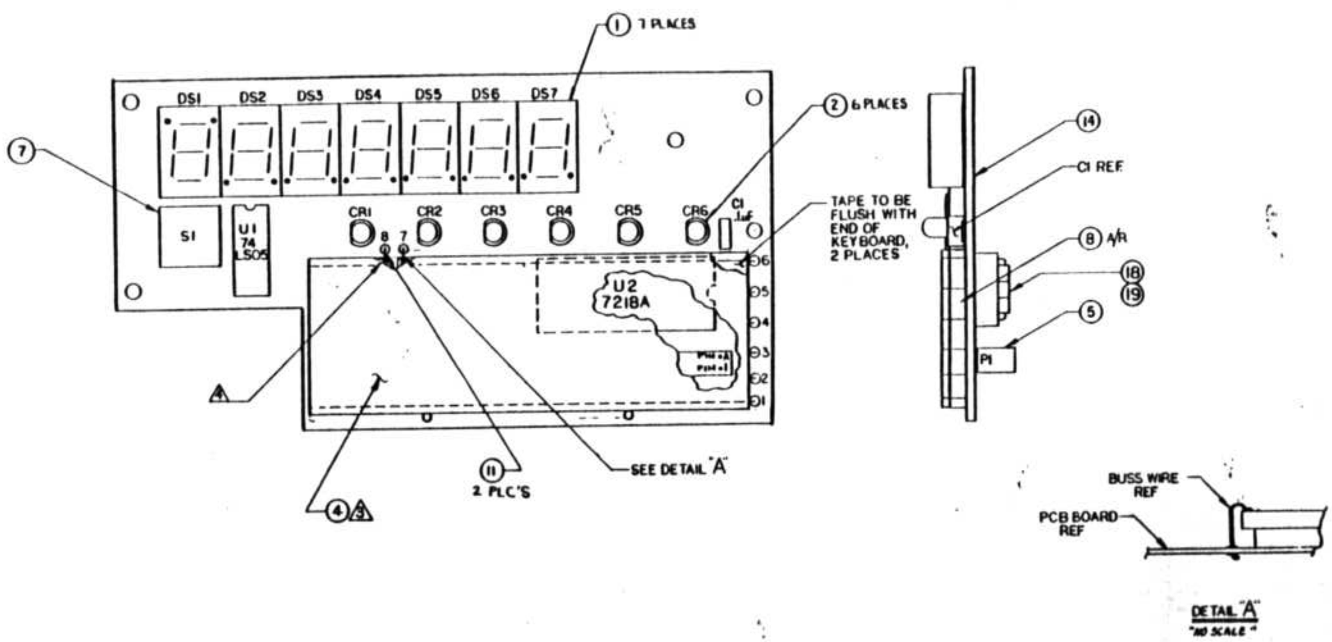
SCALE NONE | SHEET 4 OF 6

NOTES: UNLESS OTHERWISE SPECIFIED


DATA MEMORY
PROGRAM MEMORY
MICROPROCESSOR
DIGITIZER COUNT PRESCALER
CLOCK DIVIDER
DIGITIZER CONTROL LOGIC
ADDRESS DECODERS
D 21793
431648
H



FUNCTION SWITCH/ KEYBOARD READ BUFFER
DISPLAY LATCH CIRCUITRY
U1 74LS367
U2 LS174
U33 LS174
U27 6508
U26 'A' 74LS04
U28 'A' 4023
U28 'B' 4023
U28 'C' 4023
U32 8212
Z2, 10K
PART OF Z6 10K
MA-D
A-B
DC-B
FIL-B
Q26 2N5951
CR5 1N9168
VR5 1N752A 5.6V
C28 1 25V
CR4 HP2800
BT1 3.0V
R37 1K
R44 71.5K ±1% .1W
R45 26.7K ±1% .1W
R46 10K
R36 1K
C39 500PF 1KV
PWR DWN
+9V UNREG
A0-A9
D0-D7
R/W
GUARD
N.C.
ROW 2
ROW 1
MODE
WRITE
J1
NOTES: UNLESS OTHERWISE SPECIFIED
PROPRIETARY NOTICE
D 21793 431648 H
SCALE NONE
SHEET 6 OF 6

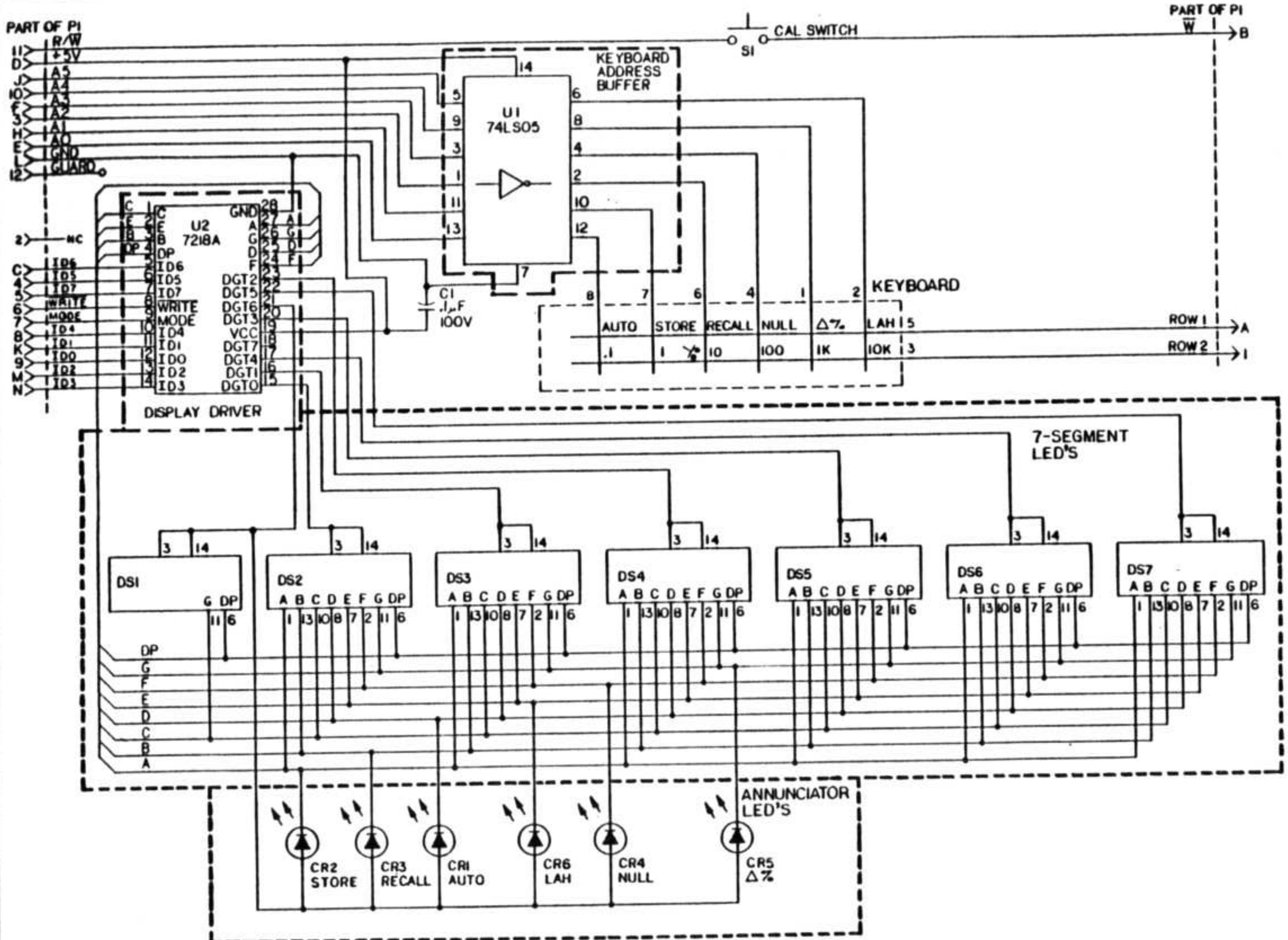


NOTES: UNLESS OTHERWISE SPECIFIED

1. ASSEMBLY PROCESSES & PROCEDURES TO CONFORM TO RACAL-DANA WORKMANSHIP STANDARD.
2. REFERENCE SCHEMATIC NO. 431649
3. INSTALL USING KEYBOARD MATRIX 2 X 6 P/N 454507.
4. CUT BACK DUST COVER AS SHOWN, REMOVE ONLY ENOUGH COVER TO PROVIDE ACCESS FOR SOLDERING.

PCB ASSY, DISPLAY

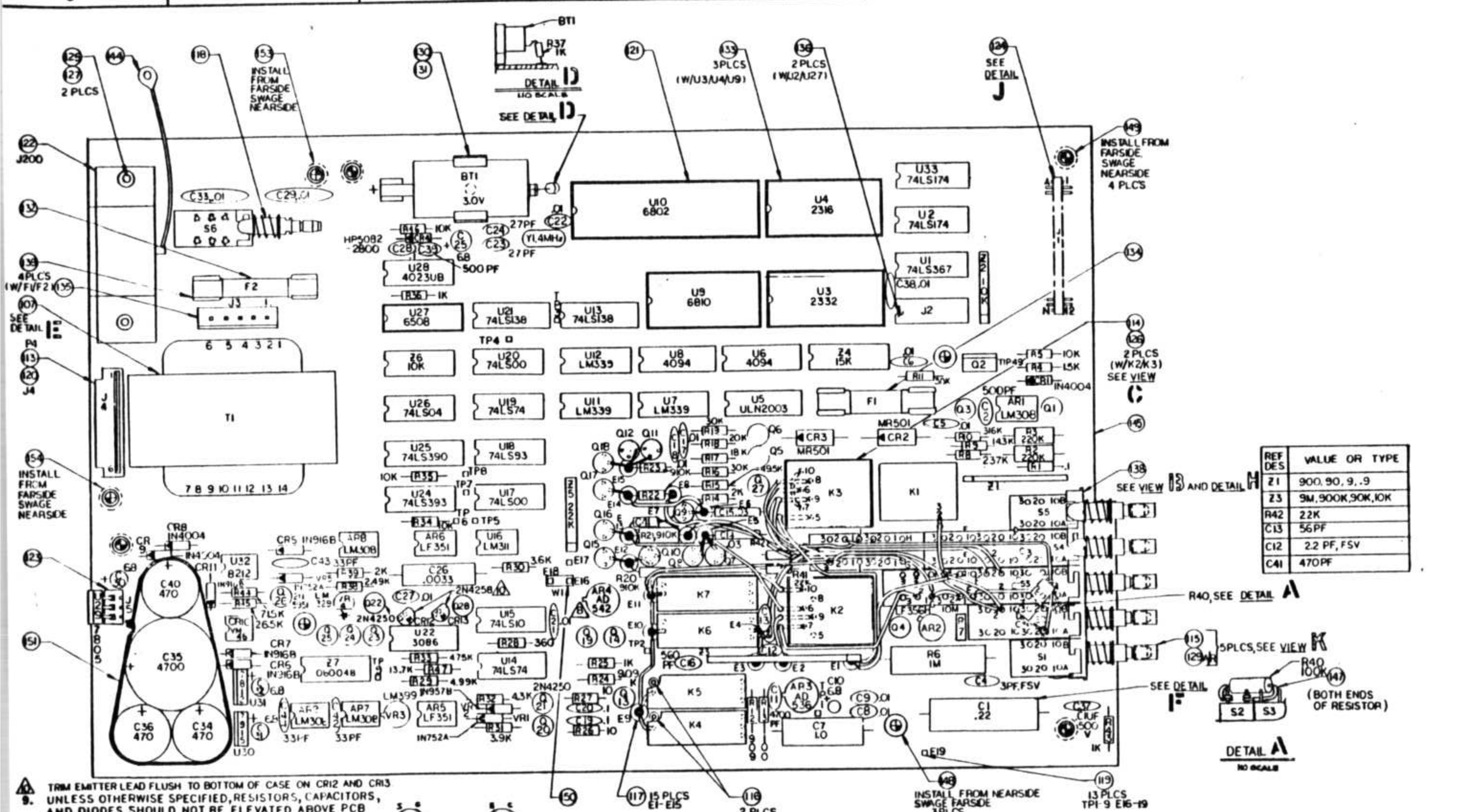
SIZE	CODE IDENT NO	DWG NO.	REV
D	21793	401649	D
SCALE 2/1		SHEET 1 OF 2	



2. CR1 THRU CR6 ARE 210071.
1. DS1 THRU DS7 ARE 210065.
NOTES: UNLESS OTHERWISE SPECIFIED

SCHEM, DISPLAY

SIZE	CODE IDENT NO	DWG NO	REV
D	21793	431649	B
SCALE NONE		SHEET 1 OF 1	



REF DES	VALUE OR TYPE
Z1	900, 90, 9, .9
Z3	9M, 900K, 90K, 10K
R42	22K
C13	56PF
C12	2.2 PF, FSV
C41	470PF

200279 VIEWED FROM COMPONENT SIDE.

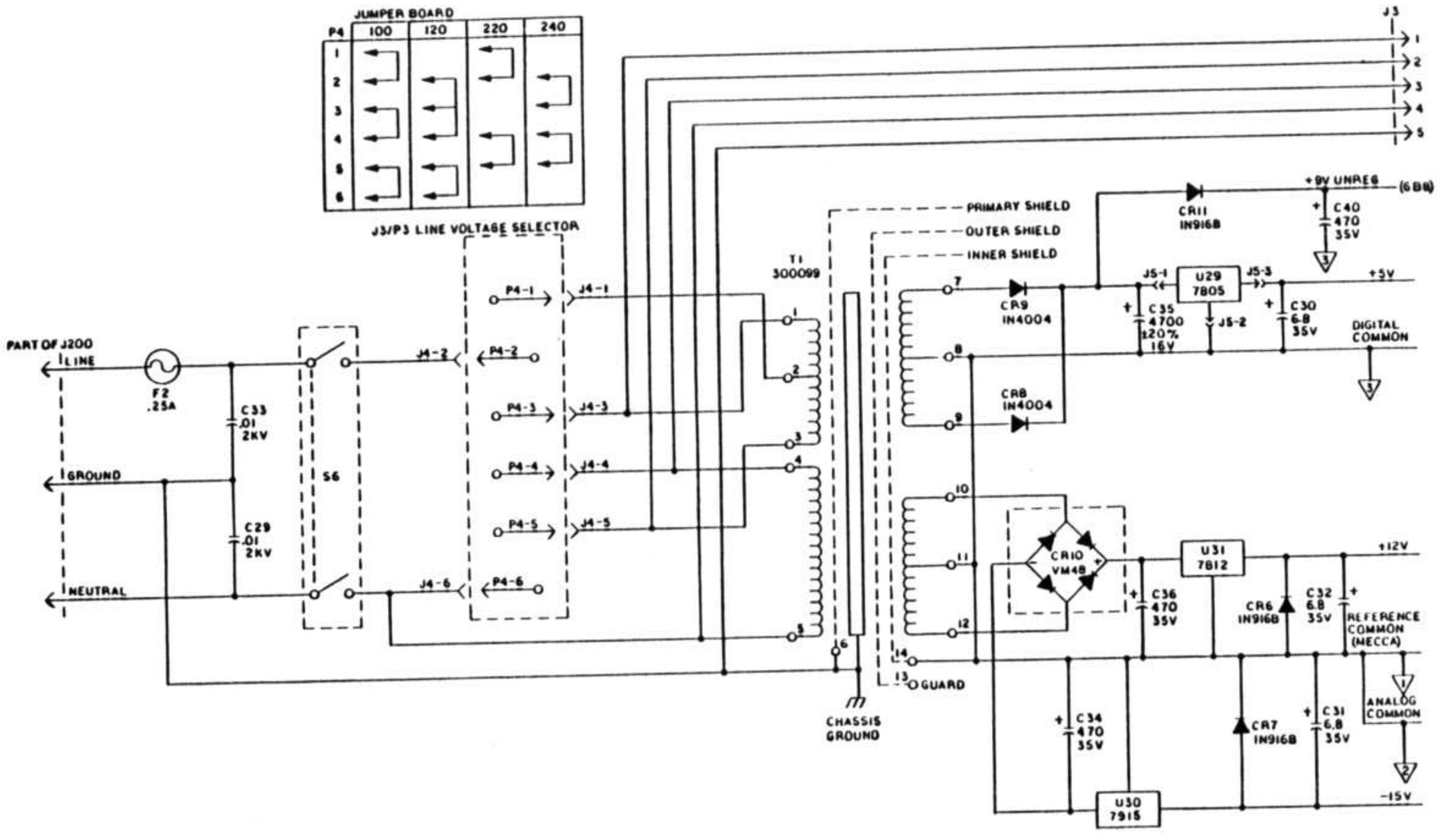
200200 VIEWED FROM COMPONENT SIDE.

10. TRIM EMITTER LEAD FLUSH TO BOTTOM OF CASE ON CR12 AND CR13
9. UNLESS OTHERWISE SPECIFIED, RESISTORS, CAPACITORS, AND DIODES SHOULD NOT BE ELEVATED ABOVE PCB PRIOR TO SOLDERING.
8. INSTALL AR4 .25 OFF PC BOARD.
7. TRANSISTORS 200279 ARE Q7,8,11,12,15-18,27.
6. TRANSISTORS 200275 ARE Q3,5,6,14,19,23,24,25
5. TRANSISTORS 2CC200 ARE Q1,4,9,10,13,20,28.
4. CAPACITORS ARE IN UF.
3. RESISTORS ARE IN OHMS.
2. REFERENCE SCHEMATIC NO. 431648.
1. ASSEMBLY PROCESSES & PROCEDURES TO CONFORM TO RACAL-DANA WORKMANSHIP STANDARD.

NOTES: UNLESS OTHERWISE SPECIFIED

PCB ASSY
MOTHERBOARD

SIZE	CODE IDENT NO	DWG NO.	REV
D	21793	401648	B
SCALE 2/1		SHEET 1 OF 2	



85	15K	8
U22	3086	12,13,14
U20	74LS00	4,5,6
DES	TYPE	PINS

UNUSED LOGIC + NETWORKS

U28	CD4023		7
U26	74LS04	14	7
U17,20	74LS00	14	7
U15	74LS10	14	7
U14,19	74LS74	14	7
REF DES	IC TYPE	+5V PIN NO	GND PIN NO

IC POWER CONNECTIONS

27	
Y1	
W4	
VR5	
U33	U29
TP9	
T1	
S6	
R47	
Q28	
P3	
K7	
J200	J6 - 199
J5	
F2	
E19	
CR13	
C41	C3
BT1	
AR9	
HIGHEST USED	NOT USED

REFERENCE DESIGNATION

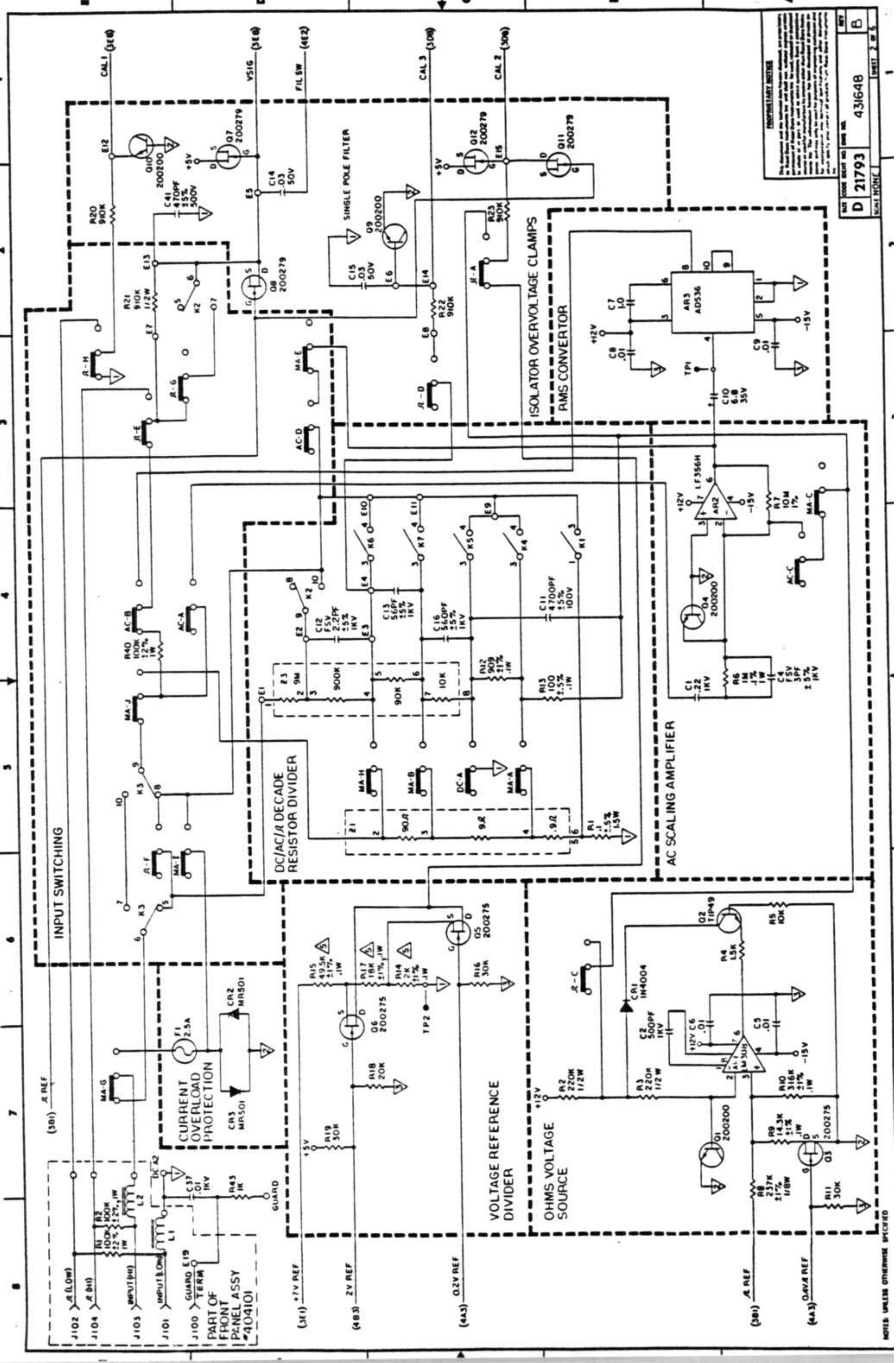
7. W2,3,4, USED FOLLOWING POWER UP TEST MODE; W1 USED DURING NORMAL OPERATION.
6. PINOUT FOR S1-S5 ARE AS FOLLOWS: 1 2 3
THE SWITCHBANK DESIGNATIONS ARE AS FOLLOWS:
S1-DC, S2-AC, S3-Ω, S4-MA, S5-FILTER.
5. R14, R15, R17 ARE MATCHED SET.
4. CAPACITORS C42, 43, 44 ARE 10%, 500V.
3. RESISTOR NETWORKS ±2%.
2. CAPACITOR VALUES ARE IN MICROFARADS, ±20%, 100VOLTS.
1. RESISTANCE VALUES ARE IN OHMS, ±5%, 1/4 WATT.

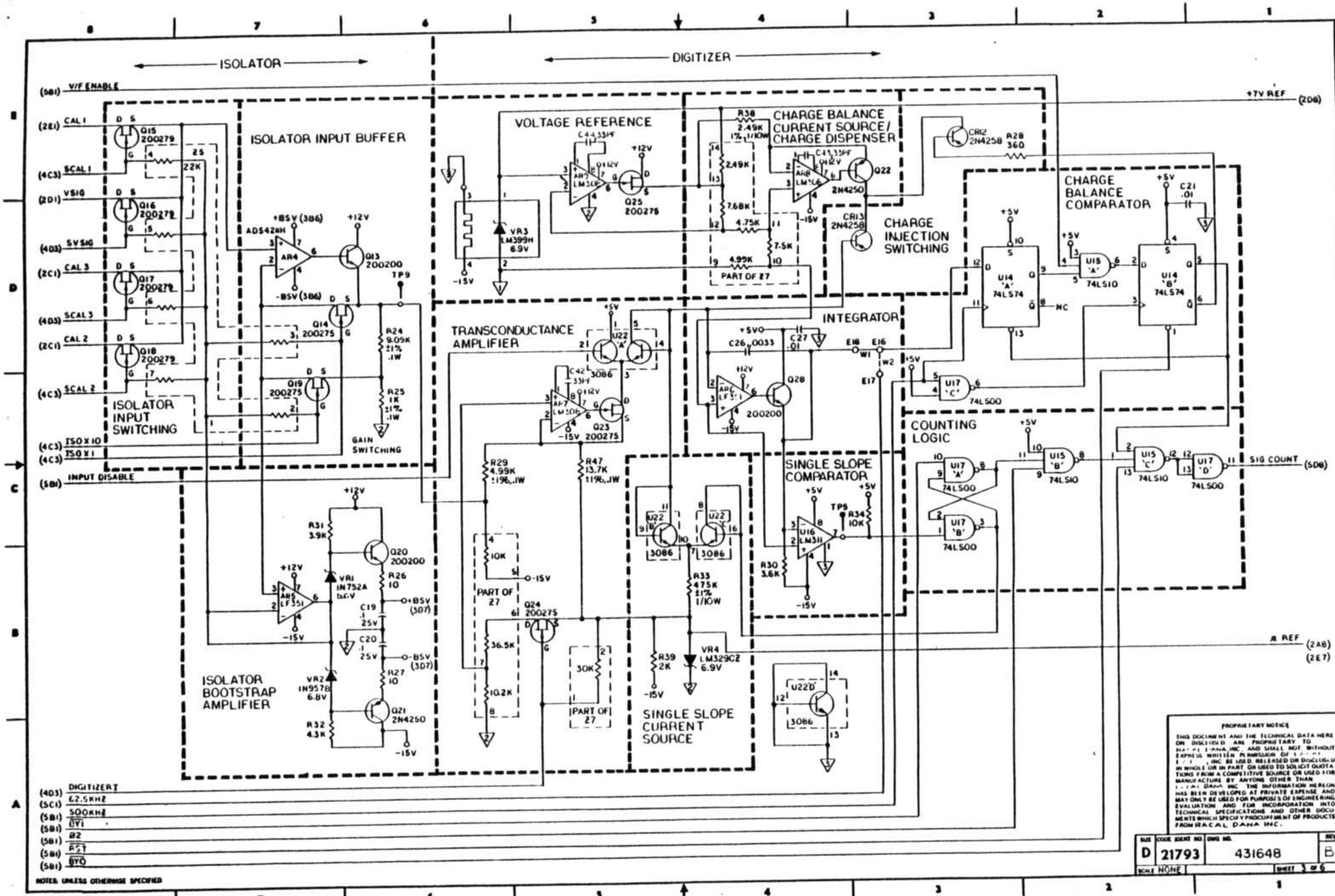
NOTES UNLESS OTHERWISE SPECIFIED

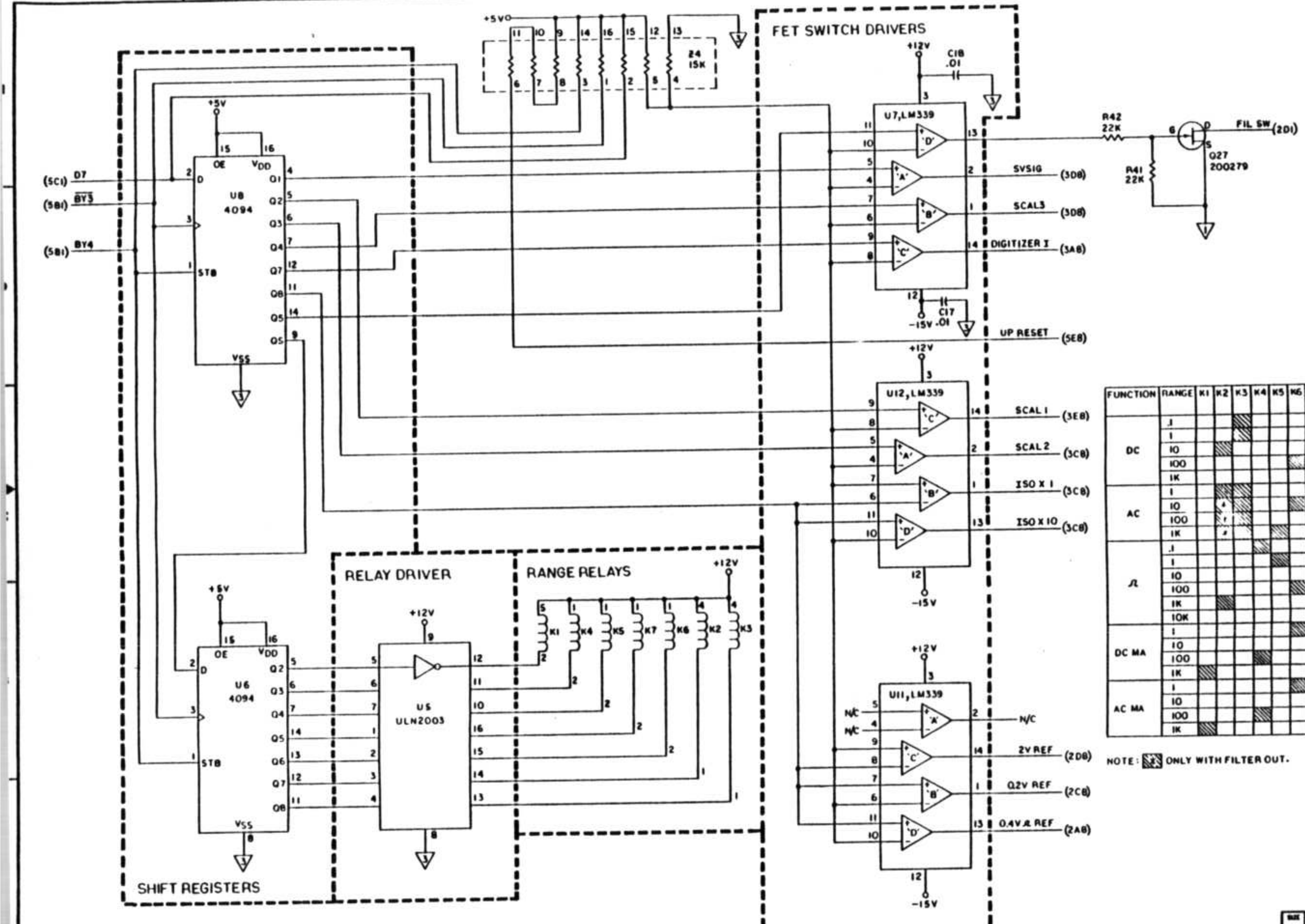
SCHEM, MOTHER BOARD

SIZE	CODE IDENT NO	DWG NO	REV
D	21793	431648	B

SCALE NONE SHEET 1 OF 6


INPUT SWITCHING
CURRENT OVERLOAD PROTECTION
DC/AC/Ω DECADE RESISTOR DIVIDER
VOLTAGE REFERENCE DIVIDER
OHMS VOLTAGE SOURCE
AC SCALING AMPLIFIER
ISOLATOR OVERVOLTAGE CLAMPS
RMS CONVERTOR
SINGLE POLE FILTER
PART OF FRONT PANEL ASSY #404101
J102 Ω (LOW)
J104 Ω (HI)
J103 INPUT (HI)
J101 INPUT (LOW)
J100 GUARD TERM
CAL 1
CAL 2
CAL 3
VSIG
FIL SW
+7V REF
2V REF
0.2V REF
Ω REF
0.2V/Ω REF
GUARD
AR3 AD536
AR2 LF356H
AR1 LM301H
Q2 TIP49
CR1 1N4004
CR2 MR501
CR3 MR501
F1 2.5A
D 21793 431648 B
SCALE NONE
SHEET 2 OF 5
PROPRIETARY NOTICE
NOTES: UNLESS OTHERWISE SPECIFIED


ISOLATOR
DIGITIZER
V/F ENABLE
CAL 1
SCAL 1
VSIG
SVSIG
CAL 3
SCAL 3
CAL 2
SCAL 2
ISO X 10
ISO X 1
INPUT DISABLE
ISOLATOR INPUT SWITCHING
ISOLATOR INPUT BUFFER
GAIN SWITCHING
ISOLATOR BOOTSTRAP AMPLIFIER
VOLTAGE REFERENCE
TRANSCONDUCTANCE AMPLIFIER
CHARGE BALANCE CURRENT SOURCE/ CHARGE DISPENSER
CHARGE INJECTION SWITCHING
INTEGRATOR
SINGLE SLOPE COMPARATOR
SINGLE SLOPE CURRENT SOURCE
CHARGE BALANCE COMPARATOR
COUNTING LOGIC
+7V REF
SIG COUNT
R REF
DIGITIZER I
62.5KHZ
500KHZ
Ø1
Ø2
RST
BYØ
NOTES: UNLESS OTHERWISE SPECIFIED
SIZE D
CODE IDENT NO. 21793
DWG NO. 431648
REV B
SCALE NONE
SHEET 3 of 6



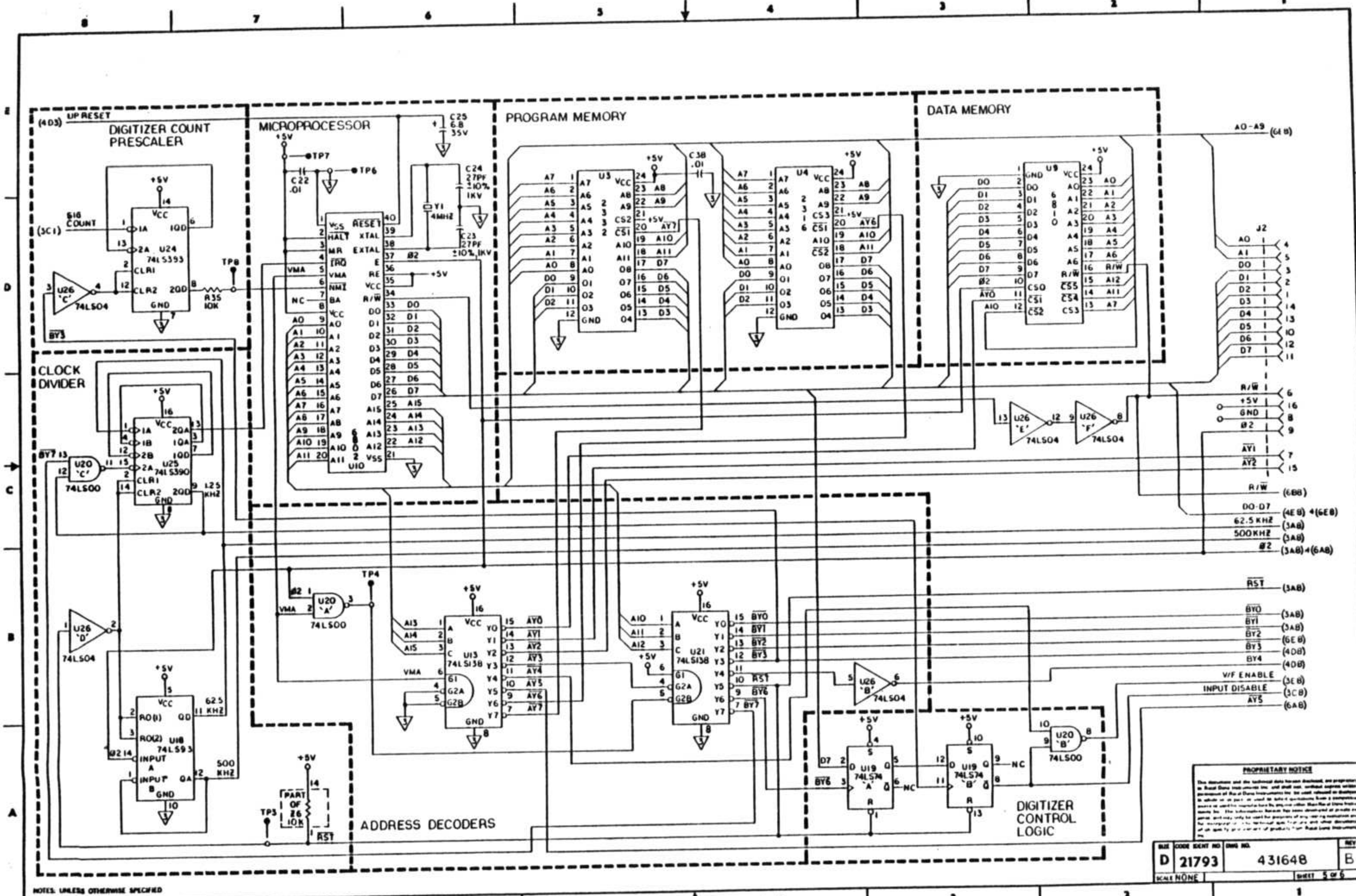
FUNCTION	RANGE	K1	K2	K3	K4	K5	K6	K7	ISO X1	ISO X10	.2V REF	2V REF	.4V REF	DIGITIZER I
DC	.1			X						X	X			
	1			X					X			X		
	10		X						X			X		
	100						X		X			X		
	1K							X	X			X		
AC	1		X	X					X			X		
	10		X	X			X		X			X		
	100		X	X				X	X			X		
	1K		X			X			X			X		
Ω	.1				X					X			X	X
	1					X			X					X
	10							X	X					X
	100						X		X					X
	1K		X						X					X
	10K								X					X
DC MA	1						X			X	X			
	10							X		X	X			
	100				X					X	X			
	1K	X								X	X			
AC MA	1						X		X			X		
	10							X	X			X		
	100				X				X			X		
	1K	X							X			X		

NOTE: [shaded] ONLY WITH FILTER OUT.

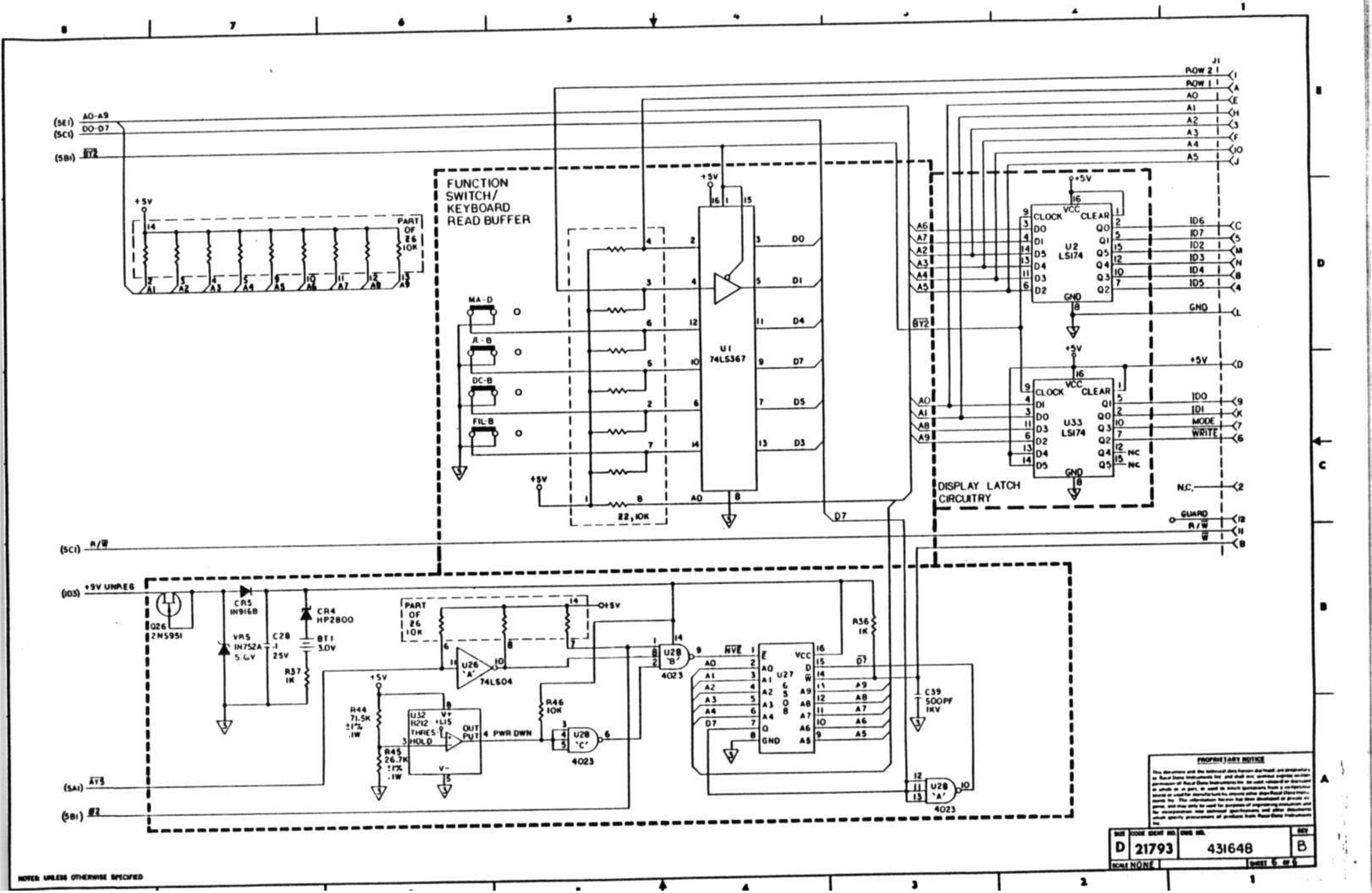
PROPRIETARY NOTICE

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	431648	B
SCALE NONE		SHEET 4 OF 6	

NOTES: UNLESS OTHERWISE SPECIFIED



DIGITIZER COUNT PRESCALER
MICROPROCESSOR
PROGRAM MEMORY
DATA MEMORY
CLOCK DIVIDER
ADDRESS DECODERS
DIGITIZER CONTROL LOGIC
UP RESET
U24 74LS393
U25 74LS390
U18 74LS93
U10
U3
U4
U9
U13 74LS138
U21 74LS138
U19 74LS74
U20 74LS00
U26 74LS04
Y1 4MHZ
R/W
+5V
GND
Ø2
D0-D7
62.5 KHZ
500 KHZ
RST
V/F ENABLE
INPUT DISABLE
J2
NOTES: UNLESS OTHERWISE SPECIFIED
PROPRIETARY NOTICE
D 21793 431648 B
SCALE NONE SHEET 5 OF 6


FUNCTION SWITCH/ KEYBOARD READ BUFFER
DISPLAY LATCH CIRCUITRY
U1 74LS367
U2 LS174
U33 LS174
U27 6508
U28 'A' 4023
U28 'B' 4023
U28 'C' 4023
U26 'A' 74LS04
U32 ICL8212
Q26 2N5951
CR5 IN9168
CR4 HP2800
VR5 IN752A 5.6V
C28 .1 25V
BT1 3.0V
R37 1K
R36 1K
R44 71.5K ±1% .1W
R45 26.7K ±1% .1W
R46 10K
C39 500PF 1KV
Z2, 10K
PART OF Z6 10K
MA-D
R-B
DC-B
FIL-B
PWR DWN
+9V UNREG
(5E1) A0-A9
(5C1) D0-D7
(5B1) BY2
(5C1) R/W
(1D3) +9V UNREG
(5A1) AY3
(5B1) Φ2
J1
ROW 2
ROW 1
GND
+5V
N.C.
GUARD
MODE
WRITE
PROPRIETARY NOTICE
D 21793 431648 B
SCALE NONE
SHEET 6 OF 6
NOTES: UNLESS OTHERWISE SPECIFIED

7.1 This section contains lists of replaceable parts arranged in the order of the following subassemblies:

7.2 Manufacturers are identified by FSC numbers listed in Table 7.1, "List of Suppliers". The code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1, H4-2, and their supplements.

NOTE

Where this reference appears in the parts list (*USED ON EARLIER MODELS), it applies to units with serial numbers before 500500.

FSC	NAME
00779	AMP, INC. HARRISBURG, PA.
01121	ALLEN BRADLEY CO. MILWAUKEE, WI.
01295	TEXAS INSTRUMENTS, INC. DALLAS, TX.
02114	FERROXCUBE CORP. SAUGERTIES, NY
03888	PYROFILM CORP. WHIPPANY, NY
04713	MOTOROLA, INC. (SEMI-CONDUCTOR PROD. DIV.) PHOENIX, AZ.
04963	3M COMPANY (ADHESIVE COATINGS & SEALER DIV.) ST. PAUL, MINNESOTA
05276	POMONA ELECTRONICS CO., INC. POMONA, CA.
05397	UNION CARBIDE CORP. (MATERIAL SYSTEMS DIV.) CLEVELAND, OH.
08257	NPC ELECTRONICS CANOGA PARK, CA.
11236	CTS OF BERNE, INC. VERNE, IN.

FSC	NAME
14298	AMERICAN COMPONENTS CONSHOHOCKEN, PA.
15636	ELEC-TROL, INC. SAUGUS, CA.
18714	RCA - (COMMERCIAL REC. TUBE & SEMI. DIVISION) FINDLAY, OH.
19647	CADDOCK ELECTRONICS RIVERSIDE, CA.
21551	C-F ELECTRONICS, INC. VAN NUYS, CA.
21793	RACAL-DANA INSTRUMENTS INC. IRVINE, CA.
23875	M-TRON YORKTOWN, SD
24355	ANALOG DEVICES NORWOOD, MA.
26625	MIAL USA, INC. NUTLEY, NJ
26806	AMERICAN ZETTLER, INC. COSTA MESA, CA.

Table 7.1 – List of Suppliers (Continued)

FSC	NAME
27014	NATIONAL SEMI-CONDUCTOR CORP SANTA CLARA, CA.
27264	MOLEX PRODUCTS CO. DOWNERS GROVE, IL.
27556	IMB ELECTRONIC PROD., INC. SANTA FE SPRINGS, CA.
27777	VARO ELECTRAN DEVICES, INC. GARLAND, TX.
30146	AP PRODUCTS PLANESVILLE, OH.
32293	INTERSIL, INC. CUPERTINO, CA.
34359	THREE (3) M COMPANY (COMMERCIAL TAPE DIVISION) ST. PAUL, MN.
50434	HEWLETT-PACKARD CO. (HPA DIVISION) PALO ALTO, CA.
50579	LITRONIX, INC. CUPERTINO, CA.
51642	CENTRE ENGINEERING, INC. STATE COLLEGE, PA.
52072	CIRCUIT ASSEMBLY CORP. COSTA MESA, CA.
52763	STETTNER-TRUSH CAZENOVIA, NY
53387	THREE (3) M COMPANY (ELECTRONIC PRODUCTS DIV.) ST. PAUL, MN.
56289	SPRAGUE ELECTRONICS CO. N. ADAMS, MA.

FSC	NAME
71450	CTS CORPORATION ELKHART, IN.
71471	AEROVOX CORPORATION (CINEMA PLANT) MONCKS CORNER, SC
71590	CENTRALAB ELECTRONICS MILWAUKEE, WI.
71785	TRW ELECTRONICS COMPONENTS (CINCH DIVISION) ELK GROVE VILLAGE, IL.
72982	ERIE TECHNOLOGICAL PRODUCTS, INC. ERIE, PA.
73445	AMPEREX ELECTRONIC CORP. HICKSVILLE, L.I., NY
75915	LITTLEFUSE, INC. DES PLAINES, IL.
80131	ELECTRONICS INDUSTRIES ASSOC WASHINGTON D.C.
81349	MILITARY SPECIFICATION
82389	SWITCHCRAFT, INC. CHICAGO, IL.
83330	HERMAN H. SMITH, INC. BROOKLYN, NY
90201	MALLORY CAPACITOR CO. INDIANAPOLIS, IN.
91506	AUGAT, INC. ATTLEBORO, MA.
91637	DALE ELECTRONICS, INC. COLUMBUS, NE
98291	SEALECTRO CORPORATION MAMARONECK, NY

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
1	401648	MOTHERBOARD ASSEMBLY	21793	401648
2	404101	FRONT PANEL ASSEMBLY	21793	404101
3	454597	SHIELD, BOTTOM LINE V	21793	454497
4	454498	LINE VOLTAGE GUARD	21793	454498
6	454502	ROD, PUSH	21793	454502
7	454504	REAR PANEL	21793	454504
8	454506	SIDE PANEL, FINISHED - (2 REQ'D)	21793	454606
9	500213	TUBING, TYGON, 1/4" OD x 1/2" ID	--	--
13	610377	SCREW, NYLON 4-40 x .5	--	--
14	610908	SCREW, PPH, TAP, 6-32 x .375 - (3 REQ'D)	--	--
15	610777	CABLE TIE	--	T18R
16	610909	SCREW, PPH, TAP, 6-32 x .500 - (6 REQ'D)	--	--
18	615057	SCREW, PPH, 6-32 x .25 - (2 REQ'D)	--	--
20	615062	SCREW, PPH, 6-32 x .625	--	--
21	617004	NUT, HEX #4	--	--
25	617005	NUT, HEX, STD, 6-32	--	--
26	630002	WASHER, B-375-120-62 INS - (2 REQ'D)	--	--
28	920885	BUTTON, SWITCH	71590	J72668-03501

404101 - FRONT PANEL ASSEMBLY D

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
J100	601027	POST, BINDING, POLYCARBONATE, BLACK	05276	SK5100-0
J101	601027	POST, BINDING, POLYCARBONATE, BLACK	05276	SK5100-0
J102	601027	POST, BINDING, POLYCARBONATE, BLACK	05276	SK5100-0
J103	601036	POST, BINDING, POLYCARBONATE, WHITE	05276	SK5100-9
J104	601036	POST, BINDING, POLYCARBONATE, WHITE	05276	SK5100-9
L1	310152	CHOKE-WIDEBAND	02114	VK200 10/3B
L2	310152	CHOKE-WIDEBAND	02114	VK200 10/3B
R1	010838	RES-CARBON - 100K - 2% - 1W	91637	SBF100K2%
R2	010838	RES-CARBON - 100K - 2% - 1W	91637	SBF100K2%
1	401649	PCB ASSEMBLY, DISPLAY	21793	401649
2	454505	PANEL, FRONT	21793	454505
3	454466	KEYBOARD, MOLDED	21793	454466
4	500119	WIRE, 20 GA, TEF, YELLOW	--	--
6	610777	CABLE TIE	--	T18R
8	615043	SCREW, PPH 4-40 x .312 - (4 REQ'D)	--	--
9	617102	WASHER, FL, LSER, #4 - (4 REQ'D)	--	--
10	617127	WASHER, SPLK, LSER, #4 - (4 REQ'D)	--	--
12	500116	WIRE, 20 GA, TEF, RED	--	--
14	524555	WIRE, 24 GA STRND, TEF, GRN	--	--
15	500017	HEAT SHRINK .50 I.D.	--	--
16	601011	TRM, CRP, SLP, U, F24, 20G - (4 REQ'D)	--	--

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
17	600978	RECEPTACLE, WIRE, CRIMP	--	--
18	500117	WIRE, 20 GA, TEF, GRN	--	--
19	500118	WIRE, 20 GA, TEF, BLU	--	--
20	920927	BUMPER	53387	SJ-5003

401649 - PCB ASSEMBLY, DISPLAY D

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
C1	100133	CAP - CERAM - .1MFD - LOW PROFILE - 20%	72982	8131LP-100-651-104M
CR1	210071	LAMP HI EFFICIENCY RED-SOLID STATE	50434	HP5082-4650
CR2	210071	LAMP HI EFFICIENCY RED-SOLID STATE	50434	HP5082-4650
CR3	210071	LAMP HI EFFICIENCY RED-SOLID STATE	50434	HP5082-4650
CR4	210071	LAMP HI EFFICIENCY RED-SOLID STATE	50434	HP5082-4650
CR5	210071	LAMP HI EFFICIENCY RED-SOLID STATE	50434	HP5082-4650
CR6	210071	LAMP HI EFFICIENCY RED-SOLID STATE	50434	HP5082-4650
DS1	210065	DIODE - LED DISPLAY	50434	HP5082-7750
DS2	210065	DIODE - LED DISPLAY	50434	HP5082-7750
DS3	210065	DIODE - LED DISPLAY	50434	HP5082-7750
DS4	210065	DIODE - LED DISPLAY	50434	HP5082-7750
DS5	210065	DIODE - LED DISPLAY	50434	HP5082-7750
DS6	210065	DIODE - LED DISPLAY	50434	HP5082-7750
DS7	210065	DIODE - LED DISPLAY	50434	HP5082-7750
P1	601066	CONNECTOR - DBL ROW - 12P - FEMALE	30146	929975-12
S1	920905	SWITCH MOMENTARY SPST	--	81519
U1	230192	IC - 14 DIP - INVERTER	01295	SN74LS05N
U2	230457	IC - LED DRIVER	50579	ICM7218A
4	454507	KEYBOARD 2 x 6 MATRIX MOD.	21793	454507
8	920860	TAPE, FOAM, DOUBLECOAT 1/8" THICK	--	--

401649 - PCB ASSEMBLY, DISPLAY D

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
11	500022	WIRE, BUSS, 22 GA	--	--
14	411649	PCB, DISPLAY (UNSTUFFED)	21793	411649
19	920891	SOCKET, 28 PIN, DIP	--	--

401648 - PCB ASSEMBLY, MOTHERBOARD

S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
AR1	230620	IC - LINEAR AMP	27014	LM308N
AR2	230324	IC - FET INPUT OP AMP	27014	LF356H
AR3*	230560	IC - LINEAR	24355	AD536AJD
AR3	230633	IC - GRADED	21793	230633
AR4	230595	IC - OP NL AMP	24355	AD542KH
AR5	230462	IC - OP AMP - LF351N	27014	LF351N
AR6	230462	IC - OP AMP - LF351N	27014	LF351N
AR7	230620	IC - LINEAR AMP	27014	LM308N
AR8	230620	IC - LINEAR AMP	27014	LM308N
AR9	230620	IC - LINEAR AMP	27014	LM308N
BT1	920847	BATTERY - 3 VOLT LITHIUM ORGANIC	90201	L032S
C1	120280	CAP - MYLAR - .22 MFD - 1000V - 10%	27556	ZA2J224K
C2	100116	CAP - CERAM - 500 PFD - 1000V - 20%	56289	C023B102E501M
C4*	100051	CAP - CERAM - 3 PFD - 500V	71471	TCD-B1-0
C4	100136	CAP - CERAM - 5.6 PFD - 1KV	--	CCD-TC-5.6PF-1KV-C-NPO
C5	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C6	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C7	120298	CAP - MYLAR - 1.0 MFD - 100V - 20%	73445	C281AH/A1M
C8	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C9	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E

* USED ON EARLIER MODELS

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued)

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
C10	110126	CAP - TANTA - 6.8 MFD - 35V - 20%	05397	T368B685M035AS
C11*	100089	CAP - CERAM - 4700 PFD - 100V - 5%	72982	8141-M100-C0G472J
C11	100141	CAP - CERAM - 6800 PFD - 100V - 5%	51642	300-100-NPO-682J
C12*	100050	CAP - CERAM - 2.2 PFD - 1000V - 5%	56289	C030B102S2R2D
C12	130166	CAP - VAR. CERAM - .5 PFD TO 3 PFD 3 TURN	52763	R-TRINO-120-05M.5/3
C13*	100053	CAP - CERAM - 56 PFD - 1000V - 5%	56289	C030A102J560J
C13	130124	CAP - TRIMMER - 1.2 PFD TO 10 PFD - 250V	52763	R-TRIKO-122-09SD
C14	120283	CAP - POLY - .03 MFD - 50V - 20%	27556	PA28303
C15	120283	CAP - POLY - .03 MFD - 50V - 20%	27556	PA28303
C16*	100038	CAP - CERAM - 560 PFD - 500V - 10%	71590	DD561
C16	130169	CAP - MICA - 750 PFD - 300V - 1%	09023	CD15FC681F03
C17	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C18	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C19	100024	CAP - CERAM - .1 MFD - 25V	72982	1C25Z5U104M050E
C20	100024	CAP - CERAM - .1 MFD - 25V	72982	1C25Z5U104M050E
C21	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C22	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C23	100016	CAP - CERAM - 27 PFD - 1000V - 10%	71590	DD270
C24	100016	CAP - CERAM - 27 PFD - 1000V - 10%	71590	DD270
C25	110126	CAP - TANTA - 6.8 MFD - 35V - 20%	05397	T368B685M035AS
C26	120353	CAP - POLY - 3300 PFD - 100V - 5%	26625	--

* USED ON EARLIER MODELS

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued) S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
C27	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C28	100024	CAP - CERAM - .1 MFD - 25V	72982	1C25Z5U104M050E
C29	100111	CAP - CERAM - .01 MFD - 2000V	71471	HVD6-2KV
C30	110126	CAP - TANTA - 6.8 MFD - 35V - 20%	05397	T368B685M035AS
C31	110126	CAP - TANTA - 6.8 MFD - 35V - 20%	05397	T368B685M035AS
C32	110126	CAP - TANTA - 6.8 MFD - 35V - 20%	05397	T368B685M035AS
C33	100111	CAP - CERAM - .01 MFD - 2000V	71471	HVD6-2KV
C34	110172	CAP - ELEC - 470 MFD - 35V	--	35VBSL470
C35	110202	CAP - 4700 MFD - 16V	--	VP16VB4700MC
C36	110172	CAP - ELEC - 470 MFD - 35V	--	35VBSL470
C37	100063	CAP - CERAM - .01 MFD - 500V - 20%	56289	C023B501E103M
C38	100017	CAP - CERAM - .01 MFD - 100V - 20%	56289	1C25Z5U103M100E
C39	100116	CAP - CERAM - 500 PFD - 1000V - 20%	56289	C023B102E501M
C40	110172	CAP - ELEC - 470 MFD - 35V	--	35VBSL470
C41	120093	CAP - POLY - 470 PFD - 630V - 5%	08257	KSO SERIES
C42	100012	CAP - CERAM - 33 PFD - 500V - 10%	71471	TCD-DI-1 (N750)
C43	100012	CAP - CERAM - 33 PFD - 500V - 10%	71471	TCD-DI-1 (N750)
C44	100012	CAP - CERAM - 33 PFD - 500V - 10%	71471	TCD-DI-1 (N750)
C53**	130168	CAP - MICA - 75 PFD - 500V - 1%	--	CM04ED680F03
C54	100100	CAP - CERAM - FSV	21793	100100
C56	100100	CAP - CERAM - FSV	21793	100100

** ON LATER MODEL ONLY

S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
CR1	210004	DIODE SILICO	81349	1N4004
CR2	210070	DIODE POWER - 3 AMP	04713	MR501
CR3	210070	DIODE POWER - 3 AMP	04713	MR501
CR4	210015	DIODE	50434	HP5082-2800
CR5	211083	DIODE SILICO - IN916B	81349	1N916B
CR6	211083	DIODE SILICO - 1N916B	81349	1N916B
CR7	211083	DIODE SILICO - 1N916B	81349	1N916B
CR8	210004	DIODE SILICO	81349	1N4004
CR9	210004	DIODE SILICO	81349	1N4004
CR10	230465	IC - DIODE BRIDGE	27777	VM48
CR11	211083	DIODE SILICO	81349	1N916B
CR12	200099	TRANS PNP	81349	2N4258
CR13	200099	TRANS PNP	81349	2N4258
F1	920698	FUSE - NORMAL BLO - 2.5 AMP - 250V	75915	312 02.5
F2	920756	FUSE - SLO-BLO - 1/4 AMP - 250V	75915	MDL 1/4
J1	601065	CONNECTOR - DBL - 12P - R ANGLE	30146	929838-01-12
J2*	920735	SOCKET - IC - 16P	71785	133-51-02-006
J3	601040	CONNECTOR - PCB - 5P	27264	09-60-1051
J4	600821	CONNECTOR - 6P	04713	09-03-1062
J5*	601012	SOCKET - 3 CIRCUIT TRANSISTOR	27264	10-18-2031

* USED ON EARLIER MODELS

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued)

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
J200	601014	CONNECTOR - PCB RECEPT. - 6A - 205V	82389	EAC-303
K1	310149	RELAY - SPDT - 12V - 400 OHM	26806	AZ4UP-E-1C-12D
K2	310147	RELAY - CRADLE - 2FORMC	26806	AZ420-08-205
K3	310147	RELAY - CRADLE - 2FORMC	26806	AZ420-08-205
K4*	310150	RELAY - REED - 1FORMA	15636	R7295-2
K4	310159	RELAY - REED - 1FORMA	15636	R7912-2
K5*	310150	RELAY - REED - 1FORMA	15636	R7295-2
K5	310159	RELAY - REED - 1FORMA	15636	R7912-2
6*	310150	RELAY - REED - 1FORMA	15636	R7295-2
K6	310159	RELAY - REED - 1FORMA	15636	R7912-2
K7*	310150	RELAY - REED - 1FORMA	15636	R7295-2
K7	310159	RELAY - REED - 1FORMA	15636	R7912-2
P4	410727	PCB - VOLTAGE SELECT	21793	410727
Q1	200200	TRANS - NPN	21793	200200
Q2	200274	TRANS - NPN - PWR - 350V	01295	TIP-49
Q3	200275	TRANS - N-CHANNEL SWITCHING FET	7014	PN4392-18
Q4	200200	TRANS - NPN	21793	200200
Q5	200275	TRANS - N-CHANNEL SWITCHING FET	27014	PN4392-18
Q6	200275	TRANS - N-CHANNEL SWITCHING FET	27014	PN4392-18
Q7	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-8

* USED ON EARLIER MODELS

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
Q8	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q9	200200	TRANS - NPN	21793	200200
Q10	200200	TRANS - NPN	21793	200200
Q11	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q12	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q13	200200	TRANS - NPN	21793	200200
Q14	200275	TRANS - N-CHANNEL SWITCHING FEET	27014	PN4392-18
Q15	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q16	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q17	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q18	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q19	200275	TRANS - N-CHANNEL SWITCHING FET	27014	PN4392-18
Q20	200200	TRANS - NPN	21793	200200
Q21	200068	TRANS - PNP	80131	2N4250
Q22	200099	TRANS - PNP	81349	2N4258
Q23	200275	TRANS - N-CHANNEL SWITCHING FET	27014	PN4392-18
Q24	200275	TRANS - N-CHANNEL SWITCHING FET	27014	PN4392-18
Q25	200275	TRANS - N-CHANNEL SWITCHING FET	27014	PN4392-18
Q26	200265	TRANS - FET	01295	2N5951
Q27	200279	TRANS - J FET LOW CAP, LOW LEAKAGE	27014	PN4119-18
Q28	200200	TRANS - NPN	21793	200200
R1	020679	RES - WW - .1006 OHM - 5% - 1.5W	21551	M-19

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued) S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
R2	001766	RES - CARBON - 220K - 5% - 1/2W	81349	RC20GF224J
R3	001766	RES - CARBON - 220K - 5% - 1/2W	81349	RC20GF224J
R4	000152	RES - CARBON - 1.5K - 5% - 1/4W	81349	RC07GF152J
R5	000103	RES - CARBON - 10K - 5% - 1/4W	81349	RC07GF103J
R6	010338	RES - METAL - 1M - 1% - 1W	03888	PME75
R7	012067	RES - PRECISION - 10M - 1%	19647	MK632
R8	010344	RES - METAL - 237K - 1% - 1/8W	81349	RN60D2373F
R9	010868	RES - METAL - 14.3K - 1% - 1/10W	81349	RN55D1432F
R10	010407	RES - METAL - 316K - 1% - 1/8W	81349	RN60D3163F
R11	000303	RES - CARBON - 30K - 5% - 1/4W	81349	RC07GF303J
R12	010685	RES - METAL - 909 OHM - 1% - 1/10W	81349	RN55E9090F
R13	010992	RES - METAL - 100 OHM - .5% - 1/10W	81349	RN55E1000D
R14	012068	RES - MATCHED SET 2K/18K/49.5K - 1%	14298	UAR-1/10
R15	012068	RES - MATCHED SET 2K/18K/49.5K - 1%	14298	UAR-1/10
R16	000303	RES - CARBON - 30K - 5% - 1/4W	81349	RC07GF303J
R17	012068	RES - MATCHED SET 2K/18K/49.5K - 1%	14298	UAR-1/10
R18	000203	RES - CARBON - 20K - 5% - 1/4W	81349	RC07GF203J
R19	000303	RES - CARBON - 30K - 5% - 1/4W	81349	RC07GF303J
R20	000914	RES - CARBON - 910K - 5% - 1/4W	81349	RC07GF914J
R21	001807	RES - CARBON - 910K - 5% - 1/2W	81349	RC20GF914J
R22	000914	RES - CARBON - 910K - 5% - 1/4W	81349	RC07GF914J
R23	000914	RES - CARBON - 910K - 5% - 1/4W	81349	RC07GF914J
R24	010630	RES - METAL - 9.09K - 1% - 1/10W	81349	RN55C9091F

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued)

S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
R25	010540	RES - METAL - 1K - 1% - 1/10W	81349	RN55C1001F
R26	000100	RES - CARBON - 10 OHM - 5% - 1/4W	81349	RC07GF100J
R27	000100	RES - CARBON - 10 OHM - 5% - 1/4W	81349	RC07GF100J
R28	000361	RES - CARBON - 360 OHM - 5% - 1/4W	81349	RC07GF361J
R29	010829	RES - METAL - 4.99K - 1% - 1/10W	81349	RN55C4991F
R30	000362	RES - CARBON - 3.6K - 5% - 1/4W	81349	RC07GF362J
R31	000392	RES - CARBON - 3.9K - 5% - 1/4W	81349	RC07GF392J
R32	000432	RES - CARBON - 4.3K - 5% - 1/4W	81349	RC07GF432J
R33	012083	RES - METAL FILM - 475K - 1% - 1/8W	81349	RN55C4753F
R34	000103	RES - CARBON - 10K - 5% - 1/4W	81349	RC07GF103J
R35	000103	RES - CARBON - 10K - 5% - 1/4W	81349	RC07GF103J
R36	000102	RES - CARBON - 1K - 5% - 1/4W	81349	RC07GF102J
R37	000102	RES - CARBON - 1K - 5% - 1/4W	81349	RC07GF102J
R38	010873	RES - METAL - 2.21K - 1% - 1/10W	81349	RN55C2211F
R39	000202	RES - CARBON - 2K - 5% - 1/4W	81349	RC07GF202J
R40	010838	RES - CARBON - 100K - 2% - 1W	91637	SBF200K2%
R41	000223	RES - CARBON - 22K - 5% - 1/4W	81349	RC07GF223J
R42	000223	RES - CARBON - 22K - 5% - 1/4W	81349	RC07GF223J
R43	000102	RES - CARBON - 1K - 5% - 1/4W	81349	RC07GF102J
R44	010643	RES - METAL - 71.5K - 1% - 1/10W	81349	RN55C7152F
R45	010697	RES - METAL - 26.7K - 1% - 1/10W	81349	RN55C2672F
R46	000103	RES - CARBON - 10K - 5% - 1/4W	81349	RC07GF103J
R47	010795	RES - METAL - 13.7K - 1% - 1/10W	81349	RN55C1372F

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued)

S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
S1-5	920906	SWITCH - P.B. 10 - 5 STATIONS	71590	920906/PB10
S6	600975	SWITCH PUSHBUTTON	71590	SPEC-PB 12.5
T1	300099	TRANSFORMER POWER	21793	300099
U1	230330	IC	01295	74LS367
U2	230366	IC	27014	DM74LS174N
U3	230617	IC - MEMORY - 4K x 8 ROM	21793	230617
U4	230618	IC - MEMORY - 2K x 8 ROM	21793	230618
U5	230358	IC	01295	ULN2003AN
U6	230404	IC	04713	CD4094BE
U7	230547	IC - QUAD COMPARATOR	27014	LM339N
U8	230404	IC	04713	CD4094BE
U9	230482	IC - MEMORY	04713	MC6810P
U10	230369	IC	04713	6802-P
U11	230547	IC - QUAD COMPARATOR	27014	LM339N
U12	230547	IC - QUAD COMPARATOR	27014	LM339N
U13	230368	IC	27014	74LS138
U14	230194	IC - 14 DIP, DUAL D FLIP-FLOP	01295	SN74LS74N
U15	230248	IC - POSITIVE NAND GATE	01295	SN74LS10N
U16	230546	IC - LINEAR	27014	LM311N
U17	230193	IC - 14 DIP, NAND GATE	01295	SN74LS00N
U18	230367	IC	27014	74LS93
U19	230194	IC - 14 DIP, DUAL D FLIP-FLOP	01295	SN74LS74N

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
U20	230193	IC - 14 DIP, NAND GATE	01295	SN74LS00N
U21	230368	IC	27014	74LS138
U22	230118	IC - NPN	04713	CA3086
U24	230538	IC - DIGITAL	01295	SN74LS393N
U25	230544	IC - DIGITAL	01295	SN74LS390N
U26	230234	IC - 14 DIP, HEX INVERTER	01295	SN74LS04N
U27	230455	IC - CMOS MEMORY	32293	IM6508
U28	230588	IC - DIGITAL	18714	4023UB
U29	230275	IC - 5.0V	04713	MC7805CT
U30	230378	IC	27014	7915CT
U31	230200	IC	04713	MC7812-CP
U32	230515	IC - VOLTAGE DETECTOR, MICROPOWER	32293	ICL8212CPA
U33	230366	IC	27014	DM74LS174N
VR1	220019	DIODE - SILICO - ZENER	81349	1N752A
VR2	220049	DIODE - ZENER	81349	1N957B
VR3	230453	IC - +7V REFERENCE	27014	LM399H
VR4	230535	IC - PRCN - REF	27014	LM329CZ
VR5	220019	DIODE - SILICO - ZENER	81349	1N752A
W1*	601023	PLUG JUMPER	98291	026-4802
Y1	920907	CRYSTAL - 4 MHz	23875	MP-1,4.0

* USED ON EARLIER MODELS

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued) S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
Z1	080046	RES - NETWORK - 900 OHM 90 OHM, 9 OHM, 0.9 OHM - .25%	19647	1787-31
Z2	080020	RES - CERMET - 10K NETWORK, 8P, 7R - 2%	11236	750-81-R10K OHM
Z3	080047	RES - NETWORK - 9M, 900K, 90K, 10K - 5%	19647	1776-105
Z4	080013	RES - CERMET - 15K NETWORK 16P, 8R - 2%	11236	761-3-R15K OHM
Z5	080030	RES - CERMET - 22K NETWORK 8P, 7R - 2%	11236	750-81-R22K OHM
Z6	080045	RES - NETWORK - 10K, 14PIN, 13R 2% - 1.5W	11236	760-1-R10K OHM
Z7	080048	RES - NETWORK - 14 PIN - 1% - .05W	71450	080048-760-S
[illegible]4	600747	SOCKET, RELAY - 2 POLE, 10P - (2 REQ'D)	26806	ST140-A1
115	454545	BUTTON, PUSH - (5 REQ'D)	21793	454454
116**	453936	RETAINER, FOAM, ADHESIVE	21793	453936
117	600766	EYELET, TEFLON - (E1 TO E15) - (15 REQ'D)	98291	X-121973-1
119	600786	POST, MACHINE APPLIED STRIP - (TP1-9, E16-19) - (13 REQ'D)	00779	1-87022-0
121	600823	SOCKET - 40 PIN - DIP TYPE	52072	405-TSD-BD
123**	610777	CABLE TIE - (3 REQ'D)	--	T18R
125	610891	RIVET, DOME, HD, BR, .116 x 1/4 - (2 REQ'D)	--	--
126	610945	STANDOFF, SHLDR, 3-48 - (2 REQ'D)	--	--
127	617102	WASHER, FLAT, #4 - (2 REQ'D)	--	--
128**	601011	TERMINAL, CRIMP, .039 DIA (2 REQ'D)	00779	60059-2

** ON LATER MODELS ONLY

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
129	920504	ADHESIVE, W/S1-S5	04963	4475
130	610904	CLIP, COMPONENT	--	--
131	610906	RIVET, 3/32 DIA	--	--
133*	920624	SOCKET, 24 PIN, DIP - (3 REQ'D)	71785	133-59-02-063
136	920735	SOCKET, 16 PIN, DIP - (2 REQ'D)	71785	133-51-02-006
139	920463	CLIP, FUSE - (4 REQ'D)	91506	6008-32AT
142**	500022	WIRE, COPPER TRIMMED, SOLID, 22 GA.	21793	500022
143	500215	WIRE, 18 GA, STRND, TEF, GRN & YEL	--	--
144	600022	LUG, SOLDER #6	83330	1416-6
145	411648	PCB, MOTHERBOARD (UNSTUFFED)	21793	411648
146**	500143	TUBING, SHRINK FIT, .062 ID, BLK	--	--
147	500060	TUBING, TEFLON, 18 GA	--	--
148	610941	STANDOFF, 4-40 x 1.250 SWG LG (3 REQ'D)	--	--
149	610288	STANDOFF, 4-40 x .187 SWG LG (4 REQ'D)	--	--
150	601023	PLUG, JUMPER	--	--
151	610899	TIE, PLASTIC, 8 INCH	--	--
153	610020	STANDOFF, 6-32 x .187 LG THROUGH SWG	--	--
143	610289	SPACER #6 x .188 LG THROUGH SWG	--	--
160**	524555	WIRE, TEFLON, STRANDED, 24 GA, GRN	--	--

* USED ON EARLIER MODELS

** ON LATER MODELS ONLY

401648 - PCB ASSEMBLY, MOTHERBOARD (Continued)

S

REF. DES.	RACAL-DANA P/N	DESCRIPTION	FSC	MFG. P/N
161**	500043	WIRE, TEFLON, SOLID, 24 GA, WHT	--	--
162**	500181	WIRE, TEFLON, SOLID, 24 GA, BRN	--	--
163**	500182	WIRE, TEFLON, SOLID, 24 GA, RED	--	--
164**	500183	WIRE, TEFLON, SOLID, 24 GA, ORN	--	--
165**	500184	WIRE, TEFLON, SOLID, 24 GA, YEL	--	--
166**	500185	WIRE, TEFLON, SOLID, 24 GA, GRN	--	--
167**	500186	WIRE, TEFLON, SOLID, 24 GA, BLU	--	--

** ON LATER MODELS ONLY

RACAL-DANA Instruments Inc.

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Quebec
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(514) 336-0392

RACAL-DANA Instruments Inc.

U. S. AND CANADIAN SERVICE CENTERS

FACTORY SERVICE

(A) RACAL-DANA INSTRUMENTS INC.
4 Goodyear Street
Irvine, California 92714
Telephone: (714) 859-8999

PRODUCT SERVICE TWX 910-595-1136

REGIONAL SERVICE CENTER

(B) RACAL-DANA INSTRUMENTS INC.
5101 "D" Blacklick Road
Annandale, Virginia 22003
Telephone: (703) 941-0525

INTERNATIONAL SERVICE CENTER:

RACAL-DANA INSTRUMENTS LTD.

Duke Street, Windsor,
Berkshire SL4 1SB, United Kingdom
Telephone: Windsor (07535) 68101, TLX: 847013

RACAL-DANA INSTRUMENTS GmbH.

Hermannstrasse 29, D-6078 Neu Isenburg,
Federal Republic of Germany
Telephone: 06102-2861/2, TLX: 412896

RACAL-DANA INSTRUMENTS S.A.

18 Avenue Dutartre, 78150 Le Chesnay, France
Telephone: (3) 955-8888, TLX: 697 215

RACAL-DANA INSTRUMENTS ITALIA srl.

Via Mecanate 84/A, 20138 Milano MI, Italy
Telephone: (02) 5062767/5052686, TLX: 315697

REPAIR REQUEST FORM

To allow us to better understand your repair requests, we suggest you use the following outline and include a copy with your instrument to be sent to your local Racal-Dana repair facility.

Model Number ____________ Options ____________ Date ____________

Serial Number ____________ P. O.# ____________

Company Name ____________

Address ____________

City ____________ State ____________ Zip Code ____________

Contact ____________ Phone Number ____________

1. Describe, in detail, the problem and symptoms you are having.

____

____

2. If you are using your unit on the bus, please list the program strings used and the controller type, if possible. ____________

____

3. List all input levels, and frequencies this failure occurs.

____

____

4. Indicate any repair work previously performed.

____

____

5. Please give any additional information you feel would be beneficial in facilitating a faster repair time. (I. E., modifications, etc.)

____

____