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UNIVERSAL LOAD UNIT 067-0883-99

INSTRUCTION MANUAL

Tektronix, Inc.
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The Universal Load Unit is a non-supported Tektronix product.

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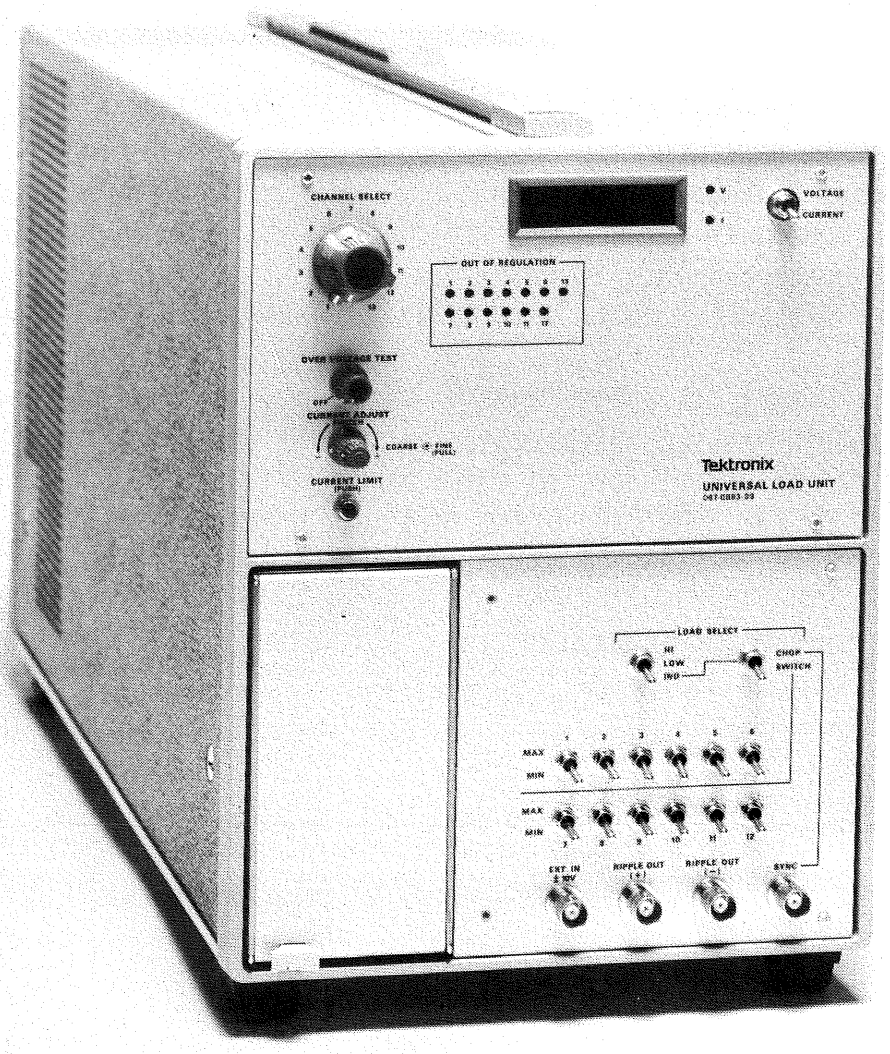

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Universal Load Unit

SECTION 1

GENERAL INFORMATION

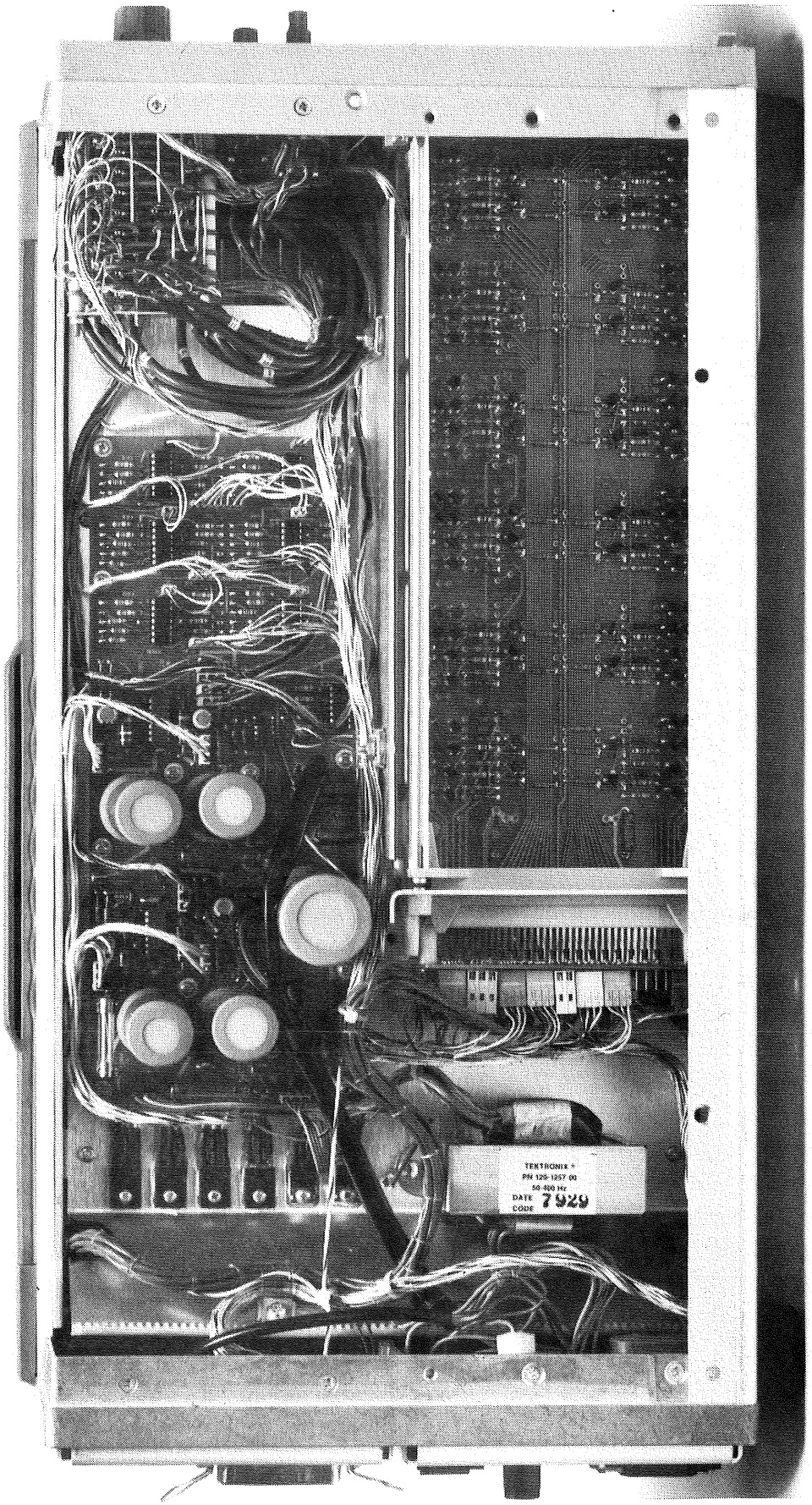
Introduction

The Universal Load Unit (ULU) is a bench top testing device that will provide a convenient method of performance checking the internal power supplies in several Tektronix instruments. It may be used to test and verify proper voltage regulation of single and multiple output supplies under variable load conditions. The ULU is used in conjunction with Programming plug-in modules that are temporarily installed, one at a time, into the Load Unit through its front panel.

Description

The Universal Load Unit includes twelve active load cells (channels) and one passive channel through which up to thirteen output voltage levels can be concurrently loaded. The current through any active channel is varied by an internal pulse generator to provide transient response testing. The voltage or current in a selected channel may be displayed on the Load Units front panel digital multi-meter. Also, each channel is monitored for an out-of-tolerance condition as indicated by one of thirteen comparator-driven, front panel LED's. The thirteen position CHANNEL SELECTOR switch is used to connect the ULU controls and output monitoring circuits to each of the 12 active cells. As selected, each active load cell or channel can be set up to provide a resistive load or a constant current load for a given power supply output. Each active load cell includes a current sensing resistor, current amplifier and cell protection circuitry. Each programming/load module supports 12 active and 1 passive channel. All twelve active channels can be programmed by the installation of six user selected resistors per channel (See Appendix A). The resistors select high or low current levels and equivalent load resistances and establish nominal voltages and tolerance limits for the ULU's comparator circuitry. The passive channel (13) is programmed with two fixed resistors.

Each programming module is used to test the internal power supplies in a specific Tektronix instrument and will be separately part numbered.



2213-02

Universal Load Unit Left Side View Including Power Supplies, Channel Selector Switch and Plug-in Module Programming Board

Electrical Characteristics

Input AC Power

The ULU may be operated at 115 or 230 VAC (48 to 67 HZ) and requires less than 80 watts during normal operation. It uses a 1 amp standard 3AG fuse. The power cord is detachable and will plug into a female receptacle conforming with NEMA #5-15. (Two-pole, three wire grounding).

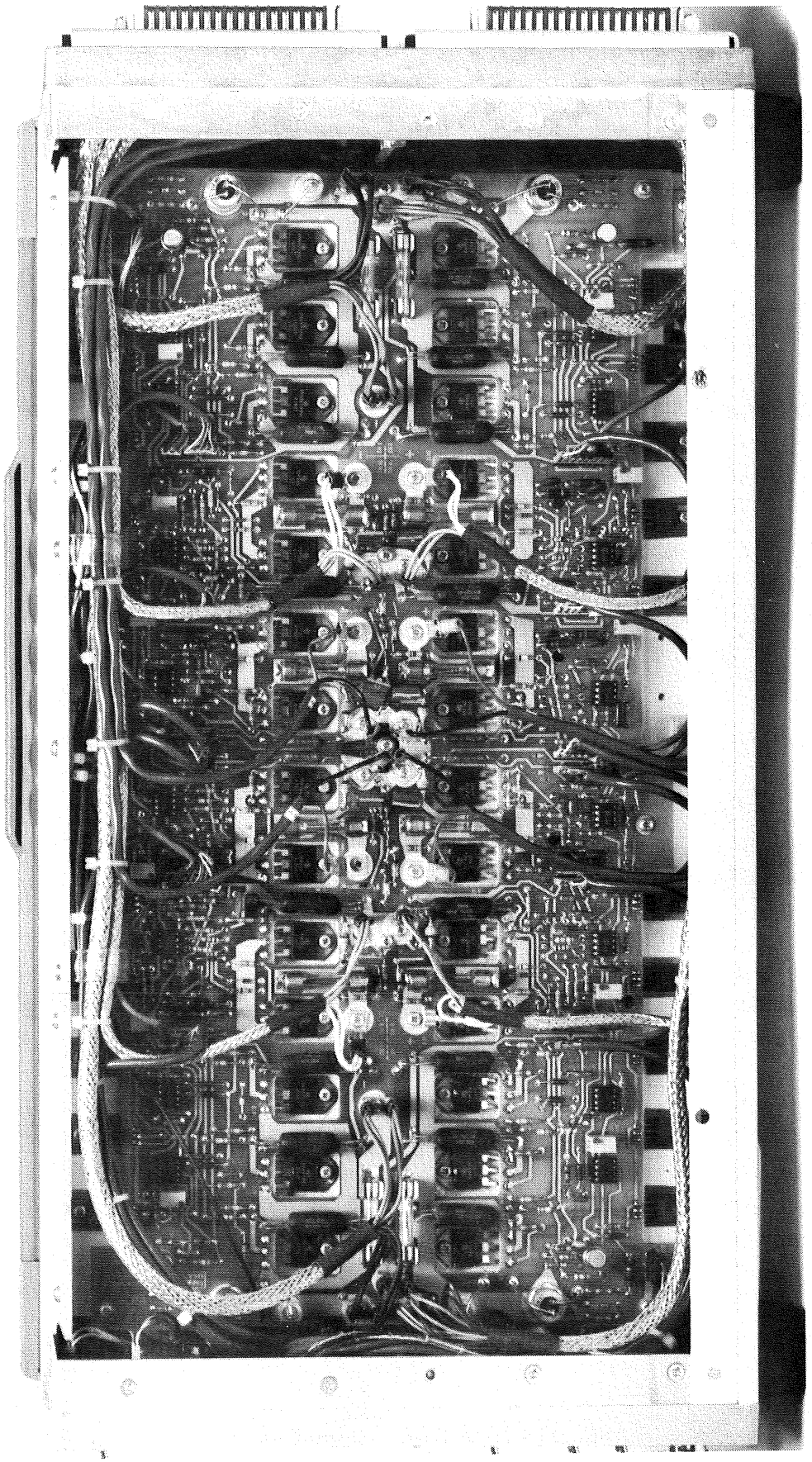
Load Cells (Channels) Maximum and minimum input voltages and currents are given in the following tabular listing.

Current:	**Max**	**Fused**	**Accuracy**
Channels 1,2,7,8	24.A	30A	±5% ± 0.5% FS
Channels 3,4,9,10	10A	15A	±5% ± 0.5% FS
Channels 5,6,11,12	2A	5A	± 5% ± 0.5% FS
Channel 13	1A		

Voltage:	**Max**	**Trip Voltage (Crowbar)**	**Saturation Amps (minimum)**
Channels 1,2	50V	55V	≤2V @ 15A max.
Channels 7,8	-50V	-55V	≤2V @ 15A max.
Channels 3,4	100V	110V	≤4.5V @ 10A max.
Channels 9,10	-100V	-110V	≤4.5V @ 10A max.
Channels 5,6	160V	180V	≤8V @ 2A max.
Channels 11,12	-160V	180V	≤8V @ 2A max.
Channels 13	350V	none	≤1V @ 1A max.

Power	**Maximum***
Channels 1,2,7,8	120W
Channels 3,4,9,10	80W
Channels 5,6,11,12	80W
Channel 13	10W

*or 500 watts total input power, all channels.



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Universal Load Unit Right Side View
Showing Main Board Assembly

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Operational Modes: The ULU includes two operational modes; Chop individual and Chop All.

Chop Rate:	96 Hz nominal
Chop Duty Cycle:	50% nominal
Chop Rise/Fall time:	$\leq$ 10 μs (10%-90%)

Indicators: The ULU includes two indicating devices - a digital multimeter (DMM) display and 10 Out-of-Regulation LED's.

	Voltage	Current
DMM Ranges:	2V,20V,200V,2000V	200A,20A, 2A
DMM Accuracy:	$\pm$0.1% $\pm$ 2 counts	1% $\pm$ 6 counts

LED Accuracy: $\pm$5% deviation from programmed value

Environmental Characteristics

The ULU has been tested and verified operable in the following class 5 categories: shake, shock, transportation, bench handling and abbreviated thermal tests (limited to 0°C to 50°C with instrument on).

Accessories

Standard. Accessories for the ULU include this manual (061-2213-00) and the following listed items:

Mating Connectors P1 & P2 (2)	131-0097-00
Mating Connector, P3	131-0293-00
AC Power Cord	161-0066-00
Packing Box	004-0766-00
Foam Pad	004-0281-00
Pad Set	004-1092-00

Optional. Optional Accessories for the ULU include the following listed items:

Unprogrammed Plug-in & Connector Set	067-0919-99
7612D Programming Plug-in	067-0921-99
7612D Programming Plug-in Inst. Manual	061-2214-00
7912AD Programming Plug-in	067-0920-99
7912AD Programming Plug-in Inst. Manual	061-2213-00

SECTION 2

OPERATION

FRONT PANEL CONTROLS

CHANNEL SELECT Control. This 13 position rotary switch connects one of the 13 channels to other Universal Load Unit front panel controls including: CURRENT ADJUST, CURRENT LIMIT, CHOP/SWITCH, OVER VOLTAGE TEST, to indicators including: Digital Multimeter and OUT-OF-REGULATION Lights and to the External Input Amplifier. The CHANNEL SELECT control also switches the AC output voltage available at the RIPPLE OUT (+) connector.

OVER VOLTAGE TEST Control. The OVER VOLTAGE TEST control is an end-of-rotation switch that inserts (or excludes) an internal 75K resistive divider in series with the remote sense line of the selected channel. CW rotation increases the magnitude of the output voltage of the selected supply under test. Note that this control will function only if the output is remote sensed. Caution is indicated in that using this control in any but the OFF (detented) position may cause damage to the supply under test. Also, if the supply under test does not have an over-voltage limit, the ULU's crowbar may be initiated causing an open fuse, damage to the supply under test or both.

CURRENT ADJUST Control. The CURRENT ADJUST control is a combination push-pull switch and dual potentimeter. Pulling out on this control engages the current adjust function; pushing in disengages it. With the control pulled out, CW rotation increases and CCW rotation decreases the programmed current level (in positive channels 1 through 6) to the full cell current. Note that CURRENT ADJUST control rotations are reversed for negative channels 7-12. In the individual chop mode, the transition level current is set with the CURRENT ADJUST potentiometer (with the push-pull switch in).

CURRENT LIMIT Control. The CURRENT LIMIT control is a momentary contact push button switch. Pushing this switch causes the selected channel to draw its maximum safe current. The CURRENT LIMIT switch overrides both programmed current and the setting of the CURRENT ADJUST control. Current magnitudes are a function of the channel number, its voltage and its internal protection circuitry.

HI/LOW/IND LOAD SELECT Control. The HI/LOW/IND LOAD SELECT control is a three position toggle switch (S2110). In its upper position (HI) all active cells are set to their high load current. In its mid position (LOW) all active cells are set to their low load current. The lower position (IND) enables the CHOP/SWITCH control.

CHOP/SWITCH Control. The CHOP/SWITCH control is a two position toggle switch (S2111). With the HI/LOW/IND LOAD SELECT switch in its IND position and the CHOP/SWITCH control down, (SWITCH position) the 12 indiviual MAX/MIN LOAD SELECT switches (S2001 through S2012) are enabled. Each individual channel is then set to its programmed high or low current value by the position of its corresponding MAX/MIN switch.

With the HI/LOW/IND LOAD SELECT switch in its IND position and the CHOP/SWITCH control up (CHOP position) the Chop mode is enabled. Operating at a clock rate of 96 hertz, the Chop mode performs two functions, one at a time, as determined by the positions of two programming jumpers on P2119 (located on the backside of the Load Select Toggle Switches circuit board). These jumpers are accessible with ULU's left side cover off and Programming/Load plug-in module removed.

With the P2119 jumpers connecting pins 1 to 2 and 4 to 5, the INDividual Chop mode is selected in which only the channel selected by the CHANNEL SELECT control is chopped or step loaded. Note that the CURRENT ADJUST switch must be pushed in to enable the chopping action. Chopper state information is available at the SYNC output BNC connector. The cell current value in effect when the SYNC output is in a TTL low state is that set by the MAX/MIN INDividual LOAD SELECT switch for that channel (cell) and the corresponding programming resistor value (in the plug-in module). The cell current value during the SYNC output TTL high state is that set by the CURRENT ADJUST controls. The magnitude of this value can be set by (temporarily) pulling out the CURRENT ADJUST switch and adjusting it to the desired value as read on the DMM in CURRENT mode. Note that the averaging nature of the DMM and the 50 percent duty cycle of the chopper cause the DMM current (while chopping) to be the average of the two switched levels.

With the P2119 jumpers connecting pins 2 to 3 and 5 to 5, the Chop ALL mode is selected. In the Chop All mode all active channels are simultaneously switched between their high and low programmed current values. Note that all channels are high at once and then all low at once irregardless of the positions of their respective MAX/MIN switches.

The Universal Load Unit includes two chop modes to accomodate those instrument power supplies that cannot tolerate all their outputs being chopped at once without activating their internal fault or protection circuits. Damage may occur to some power supplies when all outputs are concurrently chopped.

MAX/MIN Switch Array. The MAX/MIN Switch Array consists of SPST toggle switches (S2001 through S2012). These switches are used to select either high or low load current for each active channel. Both the CHOP ALL (mode) and the HI/LOW/IND LOAD SELECT switch will override the individual MAX/MIN switches.

VOLTAGE/CURRENT Control. The VOLTAGE/CURRENT control is a two position toggle switch located to the right of the Digital Multimeter. It is used to select the type of measurement displayed on the Multimeter (voltage or current). Each switch position is monitored by a corresponding LED indicator. "V" is illuminated for the VOLTAGE switch position and 'I' is illuminated for the CURRENT position.

DIGITAL MULTI-METER. The Digital Multi-Meter (DMM) is an auto-ranging, numerical display indicator with a four and a half digit readout. The DMM is used to indicate the polarity and numerical value of DC voltage or current on a selected channel.

OUT-OF-REGULATION Indicators. The OUT-OF-REGULATION, indicators consist of 13 red lights mounted in a group on the upper front panel. There is one light per channel and when illuminated, each indicates that the particular supply voltage associated with that channel has deviated fom the programmed acceptance limits. Selected resistors on the program board are used to establish the proper comparison voltages and the allowable tolerance margins for the supplies to be monitored.

EXTernal INput Connector. EXTernal INput designates a front panel BNC female connector. Applying a voltage to the center conductor of this connector causes the current in the selected channel (1-12) to be increased or decreased in proportion to the applied voltage. A ten volt level corresponds to approximately 100 percent of rated channel current. For cells 1 through 6, a positive voltage increases the absolute value of the load current while a negative voltage decreases it. For cells 7 through 12, a negative voltage increases and a positive voltage decreases the load current.

RIPPLE OUT (+) & (-) Connectors. RIPPLE OUT designates two front panel BNC female connectors. The (+) connector's center conductor is capacitively coupled (via the selected channel) to the power supply under test. The (-) connector's center conductor (shell) is connected to return (ground) of the power supply under test.

SYNC Connector. SYNC designates a front panel BNC female connector that is used to output TTL level signals. The SYNC output can drive standard TTL loads and is used to provide an oscilloscope external trigger signal when the ULU is operated in chop mode.

REAR PANEL CONTROLS AND CONNECTORS

POWER SWITCH. The POWER SWITCH is a two-position (ON-OFF) rocker switch used to apply or remove AC power.

230V-115V SWITCH. The 230V-115V switch is a two-position, flush mounted slider switch used to select input AC voltage.

FUSE/FUSEHOLDER. The AC power fuse for the ULU is a 1 amp/250 volt standard fuse. The fuseholder is located just above the AC power receptacle and is designed for 3AG type fuses.

P1 NEGATIVE/P2 POSITIVE CONNECTORS. P2 POSITIVE is the voltage/current input connector for positive channels (cells) 1 through 6. P1 NEGATIVE designates the voltage/current input connector for negative cells 7 through 12. These 32-pin male connectors mate with Tektronix P/N 131-0097-00 (Amphenol P/N 26-190-32). Pin/function lists for P1 and P2 are given in Tables 1-1 and 1-2.

Table 2-1. P1 NEGATIVE Pin/Function List

Pins	Function
1,2,3,4,5	Channel 7, high I -
6,7,8,9,10	Channel 8, high I -
11,12	Channel 9, med I -
13,14	Channel 10, med I -
15	Channel 11, low I -
16	Channel 12, low I -
17,18,19,20,21	Channel 7, high I - return
22,23,24,25,26	Channel 8, high I - return
27,28	Channel 9, med I -
29,30	Channel 10, med I -
31	Channel 11, low I -
32	Channel 12, low I - return

Table 2-2. P2 POSITIVE Pin/Function List

Pins	Function
1,2,3,4,5	Channel 1, high I +
6,7,8,9,10	Channel 2, high I +
11,12	Channel 3, med I +
13,14	Channel 4, med I +
15	Channel 5, low I +
16	Channel 6, low I +
17,18,19,20,21	Channel 1, high I + return
22,23,24,25,26	Channel 2, high I + return
27,28	Channel 3, med I + return
29,30	Channel 4, med I + return
31	Channel 5, low I + return
32	Channel 6, low I + return

P3 SENSE

P3 SENSE is the remote sense connector for all cells and is the power input connector for cell 13. This 36-pin female connector mates with Tektronix P/N 131-0293-00, Amphenol P/N 57-30360. A pin/function list is shown in Table 2-3.

Table 2-3. P3 SENSE Pin/Function List

Pin	Function
1	Voltage remote sense, high, Channel 1
2	Voltage remote sense, high, Channel 2
3	Voltage remote sense, high, Channel 3
4	Voltage remote sense, high, Channel 4
5	Voltage remote sense, high, Channel 5
6	Voltage remote sense, high, Channel 6
7	Voltage remote sense, high, Channel 7
8	Voltage remote sense, high, Channel 8
9	Voltage remote sense, high, Channel 9
10	Voltage remote sense, high, Channel 10
11	Voltage remote sense, high, Channel 11
12	Voltage remote sense, high, Channel 12
13	Channel 13 (Passive HV) high
14	Not Used
15	Not Used
16	Fan interlock jumper
17	Not Used
18	Not Used
19*	Voltage remote sense, low, Channel 1
20*	Voltage remote sense, low, Channel 2
21*	Voltage remote sense, low, Channel 3
22*	Voltage remote sense, low, Channel 4
23*	Voltage remote sense, low, Channel 5
24*	Voltage remote sense, low, Channel 6
25*	Voltage remote sense, low, Channel 7
26*	Voltage remote sense, low, Channel 8
27*	Voltage remote sense, low, Channel 9
28*	Voltage remote sense, low, Channel 10
29*	Voltage remote sense, low, Channel 11
30*	Voltage remote sense, low, Channel 12
31	Channel 13 (passive HV) return
32	Not Used
33	Not Used
34	Fan interlock jumper
35	Voltage sense return common to all channels
36	Voltage sense return common to all channels

*Not currently used

P3 SENSE also provides interlock capability for both exhaust fans. When electrical connection is made between pin 16 and pin 34 of P3 SENSE, the exhaust fans are controlled by a thermal switch internal to the ULU cabinet. When these 2 pins are not connected, both exhaust fans will run continuously whenever the ULU is turned on.

NOTE

P3-16 and P3-34 must not be connected whenever one (or more) active load cell is programmed to 80% or more of its maximum power rating; i.e., whenever any high current cells are programmed for 96 watts (80% X 120W) or more, or whenever any medium or low current cell is programmed for 64 watts (80% X 80W) or more. With the cooling fans running continuously, peak temperature overstresses which might occur before the fans cycle on, will be avoided.

Initial Turn On

Before the power is applied to the ULU. verify that:

1. The 120-230 VAC switch on the rear panel is set to match the line voltage to be used.

2. The AC line fuse is the correct value (1 amp. std.) is intact and properly installed.

3. All rear panel cables are securely connected.

4. A Programming Plug-in module configured to program the ULU to test the power supplies in a specific instrument has been installed.

Operational Notes

1. When testing Tektronix 7912AD power supplies, do not chop high current levels.

2. **CAUTION** - Hazardous voltages are present when the ULU is operated with its side covers removed.

SECTION 3

THEORY OF OPERATION

Block Diagram Description

A simplified block diagram of the Universal Load Unit is shown in Fig. 3-1. The diagram illustrates as typical one of the twelve active cells connected to ULU controls and indicators.

When the output from a power supply under test has been connected to the rear panel connectors P1, P2 and P3, continuity can be established between its output and one or more of the active cells within the ULU via the CHANNEL SELECT switch. This thirteen position wafer switch connects ULU controls and output monitoring circuits to each of the twelve active cells. The thirteenth switch position connects one or two user selected, fixed resistors between ground and the power supply under test.

The active channels are divided into six groups of two by polarity and current handling capability as shown in Table 3-1. All cells are ground referenced.

Table 3-1

Channel	Maximum Voltage	Maximum Current	Maximum Power	Polarity
1, 2	50 V	24 A	120 W*	+
3, 4	100 V	10 A	80 W*	+
5, 6	150 V	2 A	80 W*	+
7, 8	50 V	24 A	120 W*	-
9, 10	100 V	10 A	80 W*	-
11, 12	150 V	2 A	80 W*	-
13	350 V		10 W	+

* or 500 watts total input power, all channels

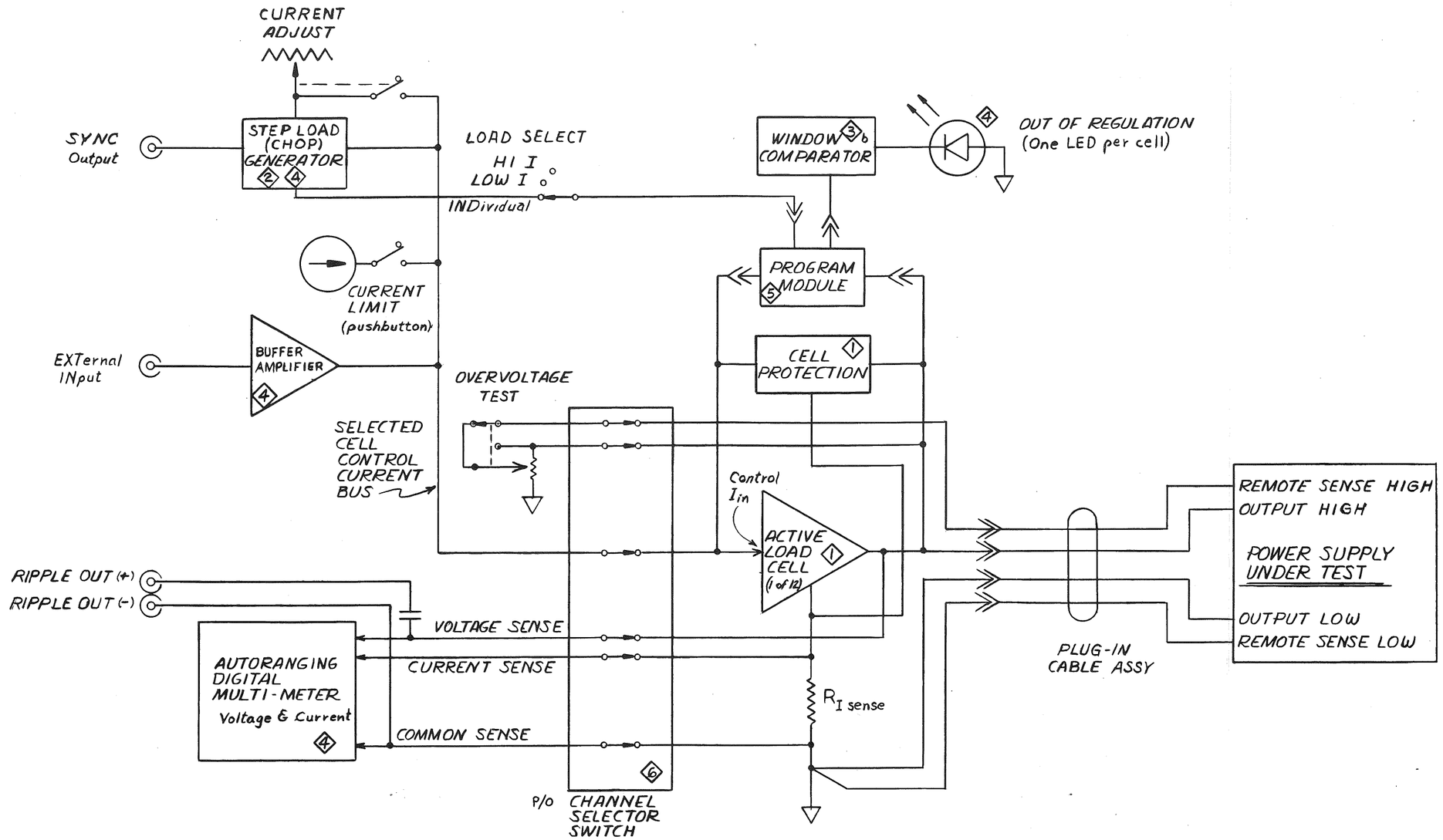


Figure 3-1. BLOCK DIAGRAM
UNIVERSAL LOAD UNIT

Outputs of the power supply under test are routed through rear panel connectors P1 and P2 to one of the inputs of an active load cell. Selected resistors in the Programming Plug-in Module determine the current fed to the other input of a cell's current amplifier. This current level can be altered by other ULU controls.

If the output voltage being tested deviates beyond predetermined limits, this condition is detected by a window comparator circuit and indicated by the illumination of the Out-Of-Regulation indicator (LED) for that load cell.

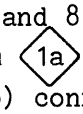
The current magnitude may be varied by applying a voltage level of up to plus or minus 10 volts dc to the front panel BNC connector EXT IN. (See EXTernal INput connector description in Section 2.)

Voltage or current from the power supply under test can be alternatively displayed on the digital multimeter. Power supply ripple is available for measurement at two front panel jacks RIPPLE OUT + and RIPPLE OUT -.

When the Step Load (Chop) Generator is activated in the individual chop mode, the control current input to the selected load cell is toggled between its preset value (set by the programming plug-in selectable resistors) and that value induced by the setting of the CURRENT ADJUST control. The toggling rate, 96 Hz is available at the front panel SYNC output BNC connector and may be used to trigger the time base of an external oscilloscope. Alternatively, the chop-all mode causes all active cells to toggle between their programmed min-max values.

CIRCUIT DESCRIPTION

High Current Cells

Each of the four high current cells (1 and 2 positive, 7 and 8 negative) have identically structured circuits as illustrated on diagram  . A typical high current cell includes a current amplifier (op-amp) connected to drive a voltage follower transistor that provides the base drive for three parallel sets of current gain transistor stages. The programming current (Ip) develops a control voltage across a 249-ohm resistor on the positive input of the op-amp. The average voltage developed across three (four terminal, .03 ohm) Kelvin sense resistors is fed back to the inverting input of the op-amp.

A second operational amplifier connected as a comparator monitors both current through the cell and voltage across it. This comparator then provides a voltage derated current limit. (This derating is a two segment approximation to a constant power curve with break points at 5.1 and 16 volts.)

A 30 amp fuse and SCR crowbar provide over-voltage protection with a nominal trip point of 57 volts. The same fuse and a diode (CR103 typical) provide circuit protection in the event of polarity reversal.

Medium Current Cells

As illustrated on diagram  , each of the four medium current cells are of similar construction with two positive channels (3 and 4) and two negative (9 and 10). The input stage for a typical medium current cell is a FET input operational amplifier. This op-amp drives a set of series connected darlington transistors. The series connection allows the applied voltage to be divided across the transistors. Three diodes in series with a 6.2K-ohm divider resistor allow the medium current cells to operate at a lower voltage (approximately 4.5 volts). The programming current (Ip) develops a control voltage across a 100-ohm resistor (R317 typical) on the positive input of the op-amp. The voltage developed across a four terminal, .01 ohm, Kelvin sense resistor is fed back to the inverting input of the input op-amp.

Connected as a comparator, a second op-amp provides a voltage-current derated limit. The derating curve is a two segment approximation to a constant power curve with break points at 10 and 30 volts.

The over voltage SCR crowbar will trip at approximately 111 volts and blow the 15 amp fuse. Reverse polarity protection is provided by a diode to ground at one fuse terminal (CR303 typical).

Low Current Cells

As shown on diagram 

, the four low current cells (5 and 6 positive, 11 and 12 negative) are similar to the medium current cells. An input operational amplifier drives two series connected, power darlington, monolithic transistor sets. The series connection serves to divide the applied voltage across both transistor sets. A zener diode in series with a 15K-ohm resistor across the transistor sets allow the low current cells to operate at approximately 4.5 volts. Programming current (Ip) develops a control voltage across the 200-ohm input resistor (R512 typical) on the positive input of the op-amp. The voltage developed across a (four terminal, .1 ohm) Kelvin sense resistor is routed to the inverting input of the op-amp.

A second operational amplifier functions as a protective comparator to provide a voltage/current derating limit. Due to the relatively small maximum current range of the low current channels (0.2 to 2.0 amps) only linear derating of current with voltage is used. The protection comparator senses only voltages above 51 volts.

The over-voltage SCR crowbar will trip at 161 volts nominal and open the 5 amp fuse. Reverse polarity protection is given by the fuse and an adjacent diode (CR504 typical).

Digital Multimeter

The Digital Multimeter function diagrammed on 

can be divided into four sub-circuits: an auto-ranging attenuator, analog-to-digital converter, the display circuit and a crystal controlled oscillator.

Auto-Ranging Attenuator

Input analog signals to be displayed are input to resistor network R4004 from harmonica connector P4002 via S4001D. The relay contacts of K4002, K4003, K4004 and K4005 are connected to the segments of R4004 to form an input attenuator.

Once during each measurement cycle, U4003 (part of the A-to-D converter) outputs an under range or an over range signal from pin 13. An under range condition is indicated by a pulse from pin 13 during the D1 strobe interval. An over range condition is indicated by a pulse from pin 13 during the D2 or D3 strobe interval (or during both intervals). The under range condition is detected by U4009A while over range is detected by U4009C via Q4005/Q4006. Outputs from these detectors drive an R-S flip-flop U4009B/D and are also OR'ed by U4011A to generate a clock signal for range counter U4012. Clocking pulses for U4012 are fed to Decade Decoder U4013. Outputs from U4013 drive four relay coils (K4002 through K4005) via four corresponding buffer amplifiers to auto-range the input attenuator.

Analog-to-Digital Converter

The analog-to-digital conversion process of input signals is completed by a four and one-half digit converter consisting of IC's U4001 and U4003. U4001 contains the analog circuitry including the switched input buffer (pins 15 and 1) integrator (pins 9 and 11) comparator (pins 11 and 14) and auto zero buffer and filter (pins 12 and 13). U4003 provides the digital control circuitry for U4001. U4003 also provides digit strobe pulses from pins 1, 2, 13, 16, 17 and 18 and Binary Coded Decimal data to four pins on U4004, the Seven Segment Decoder IC.

DMM Display

The DMM Display consists of four, seven segment LED display units, each with its own decimal point indicator, and one +1 LED display. The LED display is driven by an X-Y matrix. X information is provided by seven segment lines from the BCD decoder U4004 and one decimal point line from Q4014. Q4014 is turned on by U4021 and a logic decoder circuit. Y information is provided on six lines from U4003 consisting of five digit strobes and the sign bit strobe. These six lines are sequentially pulsed in one of five strobe intervals with S and D5 (U4003-13 and -16) concurrent.

Crystal Controlled Oscillator

IC circuits U4002B, C and D operate in conjunction with quartz crystal unit Y4001 and associated circuit components to form a crystal controlled oscillator. Its operating frequency, 2.4576 MHz is applied to pin 4 of Clock IC U4008. The ÷10 output of U4008 (pins 3 and 12) is level shifted by Q4004 and applied as a clock input to U4003-8.

Step Generator

The Step (Chop) Generator circuit illustrated on diagram ◇4◇ generates a low frequency square wave. In Chop mode, this square wave is used to toggle the current of the power supply under test (see CHOP/SWITCH Control description in Section 1). The Step Generator is operated at a sub-harmonic of the DMM clock to ensure that generator induced transients do not cause false DMM indications.

The divide by 100 output of U4008 is transformer coupled to the base of Q4024 which in turn drives decade counter U4019. A 96 Hz square wave output from U4019 drives two separate transistor amplifier circuits; one directly and one via the Chop Individual/Chop All jumper (P2119 on Lower Panel board ◇2◇. The first amplifier circuit, consisting of buffer/driver stages Q4017 and Q4020, provides an output to the front panel BNC connector SYNC. The second circuit, consisting of Q4018 and Q4019, drives the gate of DMOS switch Q4021 with a +12V to -12V square wave. Q4021 is paralled by S4067, the CURRENT ADJUST switch. Note that the $+5V_B$ supply to U4019 and the buffer/driver circuit is applied only when the CHOP/SWITCH control is set to CHOP (refer to diagram ◇2◇).

External Input Amplifier

Electrical signals applied to the front panel jack EXT IN are routed to the External Input (buffer) amplifier. Diagrammed on ◇4◇, this 1 megohm input, transconductance amplifier comprises U4020, Q4022, Q4023 and associated components. Both Q4022 and Q4023 are connected to operate as class B amplifiers. A signal applied to R4071 causes a current flow into virtual ground at the inverting input of operational amplifier U4024-2. The op-amp then forces a voltage swing across emitter R4077 or R4079 as determined by input signal polarity. This voltage swing causes a current in the appropriate transistor which is routed to the input of a load cell via the CHANNEL SELECT switch.

Program Board

The program board shown on diagram ⟨5⟩ includes thirteen separate circuits, one for each of twelve active cells and one passive circuit. Each active cell includes six programming resistors (R_{FL}, R_{FH}, R_{PL}, R_{PH}, R_{DES}, and R_{COMP}) that are selected to facilitate operational tests for a specific power supply.

R_{FH} and R_{FL} designate the resistors that are installed between the input voltage and the input to a typical cell (where R_{FH} equals the high current and R_{FL} equals the low current resistor). These feed a control current into the cell that is proportional to the applied voltage. The cell then draws a current proportional to the applied voltage and acts as a power resistor.

R_{PH} and R_{PL} designate the emitter resistors for two switched constant current source transistors. When conducting, each transistor causes 10 volts to appear across its emitter resistor. Resistor values for R_{PH} and R_{PL} are chosen to provide a constant current load for a specific power supply (where R_{PH} equals the high current and R_{PL} equals the low current resistor).

R_{COMP} (comparison) designates a resistor in each cell that supplies the upper half of a voltage divider. The output of this divider is compared to a standard to determine if the applied voltage is within prescribed limits.

R_{DES} (desensitizing) designates a resistor in each active cell that may be used to desensitize or broaden the comparator circuit "window".

Power Supplies

The power supplies used in the Universal Load Unit are shown on schematic diagrams ⟨3a⟩ and ⟨3b⟩. Input power is supplied through ac line filter assembly LF3001, the line fuse F3001, the POWER SWITCH S3001 and the 110/220 VAC SELECTOR switch to the primaries of power transformer T3001. T3001 includes three secondary windings that provide stepped down voltage to three rectifier circuits yielding 6 separate voltages. Floating supplies $+12V_A$, $-12V_A$ and $+5V_A$ are used exclusively for the front panel Digital Multimeter. The B supplies ($+12V_B$, $-12V_B$ and $+5V_B$) are distributed throughout the ULU.

CR3002 developes +21 VDC and -21 VDC that are regulated to become the $+12V_A$ and the $-12V_A$ output to the DMM Voltage regulator U3004 sets the base voltage for pass transistor Q3005 to regulate the $+12V_A$ supply. The $-12V_A$ supply is regulated by U3005 operating in conjunction with Q3006, Q3007 and pass transistor Q3008. R3018 is used to adjust the output voltage for both the $+12V_A$ and $-12V_A$ supplies.

CR3003 and CR3004 develop a dc voltage that is regulated by U3006 to become the $+5V_A$ supply. Neither the $+5V_A$ or $-5V_B$ supplies have adjustment potentiometers.

CR3001 developes +21 VDC and -21 VDC that are regulated to become the $-12V_B$, $+5V_B$ and $-12V_B$ supplies. Voltage regulator U3003 sets the base voltage for pass transistor Q3001 to regulate the $+12V_B$ supply. The $-12V_B$ supply is regulated by U3003 operating in conjunction with Q3002, Q3003 and pass transistor Q3004. R3005 is used to adjust the $+12V_B$ supply. R3010 is used to adjust the $-12V_B$ supply.

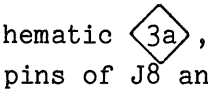
An adjustment procedure for ULU power supplies is included in Section 4, Calibration.

Power Supply Fuses

The ULU power supply includes five, 1 amp fuses that are accessable with the side covers removed. Fuse numbers and associated supplies are as follows:

F3002 protects the	$+12V_B$ and $+5V_B$ supplies
F3003	$-12V_B$ supply
F3004	$+12V_A$ supply
F3005	$-5V_A$ supply
F3006	$-12V_A$ supply

Exhaust Fans

As shown on schematic 

, AC power to both exhaust fans FM3001 and FM3002 is via four pins of J8 and through two sets of contacts in K3002. The rear panel connector P3 SENSE also provides interlock capability for both fans. When a jumper is installed between P3-16 and P3-34, the current path for the coil of K3002 is completed to thermal switch S3002. When P3-16 and -34 are not connected, the exhaust fans will run continuously whenever AC power is applied to the Universal Load Unit. (See note preceding Table 2-3 in Section 2.)

SECTION 4

CALIBRATION TEST & PROCEDURE

The following procedure consists of two self-contained parts. In the first one, a verification test is performed to see if the Universal Load Unit (U.L.U.) is in calibration. The second part is an actual calibration procedure used to align the U.L.U.

REQUIRED EQUIPMENT LIST

The following equipment is required to calibrate the Universal Load Unit or to verify that it is operational without performing a full calibration.

Description	Suggestion
Digital Multimeter (DMM) Voltage accuracy: 5 1/2 digit - 0.02%	Fluke 3875A, or HP 3490A, or equivalent
Digital Multimeter (DMM) Current accuracy: 4 1/2 digit - 0.3%	TEK DM501A or DM502, or equivalent
Variable regulated DC power supply Must float and produce up to 20 volts at 1 ampere.	TEK PS503A, or equivalent
32 Pin Female Connector Must fit P1 NEGATIVE and P2 POSITIVE rear panel connectors	TEK 131-0097-00 (Amphenol, 26-190-32)
36 Pin Male Connector - Optional Must fit P3 SENSE rear panel connector improved signal access	TEK 131-0293-00 (Amphenol, 57-30360)

CAUTION

Caution should be used wherever line potentials are present. 120 VAC is present at the power switch and line fuse, the cooling fans, the power transformer primary, and the relay for turning the fans on.

VERIFICATION PROCEDURE

Introduction

The following procedure is designed to verify the overall operability and calibration of the Universal Load Unit (U.L.U.). If this test fails, the Calibration Procedures which follow should be performed in the order in which they are given.

Procedure

1. **Set Up:** The test equipment shown in the Verification Test Set Up diagram, Figure 4-1.

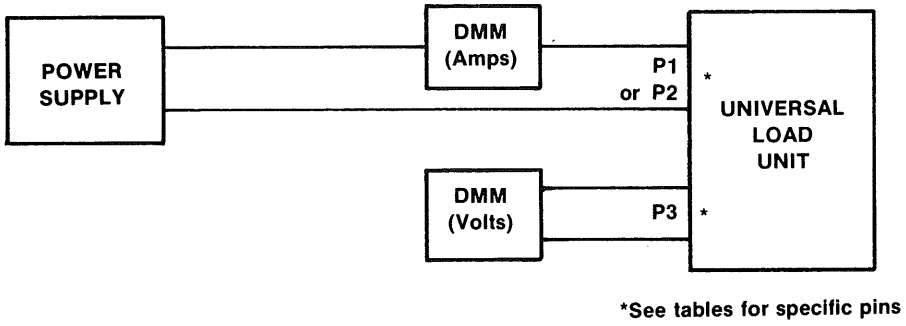


Fig. 4-1. Verification Test Set-up

2. **Refer To:** Table 4-1, Verification Test, for the Jack and Pin numbers of the inputs associated with each of the CHANNEL SELECT positions.

Table 4-1, Verification Test

Channel	Apply Floating 10 VDC Between: (+)	(-)	Measure Voltage*	I Difference** (@ 1 amp only)
1	P2-3	P2-19	P3-1	-0.02 to 0.130A
2	P2-8	P2-24	P3-2	-0.02 to 0.130A
3	P2-11	P2-27	P3-3	-0.02 to 0.035A
4	P2-13	P2-29	P3-4	-0.02 to +0.035A
5	P2-15	P2-31	P3-5	-0.015 to +0.015A
6	P2-16	P2-32	P3-6	-0.015 to +0.015A
7	P1-19	P1-3	P3-7	-0.02 to +0.130A
8	P1-24	P1-8	P3-8	-0.02 to 0.130A
9	P1-27	P1-11	P3-9	-0.02 to 0.035A
10	P1-29	P1-13	P3-10	-0.02 to 0.035A
11	P1-31	P1-15	P3-11	-0.015 to +0.015A
12	P1-32	P1-16	P3-12	-0.015 to +0.015A
13	P3-13	P3-31	P3-13	(Not applicable)

*With respect to P3-35 as a common return connection.

**I Difference = I Int. DMM - I Ext. DMM $\leq$ Above Tabulated Values.

NOTE: V Difference = $V_{Int.DMM} - V_{Ext.DMM} \leq \pm 0.012$ VDC for all channels.

3. **Connect:** A female 32 pin connector (Amphenol 26-190-32, Tek 131-0097-00) to the indicated Jacks to make it easier to connect and disconnect the test leads. Also connect a male 36 pin connector (Amphenol 57-30360, Tek 131-0293-00) to the P3 SENSE connector to facilitate connecting test leads.

4. **Set:** The Universal Load Unit controls as follows:
   230V/115V switch to the appropriate position,
   OVER VOLTAGE TEST control CCW, in OFF detent,
   CHOP/SWITCH control in SWITCH (down) position,
   CURRENT ADJUST push-pull switch in,
   both COARSE and FINE controls set at mid rotation (i.e., both markings at the top of rotation), and the Power Switch ON.

Note: Remove any Program Plug-in which may be installed. The positions of the HI/LOW/IND and MAX/MIN controls are of no consequence.

5. **Turn On:** The power supply and adjust it for 10.0±0.1 VDC as measured by the external DMM.

6. **(Before each measurement) Pull Out:** The Current Adjust push pull switch.
   Adjust: The CURRENT ADJUST control for 1.00±0.05 Amps as measured on the external (series) DMM.

7. **(For each measurement) Compare:** The readings on the U.L.U. Panel DMM to those on the external meters, in both the "Voltage" and "Current" positions of the VOLTAGE/CURRENT switch, for positions 1 thru 12 of the CHANNEL SELECT switch. The U.L.U. Panel Meter should agree with the external (voltage) DMM reading to within ±0.012 VDC. The current readings should be the values indicated in the Verification Test Table.

8. **(After each measurement) Reset:** The external power supply to OFF, (before it is disconnected and moved to the next channel), the CURRENT ADJUST push-pull switch to its "in" position, and the COARSE and FINE controls both to their mid-rotation position.

CALIBRATION PROCEDURE

1. Power Supply

Set Up

1. **Remove:** The U.L.U.'s side covers and any plug-in.

2. **Set:** The LINE SELECT switch (on the back) to the appropriate position and the POWER switch to the "On" position.

3. **Use:** Pin probes to reach the signals called out in Table 4-2, Power Supply Calibration, entering from the rear of the specified plugs and pins.
   Refer: To Figure 4-2 for the locations of the plugs and pots which are called out in Table 4-2.

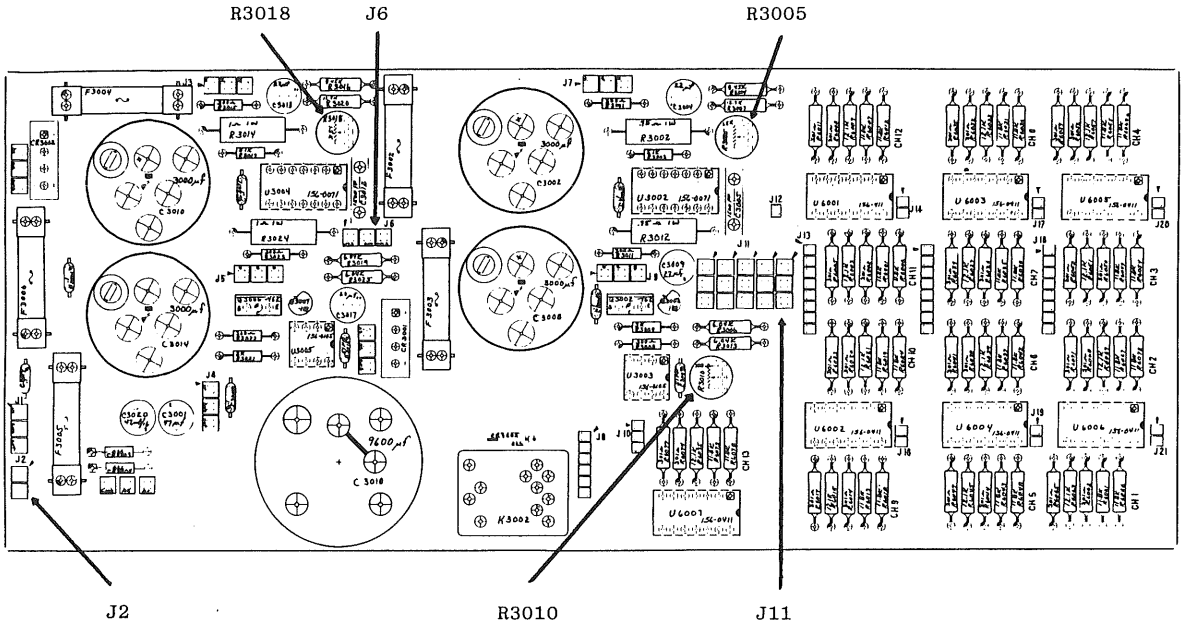


Fig. 4-2. Power Supply Board.

Table 4-2, Power Supply Calibration

On Supply A:

Measure between	**Required Voltage**	**Adjust**
P6-3 and P6-2	+11.9 to +12.1 VDC	R3018
P6-1 and P6-2	-11.9 to -12.1 VDC	**Note:** Compromise to attain R3018 both w/ R3018
P2-1 and P6-2	+4.8 to +5.2 VDC	

On Supply B:

Measure	**Required Voltage**	**Adjust**
P11-1 and P11-2	+12.000VDC	R3005
P11-3 and P11-2	-12.000 VDC	R3010
P2-2 and P11-2	+4.8 to +5.2 VDC	

2. Digital Multimeter Board

Calibration procedure

1. **Set:** The VOLTAGE/CURRENT switch to the "Voltage" position, the CHOP/SWITCH switch to the "Switch" position, and the CHANNEL SELECT switch to position "13".
   Verify: That the "Voltage" LED is illuminated.

2. **Loosen:** The four screws (through the sides) which hold the U.L.U. DMM Assembly in place. (The side covers, which must be removed first to gain access, were taken off as part of the Power Supply Calibration Procedure.)
   Tilt: The U.L.U. DMM Assembly out and down to allow access to the following measurement points.
   Refer: To Figure 4-3 for the locations of the following measurement and adjustment points.

3. **Short:** P4002-1 and P4002-4 together firmly.
   Adjust: R4022 (V_{offset}) for a reading of 0.0000 VDC on the panel meter.

4. **Remove:** The short between P4002-1 and P4002-4.
   Apply: +1.70±0.01 VDC across P4002-1(+) and P4002-4.
   Adjust: R4016 to make the U.L.U. DMM agree with the external DMM to within ±0.0001 VDC.

5. **Apply:** -1.70±0.001 VDC to P4002-1 and P4002-4(common).
   Verify: That the U.L.U. meter agrees with the external DMM to within ±0.0002 VDC.
   Readjust (if necessary): R4022 for a best compromise between this value and the requirement of Step 3 ±0.0002 VDC.

6. **Apply:** 17 VDC, and 20.00 VDC to the input.
   Verify: That the decimal point shifts to the right as it should, and that the U.L.U. DMM and the external DMM agree within 0.1%.

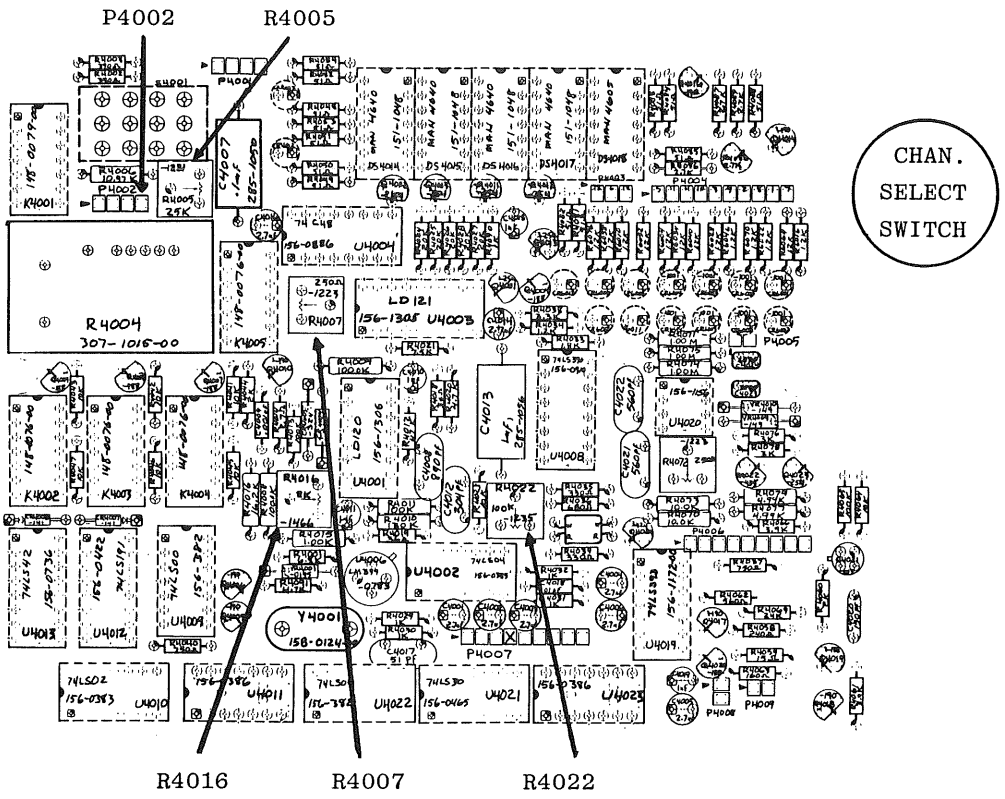


Fig. 4-3. Digital Multimeter Board.

7. **Set:** The VOLTAGE/CURRENT switch to the "Current" position.
   Short: P4002-2 and P4002-3 together firmly.
   Adjust: R4005 (I_{offset}) for a reading of 0.0000 ADC on the U.L.U. DMM.

8. **Apply:** 0.170±0.001 VDC across P4002-2 (+) and P4002-3.
   Adjust: R4007 (I_{gain}) until the U.L.U. DMM indicates a voltage 10x the input signal as measured on the external DMM ±0.001 VDC.

9. **Apply:** -.17 ± 0.01 VDC across P4002-2 and P4002-3(+).
   Adjust: R4005 (I_{offset}) for a best compromise between 10x agreement between the U.L.U. DMM and the external DMM ±0.002 VDC and the requirement of step 7.

10. **Apply:** Successively, 1.7 VDC, 17 VDC and 20.0+ VDC across P4002-2 and P4002-3.
    Verify: That the decimal point shifts to the right as it should and that the U.L.U. DMM and the external DMM agree to within 0.1%.

11. **Return:** The U.L.U. DMM Panel Assembly to its installed position, reinserting and tightening the four screws.

External Input -

1. **Verify:** That the CHANNEL SELECT Switch is in position "13".
   Set: The external DMM to the 2 mA scale.
   Measure: Between the front rotor of the 10th wafer of the CHANNEL SELECT switch (see Fig. 4-4) and chassis ground.
   Adjust: R4072 for 0.000mA on the external DMM.

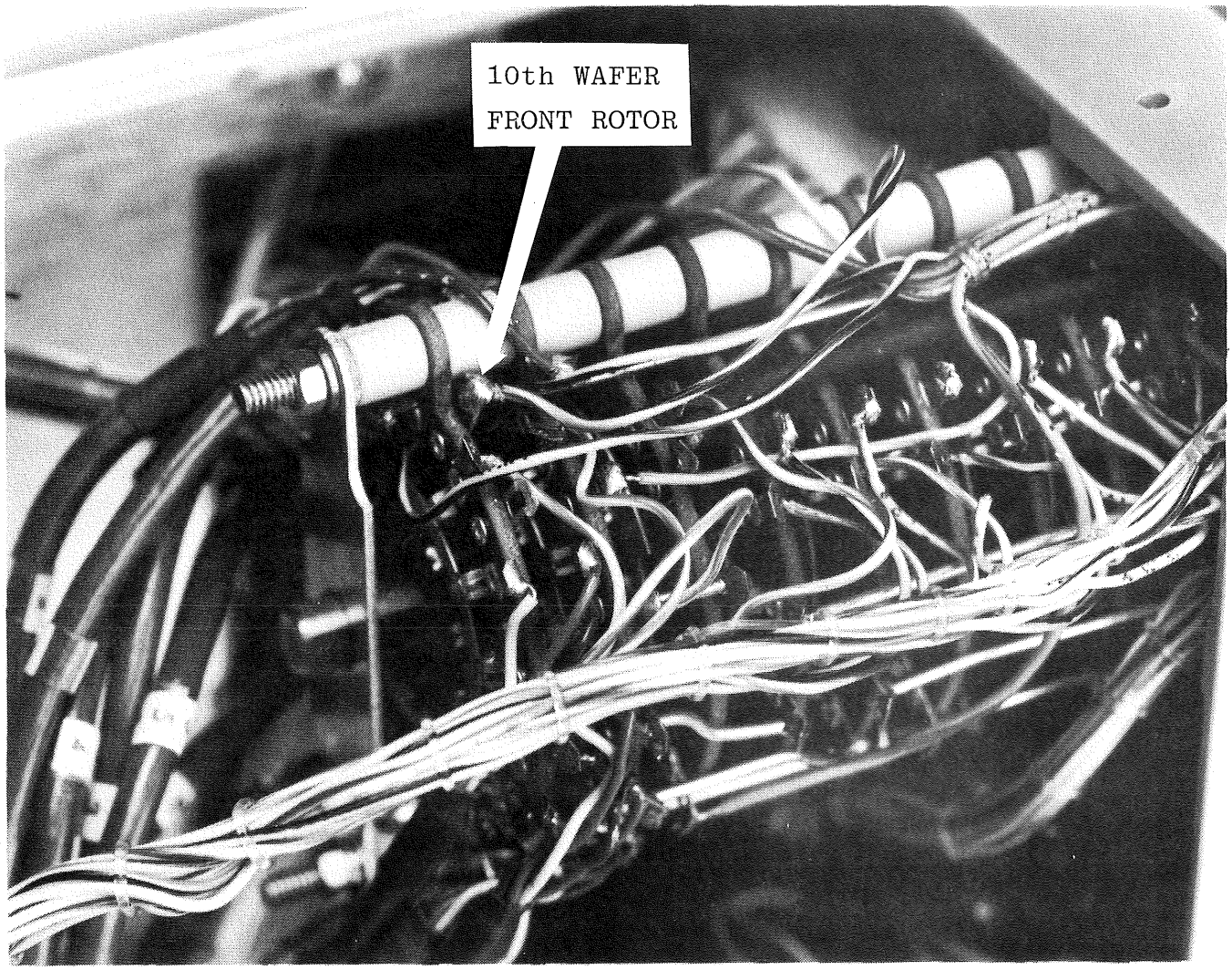


Fig. 4-4. Channel Select Switch.

2. **Apply:** +10.00±0.01 VDC to the EXT. IN center conductor. (with respect to chassis ground)
   Measure: Between chassis ground and the front rotor of the 10th wafer of the CHANNEL SELECT switch (see Fig. 4-4).
   Check: The meter for an indication of between +1.92 mA and +2.08 mA.

3. **Apply:** -10.00±0.01 VDC to the EXT. IN center conductor.
   Measure: Between chassis ground and the front rotor of the 10th wafer of the CHANNEL SELECT switch (see Fig. 4-4).
   Check: The meter for an indication of between -1.92 mA and -2.08 mA.

3. Channel Offset Null Adjustments

The adjustment procedure which follows is the same for all cells:

1. **Set:** The VOLTAGE/CURRENT switch to the "Current" position and the CHOP/SWITCH switch to the "Switch" position.
   Apply: No external voltage or signal.

2. **(Before each adjustment) Switch:** The CHANNEL SELECT switch to the next position (of positions 1 through 12).

3. **(For each position) Use:** The Null Offset Pot indicated in Figure 4-5 for the channel being adjusted.

4. **(For each position) Adjust:** The indicated pot for a U.L.U. DMM reading of 0.000 ± 2 counts in the least significant digit.
   Note: The high current positions (1,2,7,8) may be expected to "hunt" or "jitter" within this tolerance.

5. **(After adjusting every channel) Verify:** The results of these adjustments by performing the Verification Test at the beginning of this Section.

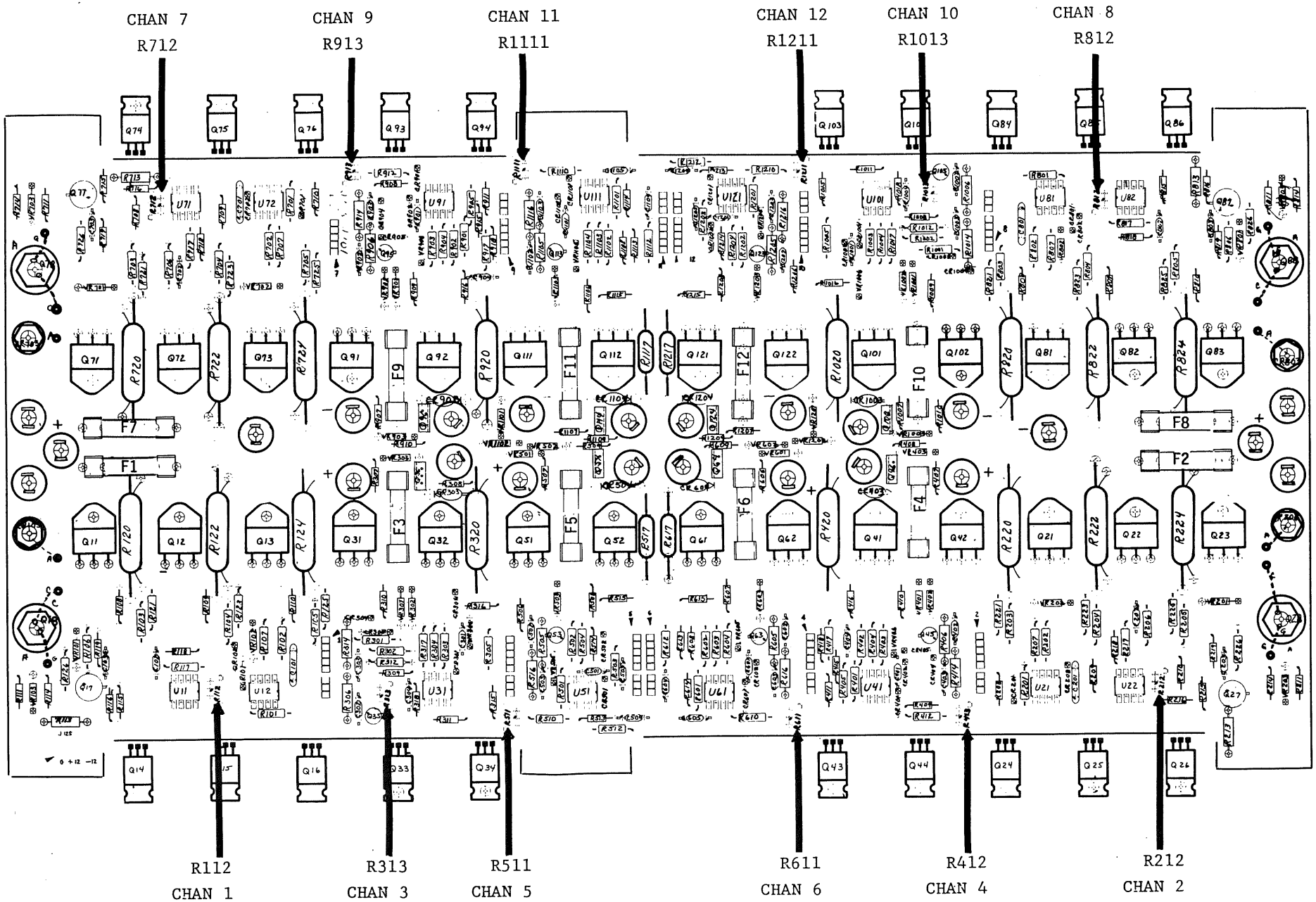


Figure 4-5. Main Board Adjustment Locations

SECTION 5

REPLACEABLE PARTS

PARTS ORDERING INFORMATION

Replacement parts are available from or through your local Tektronix, Inc. Field Office or representative.

Changes to Tektronix instruments are sometimes made to accommodate improved components as they become available, and to give you the benefit of the latest circuit improvements developed in our engineering department. It is therefore important, when ordering parts, to include the following information in your order: Part number, instrument type or number, serial number, and modification number if applicable.

If a part you have ordered has been replaced with a new or improved part, your local Tektronix, Inc. Field Office or representative will contact you concerning any change in part number.

Change information, if any, is located at the rear of this manual.

SPECIAL NOTES AND SYMBOLS

X000	Part first added at this serial number
00X	Part removed after this serial number

ITEM NAME

In the Parts List, an Item Name is separated from the description by a comma . Because of space limitations, an Item Name may sometimes appear as incomplete. For further Item Name identification, the U.S. Federal Cataloging Handbook H6-1 can be utilized where possible.

ABBREVIATIONS

ACTR	ACTUATOR	PLSTC	PLASTIC
ASSY	ASSEMBLY	QTZ	QUARTZ
CAP	CAPACITOR	RECP	RECEPTACLE
CER	CERAMIC	RES	RESISTOR
CKT	CIRCUIT	RF	RADIO FREQUENCY
COMP	COMPOSITION	SEL	SELECTED
CONN	CONNECTOR	SEMICOND	SEMICONDUCTOR
ELCTLT	ELECTROLYTIC	SENS	SENSITIVE
ELEC	ELECTRICAL	VAR	VARIABLE
INCAND	INCANDESCENT	WW	WIREWOUND
LED	LIGHT EMITTING DIODE	XFMR	TRANSFORMER
NONWIR	NON WIREWOUND	XTAL	CRYSTAL

ELECTRICAL PARTS LIST

INSTRUMENT CHASSIS ASSEMBLY
Part of 067-0883-99

Circuit No.	Tektronix Part No.	Description
	650-0138-00	ECB, Main Board Assembly
	670-6048-00	ECB, Digital Multimeter
	670-6050-00	ECB, Lower Panel
	670-6051-00	ECB, Interconnect
	670-6049-00	ECB, Power Supply
	179-2718-00	CABLE, Interconnect
	179-2719-00	CABLE, Connector No. 1
	179-2720-00	CABLE, Connector No. 2
	179-2721-00	CABLE, Negative Metering
	179-2722-00	CABLE, Positive Metering
	179-2723-00	CABLE, Negative Program
	179-2724-00	CABLE, Positive Program
	179-2725-00	CABLE, AC
	179-2726-00	CABLE, Power
J1,J2	131-0096-00	CONNECTOR, 32 Pin, Male
J3	131-0294-00	CONNECTOR, 36 Pin, Male
Q3001,3004 3005,3008	151-0373-00	TRANSISTOR, MJE2901, Power, PNP, Si.
S7002	260-1960-00	SWITCH, Rotary, **CHANNEL SELECT**
T3001	120-1257-00	TRANSFORMER, AC Power
U3001,3006	156-0277-00	IC, uA7805UC, Linear

MECHANICAL PARTS LIST

INSTRUMENT CHASSIS ASSEMBLY
Part of 067-0883-99

Tektronix Part No.	Quantity	Description
351-0295-00	1	GUIDE, Slide
334-1378-00	1	MARKER, Ident.
367-0108-00	1	HANDLE, Carrying
200-0728-00	2	COVER, Handle End
337-2612-00	1	SHIELD, Elec, HV (Rotary SW)
366-1124-00	1	KNOB (**CHANNEL SELECT**)
377-0119-00	4	INSERT, Foot
358-0215-00	1	GROMMET, Plastic, Black
129-0222-00	2	SPACER, Post
342-0203-00	6	INSULATOR, Mica
163-0589-00	A/R	THERMOFIT
386-3657-01	1	SUPPORT, Plug-in
343-0003-00	2	CLAMP, Cable
343-0006-00	1	CLAMP, Cable
343-0008-00	2	CLAMP, Cable
343-0009-00	2	CLAMP, Cable
343-0013-00	2	CLAMP, Cable
343-0049-00	2	CLAMP, Cable
343-0056-00	2	CLAMP, Cable
352-0161-00	1	HOLDER, 3 Wire, 0.1 Spacing
352-0198-00	1	HOLDER, 2 Wire, 0.15 Spacing
210-0201-00	1	TERMINAL, Lug, 0.12 ID
210-0205-00	1	TERMINAL, Lug, 4-40 x 0.42
210-0241-00	2	TERMINAL, Lug, 0.515 ID
211-0062-00	2	SCREW, 2-56 x 0.312, Panhead
211-0159-00	2	SCREW, 2-56 x 0.375, Panhead
211-0008-00	14	SCREW, 4-40 x 0.250, Panhead
212-0628-00	4	SCREW, 4-40 x 0.250, Flathead
211-0097-00	8	SCREW, 4-40 x 0.312, Panhead
211-0016-00	2	SCREW, 4-40 x 0.625, Panhead
211-0502-00	6	SCREW, 6-32 x 0.188, Flathead
211-0541-00	8	SCREW, 6-32 x 0.250, Flathead
211-0504-00	17	SCREW, 6-32 x 0.250, Panhead
211-0507-00	14	SCREW, 6-32 x 0.312, Panhead

MECHANICAL PARTS LIST

INSTRUMENT CHASSIS ASSEMBLY (Cont.)
Part of 067-0883-99

Tektronix Part No.	Quantity	Description
211-0538-00	23	SCREW, 6-32 x 0.312, Flathead
211-0510-00	2	SCREW, 6-32 x 0.375, Panhead
211-0511-00	2	SCREW, 6-32 x 0.500, Panhead
211-0512-00	2	SCREW, 6-32 x 0.500, Flathead
211-0522-00	1	SCREW, 6-32 x 0.625, Flathead
211-0532-00	8	SCREW, 6-32 x 0.750, Fillisterhead
212-0023-00	2	SCREW, 8-32 x 0.375, Flathead
210-0405-00	2	NUT, 2-56
210-0586-00	4	NUT, 4-40, Keps
210-0457-00	17	NUT, 6-32, Keps
210-0590-00	1	NUT, 6-32
210-0001-00	2	WASHER, Intl
210-0054-00	13	WASHER, Split
210-0840-00	1	WASHER, Flat
210-0863-00	9	WASHER, D
210-0994-00	6	WASHER, Flat
210-1122-00	4	WASHER, Concave
210-1178-00	2	WASHER, Shld

ELECTRICAL PARTS LIST

FRONT PANEL ASSEMBLY
Part of 667-0883-00

Circuit No.	Tektronix Part No.	Description
	670-6048-00	ECB, Digital Multimeter
	670-6050-00	ECB, Lower Panel
J4001, 4002, 4003, 4004	131-0106-02	CONNECTOR, BNC, [EXT IN ±10V, SYNC, RIPPLE OUT (+), RIPPLE OUT (-)]
R602	311-2070-00	VARIABLE RESISTOR, 75k, 2W, 10%, Linear **OVER VOLTAGE TEST**
R4067	311-2053-00	VARIABLE RESISTOR, Dual (w/switch), 5k, 1/2W, 20%, Linear, **CURRENT ADJUST**
R4068	315-0123-00	RESISTOR, 12k, 1/4W, 5%
R4080	315-0154-00	RESISTOR, 150k, 1/4W, 5%
R601	321-0097-00	RESISTOR, 100 ohm, 1/8W, 1%
S4010	260-0247-00	SWITCH, SPST, Push, **CURRENT LIMIT**

MECHANICAL PARTS LIST

FRONT PANEL ASSEMBLY
Part of 667-0883-00

Tektronix Part No.	Quantity	Description
333-2526-00	1	PANEL, Front, Top
333-2525-00	1	PANEL, Front, Lower
386-4107-00	1	SUB-PANEL, Front, Top
386-4106-00	1	SUB-PANEL, Front, Lower
331-0314-00	1	WINDOW, Readout
426-0916-00	1	FRAME, Readout Window
366-1077-00	1	KNOB, **CURRENT ADJUST**, Outer
366-1173-00	1	KNOB, **CURRENT ADJUST**, Inner
366-1189-00	1	KNOB, **OVER VOLTAGE TEST**
211-0022-00	6	SCREW, 2-56 x 0.188, Panhead
211-0159-00	2	SCREW, 2-56 x 0.375, Panhead
211-0008-00	4	SCREW, 4-40 x 0.250, Panhead
211-0101-00	4	SCREW, 4-40 x 0.250, Flathead
210-0583-00	3	NUT, 6-32
220-0449-00	4	NUT, Sleeve, 4-40
210-0046-00	1	WASHER, Lock, 0.261 ID
210-0905-00	4	WASHER, Flat, 0.256 ID
210-0940-00	17	WASHER, Flat, 0.25 ID
210-0255-00	4	TERMINAL, Lug, 0.391 ID
210-0269-00	1	TERMINAL, Lug, 0.257 ID

ELECTRICAL PARTS LIST

REAR PANEL ASSEMBLY
Part of 667-0883-00

Circuit No.	Tektronix Part No.	Description
F3001	159-0074-00	FUSE, 1.0 Amp/250V, 0.35 sec
FM3001, 3002	119-1024-00	FAN, 115 CFM, 115V, 18W
LF3001	119-0389-00	FILTER/RCPTL, RFI, 60Hz, 3A
S3001	260-1842-00	SWITCH, Rocker, DPST, 16A, 250 VAC, **POWER SWITCH**
S3003	260-1780-00	SWITCH, Slide, DPDT, 3A, **125V/250V**
W	179-2725-00	WIRING HARNESS, AC Power

MECHANICAL PARTS LIST

REAR PANEL ASSEMBLY
Part of 067-0883-99

Tektronix Part No.	Quantity	Description
200-2222-00	1	GUARD, Fan
441-1469-00	1	CHASSIS, Calib. Fix., Lower Fan
441-1470-00	1	CHASSIS, Calib. Fix., Upper Fan
334-3379-01	1	LABEL, GND Marker
204-0833-00	1	HOLDER, Fuse
210-0202-00	1	LUG, Solder
200-2264-00	1	COVER, Fuse
200-0237-03	1	COVER, Fuse
200-1788-00	1	COVER, Filter
200-1903-00	1	COVER, Power Switch
200-2222-00	1	COVER, Fan Guard
211-0008-00	2	SCREW, 4-40 x 0.250, Panhead
211-0012-00	2	SCREW, 4-40 x 0.375, Panhead
211-0510-00	1	SCREW, 6-32 x 0.375, Panhead
211-0514-00	1	SCREW, 6-32 x 0.750, Panhead
210-0586-00	1	NUT, Keps, 4-40
210-0407-00	1	NUT, Keps, 6-32
210-0457-00	1	NUT, Keps, 6-32
210-1039-00	1	WASHER, Lock, 0.521 ID

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD ASSEMBLY
650-0138-00

Circuit No.	Tektronix Part No.	Description
	670-6052-00	ECB, Main (Complete)
S3002	260-0678-00	SWITCH, Thermal
Q11,12,13,21 22,23,91, 92,101,102	151-0616-00	TRANSISTOR, TIP36A, Power, PNP, Si.
Q14,15,16, 24,25,26, 33,34,43, 44	151-0426-00	TRANSISTOR, D44H11, Power, NPN, Si.
Q31,32,41, 42,71,72, 73,81,82, 83	151-0477-00	TRANSISTOR, TIP35A, Power, NPN, Si.
Q51,52,61 62	151-0606-00	TRANSISTOR, TIP142, Power, NPN, Si.
Q74,75,76,84 85,86,93,94 103,104	161-0625-00	TRANSISTOR, D45H11, Power, PNP, Si.
Q111,112,121, 122	151-0607-00	TRANSISTOR, TIP147, Power, PNP, Si.

MECHANICAL PARTS LIST

MAIN CIRCUIT BOARD ASSEMBLY
650-0138-00

Tektronix Part No.	Quantity	Description
214-2864-00	1	HEAT SINK
386-4108-00	1	SUPPORT, Heat Sink
342-0354-00	20	INSULATOR
129-0285-00	11	SPACER, Post
210-0201-00	2	LUG, Solder
211-0511-00	6	SCREW, 6-32 x 0.500, Panhead
211-0007-00	11	SCREW, 4-40 x 0.188, Panhead
211-0097-00	50	SCREW, 4-40 x 0.312, Panhead
211-0061-00	11	SCREW, 4-40 x 0.500, Fillisterhead
210-0054-00	59	WASHER, Split
210-1002-00	48	WASHER, Flat
210-1178-00	12	WASHER, Shld
210-0004-00	11	WASHER, Itl.

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD
670-6052-00

Circuit No.	Tektronix Part No.	Description
	670-6052-00	ECB, Main (Complete)
C101, 201, 701, 801	283-0010-00	CAPACITOR, .05uF, 50V, Ceramic
C102, 202, 702, 802	283-0100-00	CAPACITOR, 4700pF, 200V, Ceramic
C103, 203 301, 401, 901, 1001	283-0339-00	CAPACITOR, 0.22uF, 50V, Ceramic
C302, 303, 402, 403, 502, 503, 602, 603, 902, 903, 1002, 1003, 1102, 1103, 1202, 1203	283-0114-00	CAPACITOR, .0015uF, 200V, Ceramic
C304, 404, 904, 1004	283-0104-00	CAPACITOR, .002uF, 500V, Ceramic
C501, 601, 1101, 1201	283-0005-00	CAPACITOR, .01uF, 250V, Ceramic
C504, 604, 1104, 1204	283-0110-00	CAPACITOR, .005uF, 150V, Ceramic
C505, 605 1105, 1205	283-0164-00	CAPACITOR, 2.2uF, 25V, Ceramic
C703, 803	283-0177-00	CAPACITOR, 1uF, 25V, Ceramic
CR101, 102, 201, 202, 301, 302, 304, 305, 401, 405, 501, 502, 601, 602, 701, 702, 801, 802, 901, 902, 904, 905,	152-0141-02	DIODE, 1N4152, Signal, Si.

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD (Cont.)
Part of 670-6052-00

Circuit No.	Tektronix Part No.	Description
CR1001, 1002, 1004, 1005, 1101, 1102, 1201, 1202	152-0141-02	DIODE, 1N4152, Signal, Si.
CR303, 403, 504, 604, 903, 1003, 1104, 1204	152-0676-00	DIODE, 1N5625, Rectifier, Si.
F1, 2, 7, 8	159-0162-00	FUSE, 30A, Medium
F3, 4, 9, 10	159-0038-00	FUSE, 15A, Medium
F5, 6, 11, 12	159-0014-00	FUSE, 5A, Fast
Q17, 27	151-0103-00	TRANSISTOR, 2N2219A, Signal, NPN, Si.
Q18, 28, 78, 88	151-0526-00	TRANSISTOR, 2N3896, Thyrister
Q35, 45, 53, 63	151-0347-00	TRANSISTOR, 2N5551, Signal, NPN, Si.
Q36, 46, 54, 64, 96, 106, 114, 124	151-0521-00	TRANSISTOR, C122B, Thyristor
Q77, 87	151-0134-00	TRANSISTOR, 2N2905A, Signal, PNP, Si.
Q95, 105, 113,	151-0350-00	TRANSISTOR, 2N5401, Signal, PNP, Si.
R101, 201, 701, 801	321-1295-01	RESISTOR, 11.7k, 1/8W, .5%, Mtl. Flm.
R102, 117, 202, 217, 702, 717, 802, 817	321-0135-00	RESISTOR, 249 ohm, 1/8W, 1%, Mtl. Flm.
R103, 104, 105, 203, 204, 205, 503, 603, 703, 704, 705, 803, 804, 805, 1103, 1203	321-0164-00	RESISTOR, 499 ohm, 1/8W, 1%, Mtl. Flm.

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD (Cont.)
Part of 670-6052-00

Circuit No.	Tektronix Part No.	Description
R106, 206, 706, 806	321-0290-00	RESISTOR, 10.2k, 1/8W, 1%, Mtl. Flm.
R107, 207, 707, 807	321-0310-00	RESISTOR, 16.5k, 1/8W, 1%, Mtl. Flm.
R108, 109, 110, 114, 208, 209, 210, 214, 308, 408, 509, 513, 609, 613, 708, 709, 710, 711, 808, 809, 810, 811, 907, 1007, 1107, 1113, 1207, 1213	315-0201-00	RESISTOR, 200 ohm, 1/4W, 5%, Carbon
R111, 115, 211, 215, 307, 311, 407, 411, 507, 606, 714, 715, 814, 815, 910, 911, 1010, 1011, 1109, 1209	315-0200-00	RESISTOR, 20 ohm, 1/4W, 5%, Carbon
R112, 212, 313, 413, 511, 611, 712, 812, 913, 1013, 1111, 1211	311-1557-00	VARIABLE RESISTOR, 25k, 1/2W, Linear

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD (Cont.)
Part of 670-6052-00

Circuit No.	Tektronix Part No.	Description
R113, 213, 713, 813	301-0101-00	RESISTOR, 100 ohm, 1/4W, 5%, Carbon
R116, 216, 716, 816	315-0302-00	RESISTOR, 3k, 1/4W, 5%, Carbon
R118, 218, 718, 818	315-0560-00	RESISTOR, 56 ohm, 1/4W, 5%, Carbon
R119, 219, 508, 514, 608, 614, 719, 819, 1108, 1114, 1208, 1214	315-0100-00	RESISTOR, 10 ohm, 1/4W, 5%, Carbon
R120, 122, 124, 220, 222, 224, 720, 722, 724, 820, 822, 824	308-0769-00	RESISTOR, .1 ohm, 3W, .1%, WW.
R121, 123, 125, 221, 223, 225, 721, 723, 725, 821, 823, 825	321-0001-00	RESISTOR, 10.0 ohm, 1/8W, 1%, Mtl. Flm.
R301, 401, 901, 1001	321-1646-03	RESISTOR, 11.87k, 1/8W, .25%, Mtl. Flm.
R302, 402, 902, 1002	321-0102-00	RESISTOR, 113. ohm, 1/8W, 1%, Mtl. Flm.
R303, 403, 903, 1003	321-0333-00	RESISTOR, 28.7k, 1/8W, 1%, Mtl. Flm.
R304, 404, 904, 1004	321-0337-00	RESISTOR, 31.6k, 1/8W, 1%, Mtl. Flm.
R305, 317, 405, 417, 905, 917, 1005, 1017	315-0097-00	RESISTOR, 100. ohm, 1/8W, 1%, Mtl. Flm.

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD (Cont.)
Part of 670-6052-00

Circuit No.	Tektronix Part No.	Description
R309, 315, 318, 409, 415, 418, 506, 515, 607, 615, 908, 915, 918, 1008, 1015, 1018, 1106, 1115, 1206, 1215	315-0102-00	RESISTOR, 1k, 1/4W, 5%, Carbon
R310, 316, 410, 416, 909, 916, 1009, 1016	315-0331-00	RESISTOR, 330 ohm, 1/4W, 5%, Carbon
R312, 412, 510, 610, 912, 1012, 1110, 1210	321-0414-00	RESISTOR, 200.k, 1/8W, 1%, Mtl. Flm.
R320, 420, 920, 1020	308-0815-00	RESISTOR, .01 ohm, 5W, .25%, WW
R501, 601, 1101, 1201	321-0296-00	RESISTOR, 11.8k, 1/8W, 1%, Mtl. Flm.
R502, 602, 1102, 1202,	321-0129-00	RESISTOR, 215. ohm, 1/8W, 1%, Mtl. Flm.
R504, 604, 1104, 1204	321-0431-00	RESISTOR, 301.k, 1/8W, 1%, Mtl. Flm.
R505, 516, 605, 616, 1105, 1116, 1205, 1216	301-0153-00	RESISTOR, 15k, 1/2W, 5%, Carbon
R512, 612, 1112, 1212	321-0126-00	RESISTOR, 200. ohm, 1/8W, 1%, Mtl. Flm.
R517, 617, 1117, 1217	308-0769-00	RESISTOR, .1 ohm, 3W, .1%, WW

ELECTRICAL PARTS LIST

MAIN CIRCUIT BOARD (Cont.)

Part of 670-6052-00

Circuit No.	Tektronix Part No.	Description
U11, 12, 21, 22, 71, 72, 81, 82	156-1156-00	IC, LF356N, Op Amp
U31, 41, 51, 61, 91, 101, 111, 121	156-1191-00	IC, TL072CP, Op Amp
VR101, 201, 701, 801	152-0195-00	ZENER DIODE, 1N751A, 5.1V, .4W
VR102, 202, 702, 802	152-0571-00	ZENER DIODE, 1N966B, 16V, .4W
VR103, 203, 703, 803	152-0268-00	ZENER DIODE, 1N979B, 56V, .4W
VR301, 401, 502, 602, 901, 1001, 1101, 1201	152-0149-00	ZENER DIODE, 1N961B, 10V, .4W
VR302, 402, 902, 1002	152-0282-00	ZENER DIODE, 1N972B, 30V, .4W
VR303, 403, 903, 1003	152-0287-00	ZENER DIODE, 1N986B, 110V, .4W
VR306, 406, 505, 605, 906, 1006, 1105, 1205	152-0395-00	ZENER DIODE, 1N749A, 4.3V, .4W
VR501, 601, 1102, 1202	152-0247-00	ZENER DIODE, 1N989B, 150V, .4W
VR503, 603, 1103, 1203	152-0255-00	ZENER DIODE, 1N978B, 51V, .4W
	136-0514-00	SOCKET, Dual-In-Line, 8 contact
	131-0589-00	TERMINAL, Pin
	131-0608-00	TERMINAL, Pin
	131-1687-00	TERMINAL, Quick Disconn.
	131-1816-00	TERMINAL, Quick Disconn.

MECHANICAL PARTS LIST

MAIN CIRCUIT BOARD
670-6052-00

Tektronix Part No.	Quantity	Description
210-0455-00	4	NUT, .25-28 (1/4)
210-0586-00	24	NUT, Keps, 4-40
162-0684-00	1.167 feet	SLEEVING, Elec, 16 AWG
211-0008-00	24	SCREW, 4-40 x .250, Panhead

ELECTRICAL PARTS LIST

DIGITAL MULTIMETER BOARD

067-6048-00

Circuit No.	Tektronix Part No.	Description
	670-6048-00	ECB, Digital Multimeter (Complete)
C4001, 4002, 4003, 4004, 4005, 4006, 4014, 4016	290-0573-00	CAPACITOR, 2.7uF, 50V, Electr.
C4007	285-1050-00	CAPACITOR, .1uF, 200V, Mtl'd Mylar
C4008	283-0666-00	CAPACITOR, 890pF, 100V, Mica
C4009	281-0812-00	CAPACITOR, .001uF, 100V, Ceramic
C4010	290-0534-00	CAPACITOR, 1uF, 35V, Electr.
C4012	283-0604-00	CAPACITOR, 304pF, 300V, Mica
C4013	285-1056-00	CAPACITOR, 1uF, 50V, Mtl'd Polycarb.
C4017	283-0635-00	CAPACITOR, 51pF, 100V, Mica
C4018	281-0773-00	CAPACITOR, .01uF, Ceramic
C4020	283-0054-00	CAPACITOR, 150pF, 500V, Ceramic
C4021, 4022	283-0687-00	CAPACITOR, 560pF, 300V, Mica
C4023, 4024	283-0158-00	CAPACITOR, 1.0pF, 50V, Ceramic
CR4002, 4003, 6001, 6002, 6003, 6004, 6005, 6006, 6007, 6008, 6009, 6010, 6011, 6012, 6013	150-1001-00	LED, MV5024, Red
CR4004, 4005	152-0324-00	DIODE, TD55125, Signal, Si.
CR4007, 4008	152-0141-02	DIODE, 1N4152, Signal, Si.
DS4014, 4015, 4016, 4017	150-1048-00	LED DISPLAY, 7 Seg
DS4018	150-1066-00	LED DISPLAY, MAN4605, 7 Seg
K4001	148-0079-00	RELAY, DIP, 28VDC
K4002, 4003, 4004, 4005	148-0079-00	RELAY, DIP, 100VDC
Q4001, 4002,	151-0254-00	TRANSISTOR, 2N5308, Signal, NPN, Si.

ELECTRICAL PARTS LIST

DIGITAL MULTIMETER BOARD (Cont.)
Part of 067-6048-00

Circuit No.	Tektronix Part No.	Description
Q4003, 4011, 4012, 4013, 4023	151-0254-00	TRANSISTOR, 2N5308, Signal, NPN, Si.
Q4004, 4007, 4008, 4009, 4019, 4020,	151-0188-00	TRANSISTOR, 2N3906, Signal, PNP, Si.
Q4005, 4006, 4010, 4014, 4015, 4016, 4017, 4018	151-0190-00	TRANSISTOR, 2N3904, Signal, NPN, Si.
Q4021	151-1103-00	TRANSISTOR, SD210, MOS FET, N-Ch
Q4022	151-0435-00	TRANSISTOR, MPSA65, Signal, PNP, Si.
Q4024	151-0424-00	TRANSISTOR, 2N5769
R4001	315-0682-00	RESISTOR, 6.8k, 1/4W, 5%, Carbon
R4002, 4003	315-0391-00	RESISTOR, 390 ohm, 1/4W, 5%, Carbon
R4004	307-1015-00	RESISTOR NETWORK, 9M, 900k, 90k, 9k, 900 ohm, 90 ohm, 10 ohm; DIP
R4005	311-1231-00	VARIABLE RESISTOR, 25k, 1/2W, 10%, Linear
R4006	321-1686-07	RESISTOR, 10.97k, 1/8W, .1%, Mtl. Flm.
R4007, 4072	311-1223-00	VARIABLE RESISTOR, 250 ohm, 1/2W, 10%, Linear
R4008, 4009, 4011	321-0385-00	RESISTOR, 100.k, 1/8W, 1%, Mtl. Flm.
R4010	321-0396-00	RESISTOR, 130.k, 1/8W, 1%, Mtl. Flm.
R4012	315-0473-00	RESISTOR, 47k, 1/4W, 5%, Carbon
R4013, 4065	315-0104-00	RESISTOR, 100k, 1/4W, 5%, Carbon
R4014	307-0103-00	RESISTOR, 2.7 ohm, 1/4W, 5%, Carbon
R4015	321-0193-00	RESISTOR, 1.00k, 1/8W, 1%, Mtl. Flm.
R4016	311-1466-00	VARIABLE RESISTOR, 2k, 1/2W, 10%, Linear
R4017	321-0309-00	RESISTOR, 16.2k, 1/8W, 1%, Mtl. Flm.
R4018, 4019	315-0360-00	RESISTOR, 36 ohm, 1/4W, 5%, Carbon
R4020, 4091	315-0472-00	RESISTOR, 4.7k, 1/4W, 5%, Carbon
R4021	315-0752-00	RESISTOR, 7.5k, 1/4W, 5%, Carbon
R4022	311-1235-00	VARIABLE RESISTOR, 100k, 1/2W, 10%, Linear
R4023, 4041, 4042, 4043, 4045, 4046, 4047, 4064	315-0103-00	RESISTOR, 10k, 1/4W, 5%, Carbon

ELECTRICAL PARTS LIST

DIGITAL MULTIMETER BOARD (Cont.)
Part of 067-6048-00

Circuit No.	Tektronix Part No.	Description
R4024, 4025, 4026, 4027 4028	315-0203-00	RESISTOR, 20k, 1/4W, 5%, Carbon
R4029, 4030, 4031, 4032, 4090	315-0102-00	RESISTOR, 1k, 1/4W, 5%, Carbon
R4033	315-0182-00	RESISTOR, 1.8k, 1/4W, 5%, Carbon
R4034, 6004, 6010, 6016, 6022, 6028, 6034, 6040, 6046, 6052, 6058, 6064, 6070, 6076	315-0122-00	RESISTOR, 1.2k, 1/4W, 5%, Carbon
R4035, 4039	315-0331-00	RESISTOR, 330 ohm, 1/4W, 5%, Carbon
R4036	315-0681-00	RESISTOR, 680 ohm, 1/4W, 5%, Carbon
R4037, 4040	315-0751-00	RESISTOR, 750 ohm, 1/4W, 5%, Carbon
R4044, 4060	315-0202-00	RESISTOR, 2k, 1/4W, 5%, Carbon
R4048, 4049, 4050, 4051, 4052, 4053, 4054, 4081, 4082, 4083, 4084, 4085, 4088	315-0510-00	RESISTOR, 51 ohm, 1/4W, 5%, Carbon
R4058	315-0241-00	RESISTOR, 240 ohm, 1/4W, 5%, Carbon
R4059	315-0150-00	RESISTOR, 15 ohm, 1/4W, 5%, Carbon
R4062	315-0561-00	RESISTOR, 560 ohm, 1/4W, 5%, Carbon
R4063	315-0161-00	RESISTOR, 160 ohm, 1.4W, 5%, Carbon
R4069	315-0243-00	RESISTOR, 24k, 1/4W, 5%, Carbon
R4070, 4073	321-0289-00	RESISTOR, 10.0k, 1/8W, 1%, Mtl. Flm.
R4071, 4074, 4075	321-0481-00	RESISTOR, 1.00M, 1/8W, 1%, Mtl. Flm.
R4076, 4078	315-0302-00	RESISTOR, 3k, 1/4W, 5%, Carbon
R4077, 4079	321-0260-00	RESISTOR, 4.99k, 1/8W, 1%, Mtl. Flm.
R4086, 4087,	315-0272-00	RESISTOR, 2.7k, 1/4W, 5%, Carbon

ELECTRICAL PARTS LIST

DIGITAL MULTIMETER BOARD (Cont.)
Part of 067-6048-00

Circuit No.	Tektronix Part No.	Description
S4001	260-1840-00	SWITCH, Toggle, 4PDT, **VOLTAGE/CURRENT**
T4001	120-1276-00	TRANSFORMER, Line Freq
U4001	156-1306-00	IC, LD120, Analog A to D
U4002	156-0385-00	IC, 74LS04, TTL, Hex-Inverter
U4003	156-1305-00	IC, LD121, Digital A to D
U4004	156-0886-00	IC, 74C48, CMOS, BCD to 7 Seg. Decoder
U4006	156-0783-00	IC, LM399H, 6.95V Reg.
U4008	156-0910-00	IC, 74LS390, TTL, Dual-Decade
U4009, 4022	156-0382-00	IC, 74LS00, TTL, Quad 2-Input NAND
U4010	156-0383-00	IC, 74LS02, TTL, Quad 2-Input NOR
U4011, 4023	156-0386-00	IC, 74LS10, TTL, Triple 3-Input NAND
U4012	156-0422-00	IC, 74LS191, TTL, Syn. 4-bit Up/Dwn Binary
U4013	156-0736-00	IC, 74LS42, TTL, BCD to Deci. Decoder
U4019	156-1172-00	IC, 74LS393, TTL, Dual 4-bit Binary
U4020	156-1156-00	IC, LF356, Op Amp
U4021	156-0465-00	IC, 74LS30, TTL, Single 8-Input NAND
VR4001	152-0195-00	ZENER DIODE, 1N751A, 5.1V, .4W
VR4009, 4010	152-0149-00	ZENER DIODE, 1N961B, 10V, .4W
Y4001	158-0124-00	CRYSTAL, 2.4576MHz, .05%
	136-0260-02	SOCKET, Dual In-Line, 16 Contact
	136-0269-02	SOCKET, Dual In-Line, 14 Contact
	136-0494-00	SOCKET, Dual In-Line, 14 Contact
	136-0514-00	SOCKET, Dual In-Line, 8 Contact
	136-0670-00	SOCKET, Dual In-Line, 18 Contact
	136-0338-00	SOCKET, Spring
	136-0352-00	SOCKET, Spring
	131-0608-00	TERMINAL, Pin
	131-1343-00	TERMINAL SET PIN

MECHANICAL PARTS LIST

INTERCONNECT CIRCUIT BOARD
670-6051-00

Tektronix Part No.	Quantity	Description
131-0767-00	1	CONNECTOR, Rcpt. Elec.
131-0589-00	1	TERMINAL, Pin
131-0608-00	1	TERMINAL, Pin
131-0767-00	1	TERMINAL SET, Pin
213-0034-00	1	SCREW, 4-40 x .312, Panhead

ELECTRICAL PARTS LIST

LOWER PANEL CIRCUIT BOARD
670-6050-00

Circuit No.	Tektronix Part No.	Description
	670-6050-00	ECB, Lower Panel (Complete)
C2100	281-0775-00	CAPACITOR, .1uF, 50V, Ceramic
CR2100	152-0141-02	DIODE, 1N4152, Signal, Si.
Q2100, 2101	151-0188-00	TRANSISTOR, 2N3906, Signal, PNP, Si
R2108, 2110, 2114, 2118, 2124, 2126	315-0152-00	RESISTOR, 1.5k, 1/4W, 5%
R2112, 2120	315-0200-00	RESISTOR, 20 ohm, 1/4W, 5%
S2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2111	260-1335-00	SWITCH, Toggle, SPDT, **MAX/MIN 1** thru **MAX/MIN 12** and **CHOP/SWITCH**
S2110	260-1206-00	SWITCH, Toggle, SPDT (Center Off), **HI/LOW/IND**
U2100	156-0383-00	IC, 74LS02, TTL, Quad 2-input NOR

ELECTRICAL PARTS LIST

POWER SUPPLY BOARD
670-6049-00

Circuit No.	Tektronix Part No.	Description
	670-6049-00	ECB, Power Supply (Complete)
C3000, 3003 3006, 3011, 3015, 3019	283-0111-00	CAPACITOR, .1uF, 50V, Ceramic
C3001, 3020	290-0746-00	CAPACITOR, 47uF, 16V, Electr.
C3002, 3008, 3010, 3014	290-0583-00	CAPACITOR, 3000uF, 35V, Electr.
C3004, 3009, 3013, 3017	290-0745-00	CAPACITOR, 22uF, 25V, Electr.
C3005, 3012	283-0114-00	CAPACITOR, 1500pF, 200V, Electr.
C3007, 3016	283-0299-00	CAPACITOR, 51pF, 500V, Electr.
C3018	290-0506-00	CAPACITOR, 9600uF, 30V, Elactr.
CR3001, 3002	152-0488-00	DIODE RECTIFIER, KBP02, Bridge
CR3003, 3004, 3005	152-0066-00	DIODE, 1N4004G, Rectifier, Si.
F3002, 3003, 3004, 3005, 3006	159-0022-00	FUSE, 1A, Fast, 250V
K3002	148-0022-00	RELAY, 12 VDC, Armature, 2 Form C
Q3001, 3004, 3005, 3008	151-0373-00	TRANSISTOR, Power, MJE2901, PNP, Si.
Q3002, 3006	151-0462-00	TRANSISTOR, Power, TIP30C, PNP, Si.
Q3003, 3007	151-0188-00	TRANSISTOR, Signal, 2N3906, PNP, Si.
R3001, 3008, 3011, 3015, 3022, 3023	315-0301-00	RESISTOR, 300 ohms, 1/4W, 5%
R3002, 3012	308-0755-00	RESISTOR, .75 ohms, 3W, 10%
R3003, 3017	315-0512-00	RESISTOR, 5.1k, 1/4W, 5%
R3004, 3016	321-0282-00	RESISTOR, 8.45k, 1/8W, 1%
R3005, 3018	311-1749-00	VARIABLE RESISTOR, 1.5k, 1/2W, 20%
R3006, 3013,	321-0268-00	RESISTOR, 6.04k, 1/8W, 1%

ELECTRICAL PARTS LIST

POWER SUPPLY BOARD (Cont.)

Part of 670-6052-00

Circuit No.	Tektronix Part No.	Description
R3007, 3020	321-0299-00	RESISTOR, 12.7k, 1/8W, 1%
R3009, 3021	315-0302-00	RESISTOR, 3k, 1/4W, 5%
R3010	311-1567-00	VARIABLE RESISTOR, 100 ohms, 1/2W, 20%
R3014, 3024	308-0677-00	RESISTOR, 1 ohm, 2W, 5%
R6001, 6006, 6007, 6012, 6013, 6018, 6019, 6024, 6025, 6030, 6031, 6036, 6037, 6042, 6043, 6048, 6049, 6054, 6055, 6060, 6061, 6066, 6067, 6072, 6073, 6078	321-0296-00	RESISTOR, 11.8k, 1/8W, 1%
R6002, 6005, 6008, 6011, 6014, 6017, 6020, 6023, 6026, 6029, 6032, 6035, 6038, 6041, 6044, 6047, 6050, 6053, 6056, 6059, 6062, 6065, 6068, 6071, 6074, 6077	321-0143-00	RESISTOR, 301 ohms, 1/8W, 1%
R6003, 6009, 6015, 6021, 6027, 6033, 6039, 6045, 6051, 6057, 6063, 6069, 6075	321-0297-00	RESISTOR, 12.1k, 1/8W, 1%

ELECTRICAL PARTS LIST

POWER SUPPLY ECB (Cont.)
Part of 670-6049-00

Circuit No.	Tektronix Part No.	Description
U3001, 3006	156-0277-00	IC, uA7805UC, Linear
U3002, 3004	156-0071-00	IC, uA723DC, Linear
U3003, 3005	156-0105-00	IC, LM301AN, Op Amp
U6001, 6002, 6003, 6004, 6005, 6006, 6007	156-0411-00	IC, LM339N, Linear
	388-6546-01	ECB, w/o components
	136-0394-00	SOCKET, Relay
	136-0269-02	SOCKET, Relay, 14 pin
	136-0514-00	SOCKET, Relay, 8 pin
	131-0589-00	TERMINAL, Pin
	131-0608-00	TERMINAL, Pin
	344-0154-00	HOLDER, Fuse

SECTION 6

DIAGRAMS AND CIRCUIT BOARD ILLUSTRATIONS

Symbols and Reference Designators

Electrical components shown on the diagrams are in the following units unless noted otherwise:

Capacitors = Values one or greater are in picofarads (pF).
Values less than one are in microfarads (μF).

Resistors = Ohms (Ω).

Graphic symbols and class designation letters are based on ANSI Standard Y32.2-1975.

Logic symbology is based on ANSI Y32.14-1973 in terms of positive logic. Logic symbols depict the logic function performed and may differ from the manufacturer's data.

The overline on a signal name indicates that the signal performs its intended function when it goes to the low state.

Abbreviations are based on ANSI Y1.1-1972.

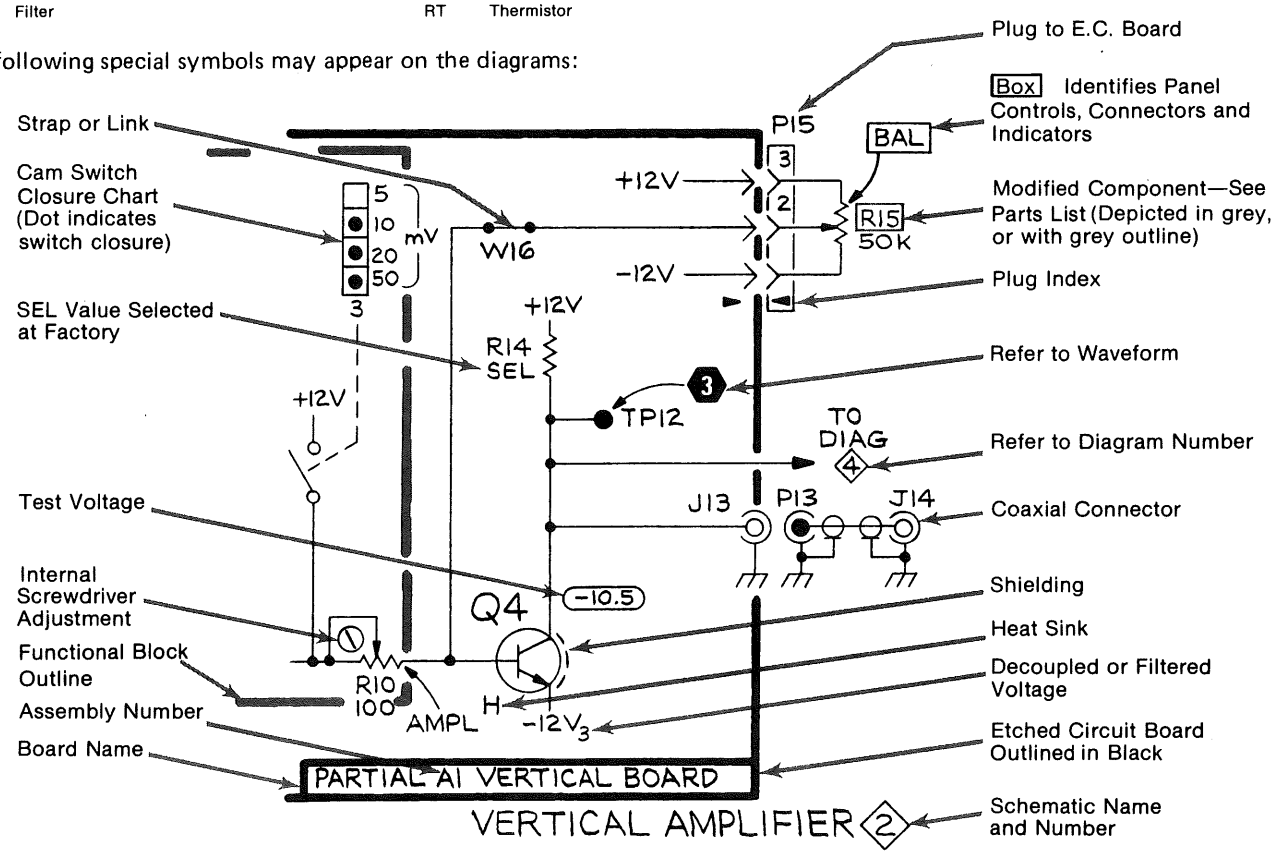
Other ANSI standards that are used in the preparation of diagrams by Tektronix, Inc. are:

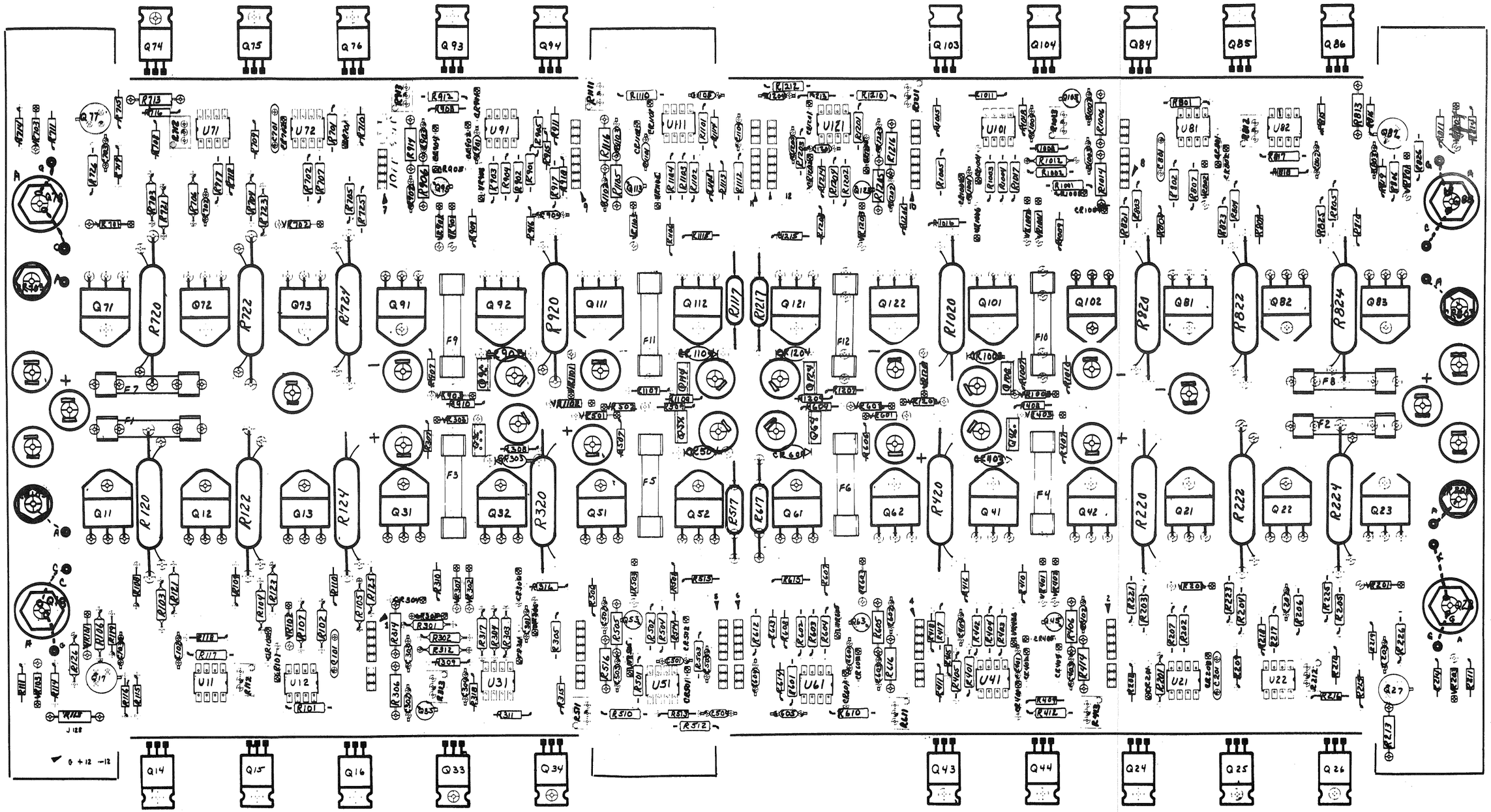
Y14.15, 1966	Drafting Practices.
Y14.2, 1973	Line Conventions and Lettering.
Y10.5, 1968	Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering.

The following prefix letters are used as reference designators to identify components or assemblies on the diagrams.

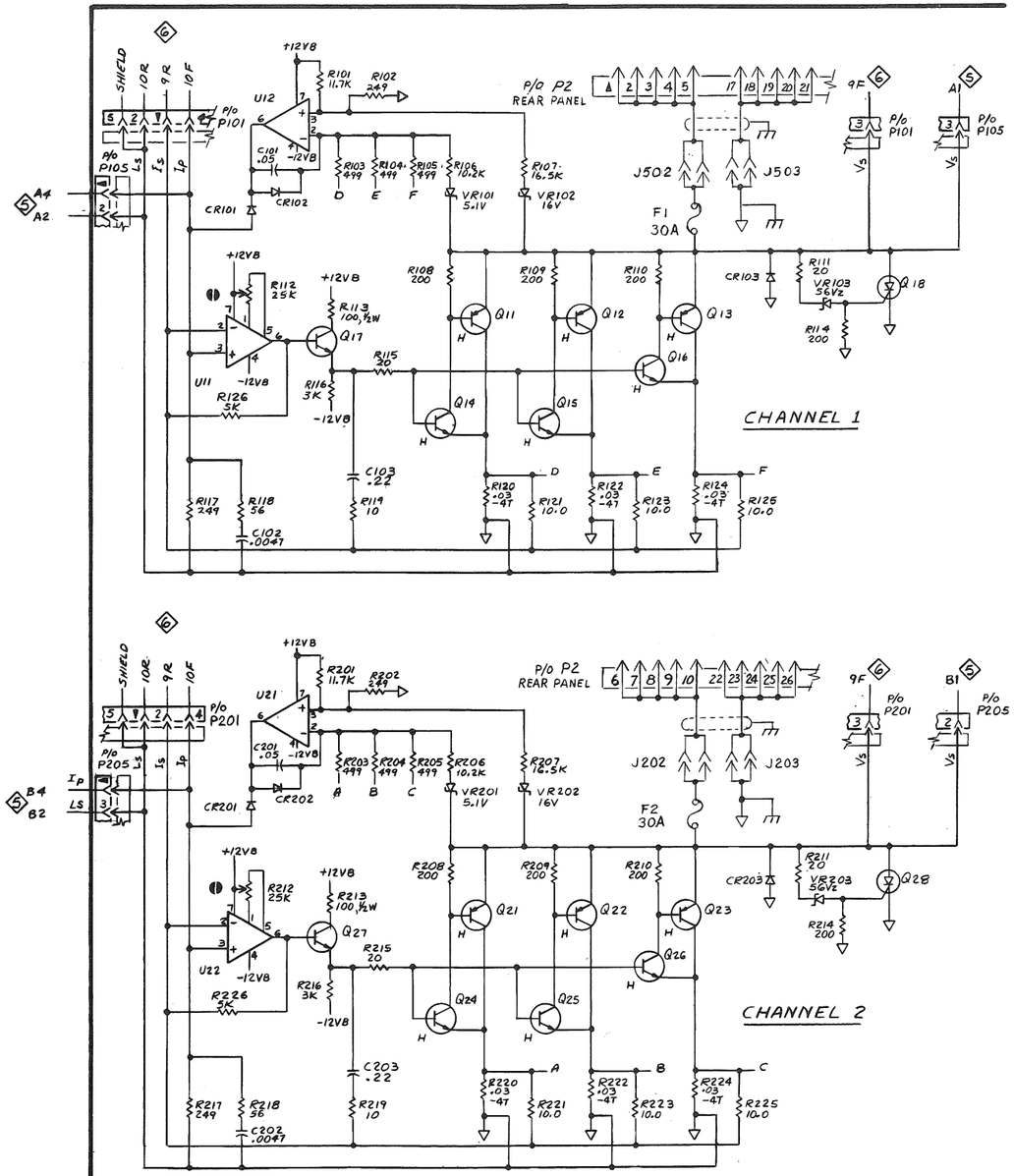
A	Assembly, separable or repairable (circuit board, etc)	H	Heat dissipating device (heat sink, heat radiator, etc)	S	Switch or contactor
AT	Attenuator, fixed or variable	HR	Heater	T	Transformer
B	Motor	HY	Hybrid circuit	TC	Thermocouple
BT	Battery	J	Connector, stationary portion	TP	Test point
C	Capacitor, fixed or variable	K	Relay	U	Assembly, inseparable or non-repairable (integrated circuit, etc.)
CB	Circuit breaker	L	Inductor, fixed or variable	V	Electron tube
CR	Diode, signal or rectifier	M	Meter	VR	Voltage regulator (zener diode, etc.)
DL	Delay line	P	Connector, movable portion	W	Wirestrap or cable
DS	Indicating device (lamp)	Q	Transistor or silicon-controlled rectifier	Y	Crystal
E	Spark Gap, Ferrite bead	R	Resistor, fixed or variable	Z	Phase shifter
F	Fuse	RT	Thermistor		
FL	Filter				

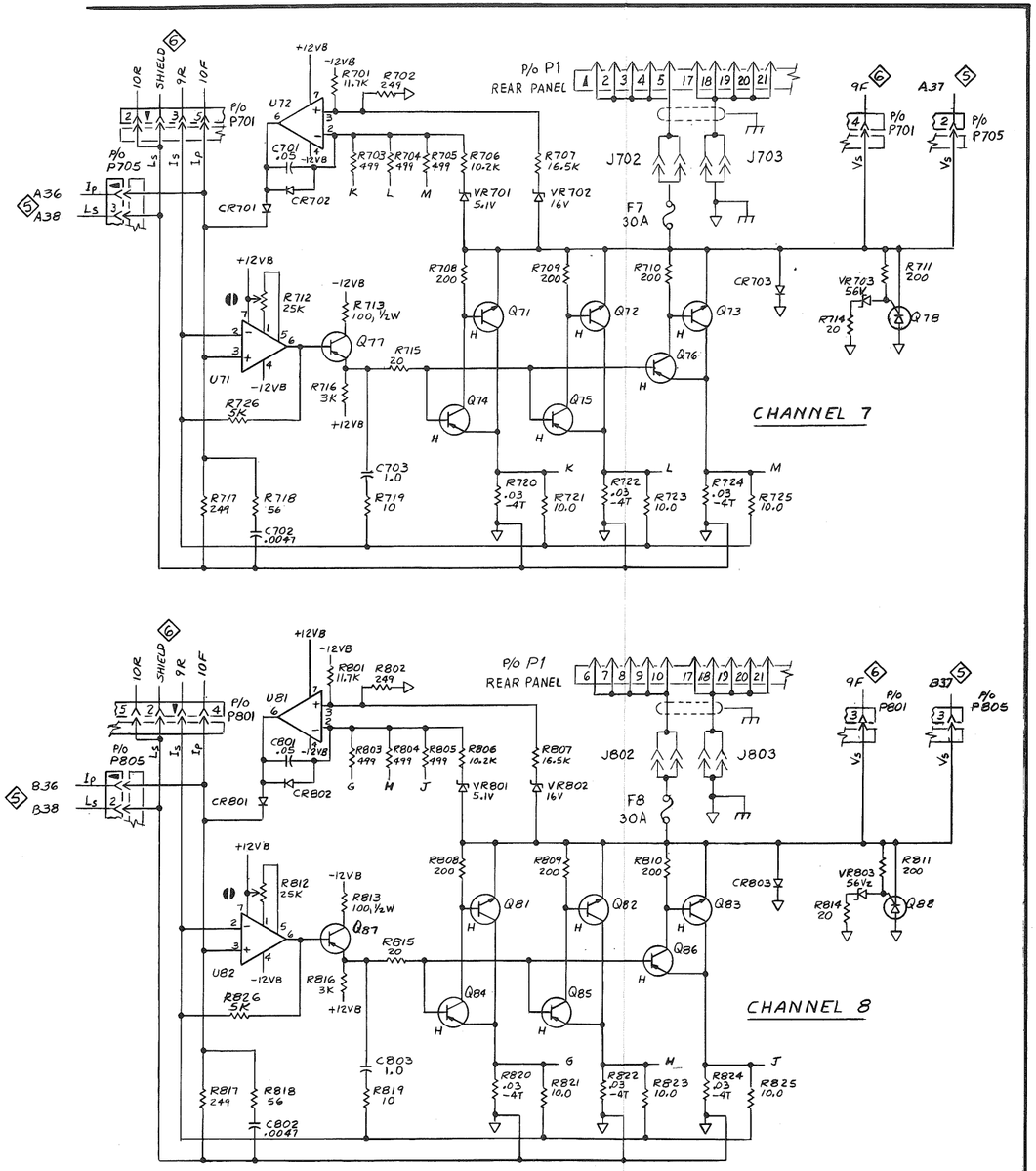
The following special symbols may appear on the diagrams:





Component Location Diagram
MAIN BOARD 670-6052-00





PARTIAL A1 MAIN BOARD

P/O 670-0138-00

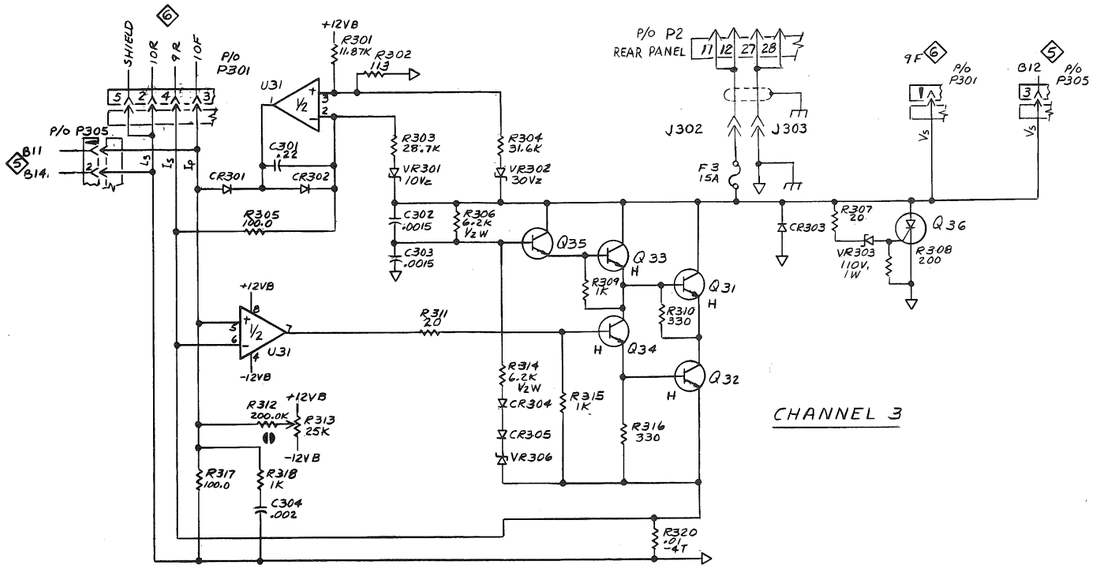
PARTIAL A1 MAIN BOARD

067-0883-99

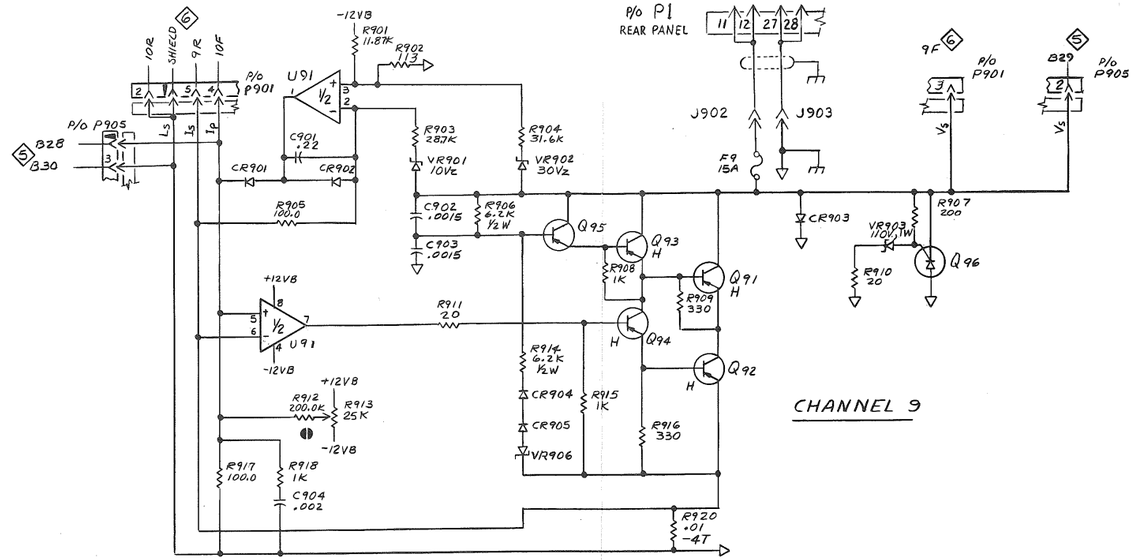
HIGH CURRENT CHANNELS

REV D 9-79

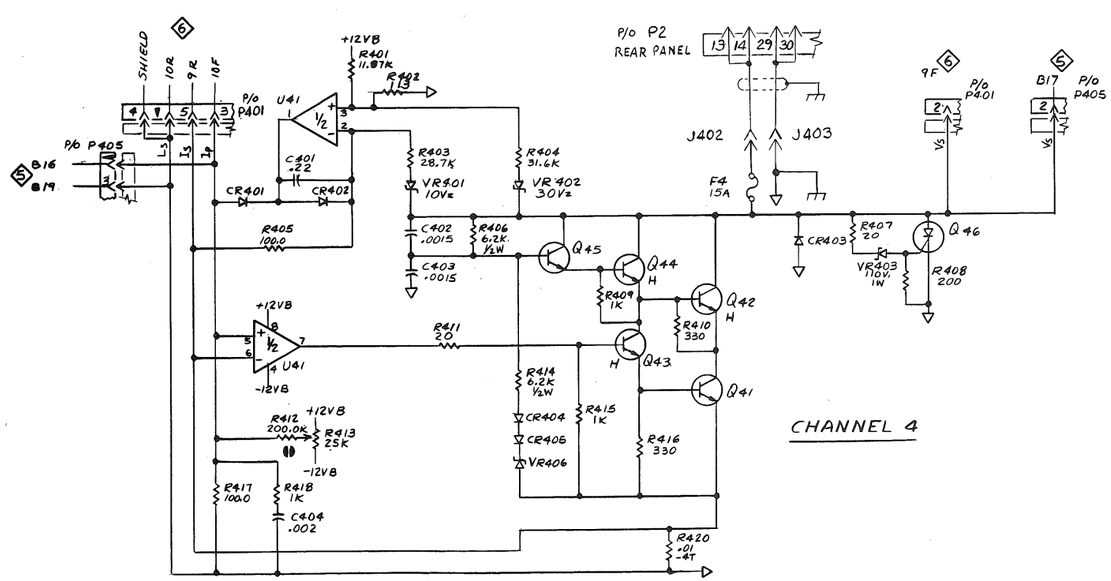
1a



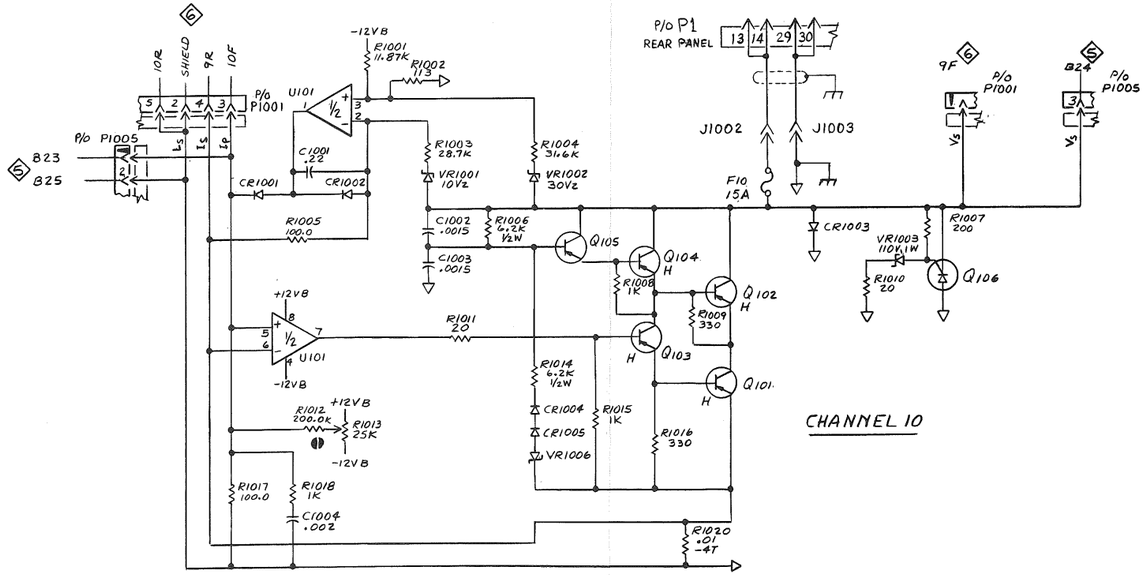
CHANNEL 3



CHANNEL 9



CHANNEL 4



CHANNEL 10

PARTIAL 1A MAIN BOARD

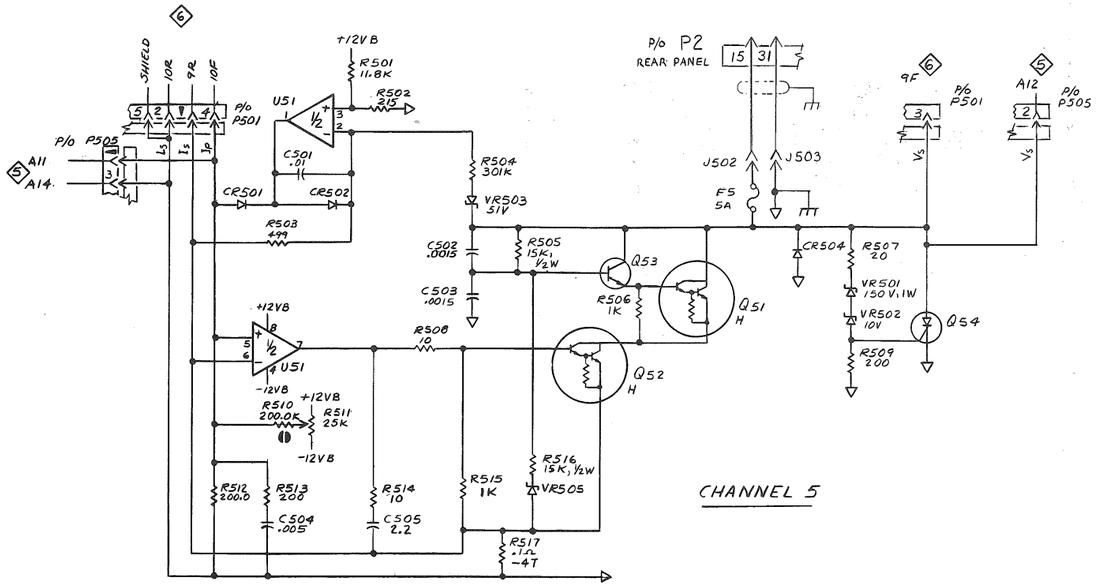
P/O 670-0138-00

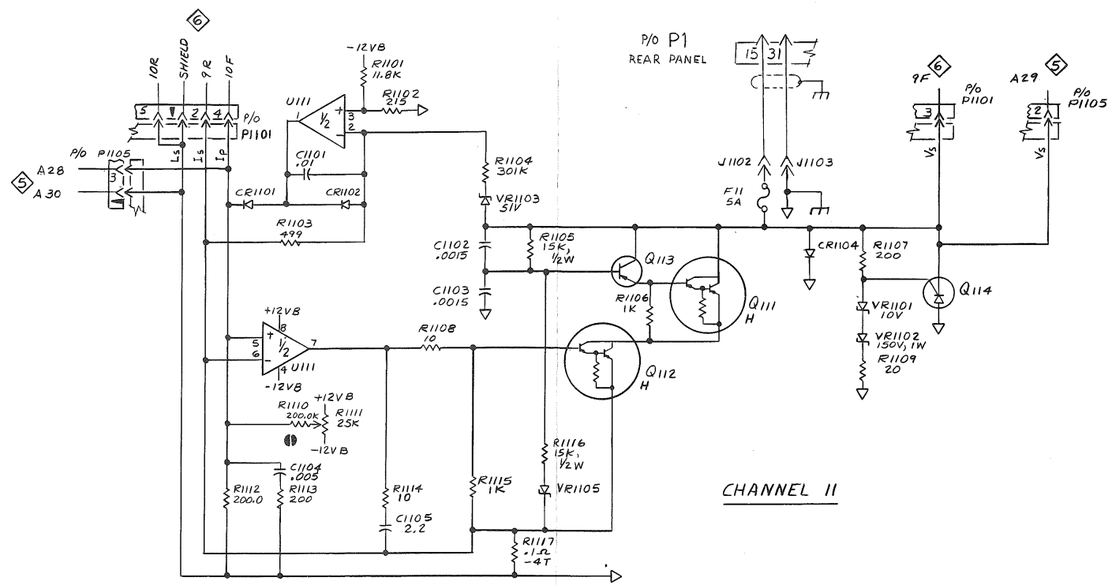
067-0883-99

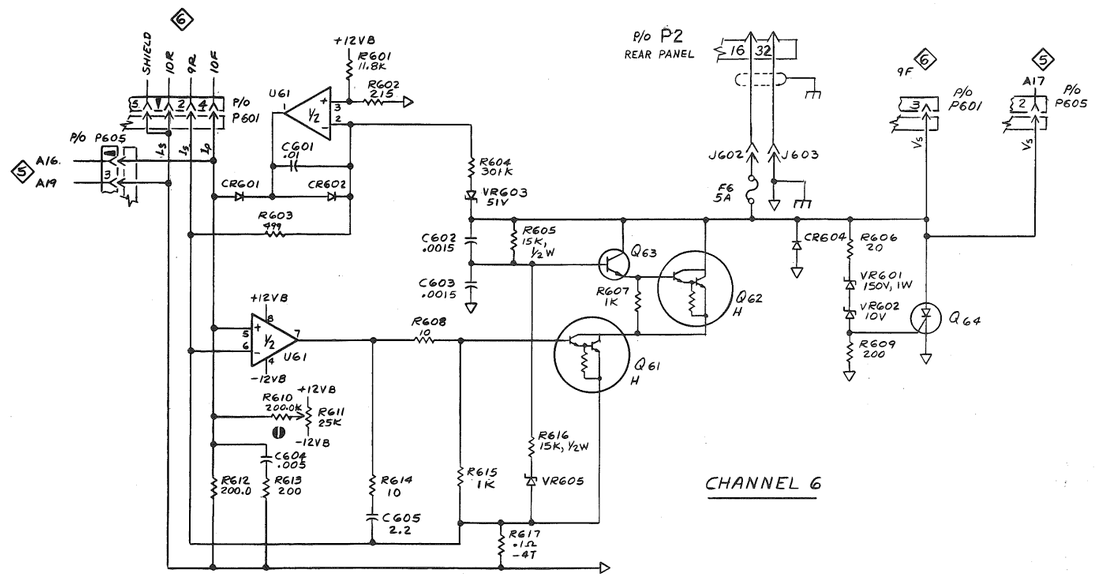
PARTIAL 1A MAIN BOARD

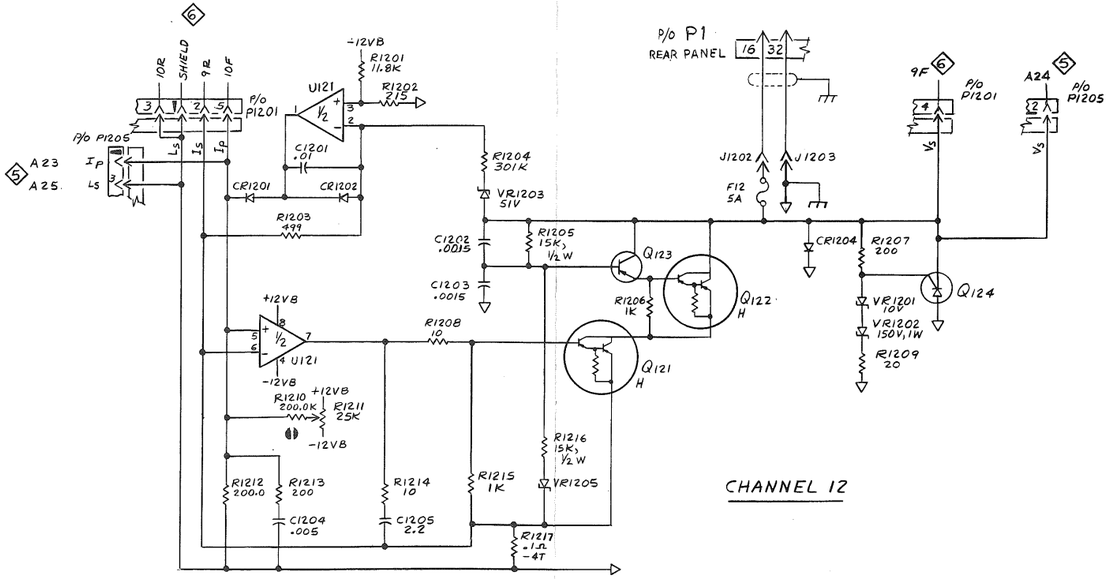
MEDIUM CURRENT CHANNELS 1b

REV C 9-20-79









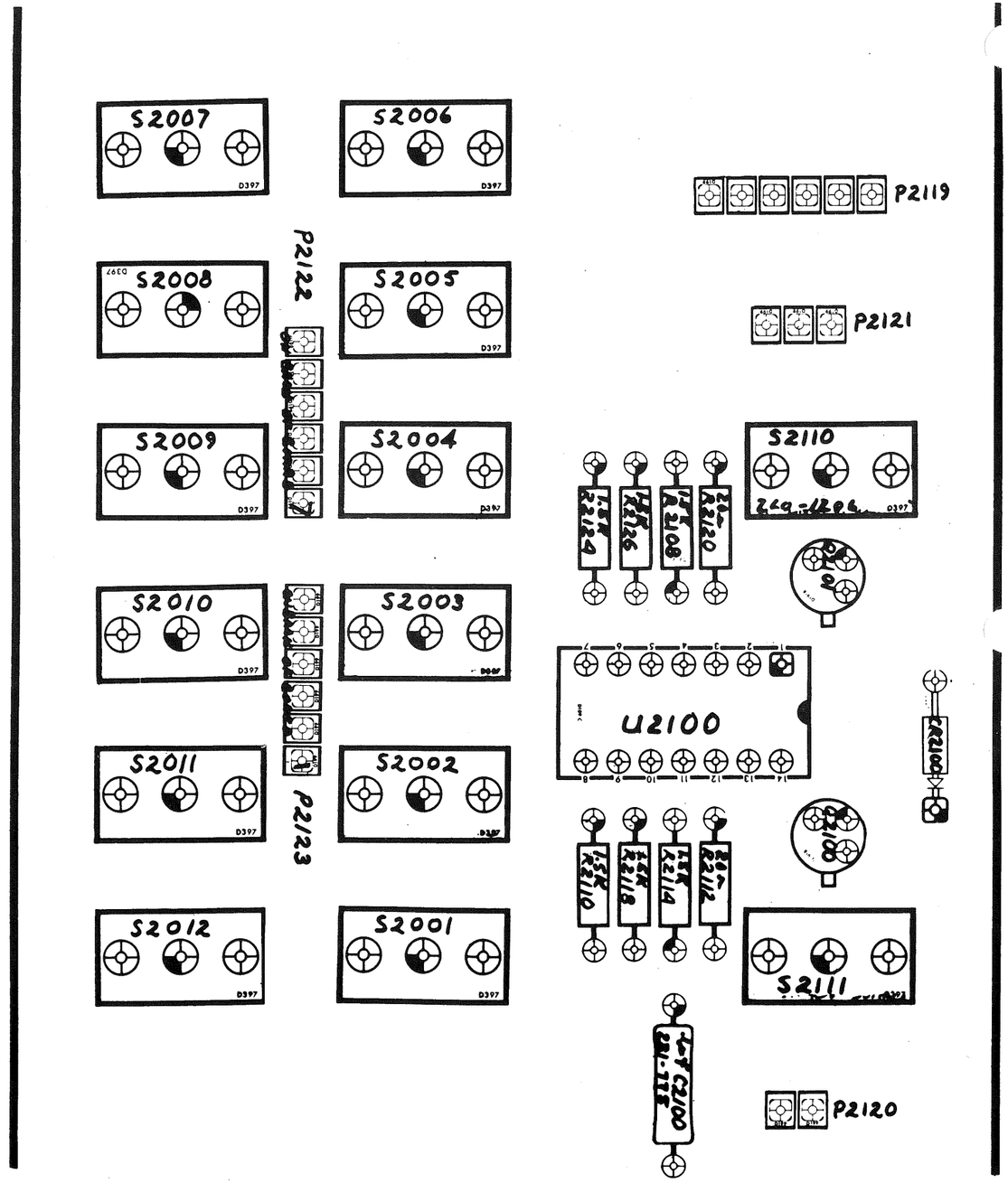
P/O 670-0138-00

PARTIAL 1A MAIN BOARD

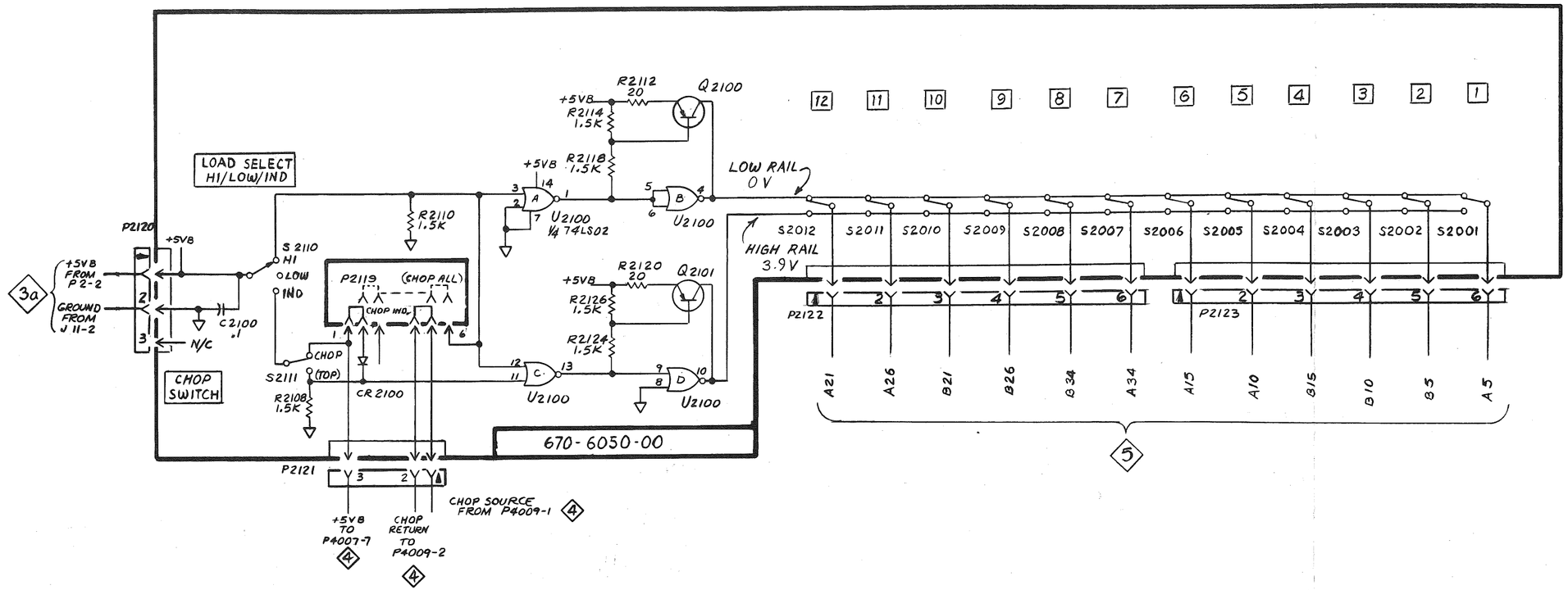
067-0883-99

LOW CURRENT CHANNELS 1C

REV C 9-20-79



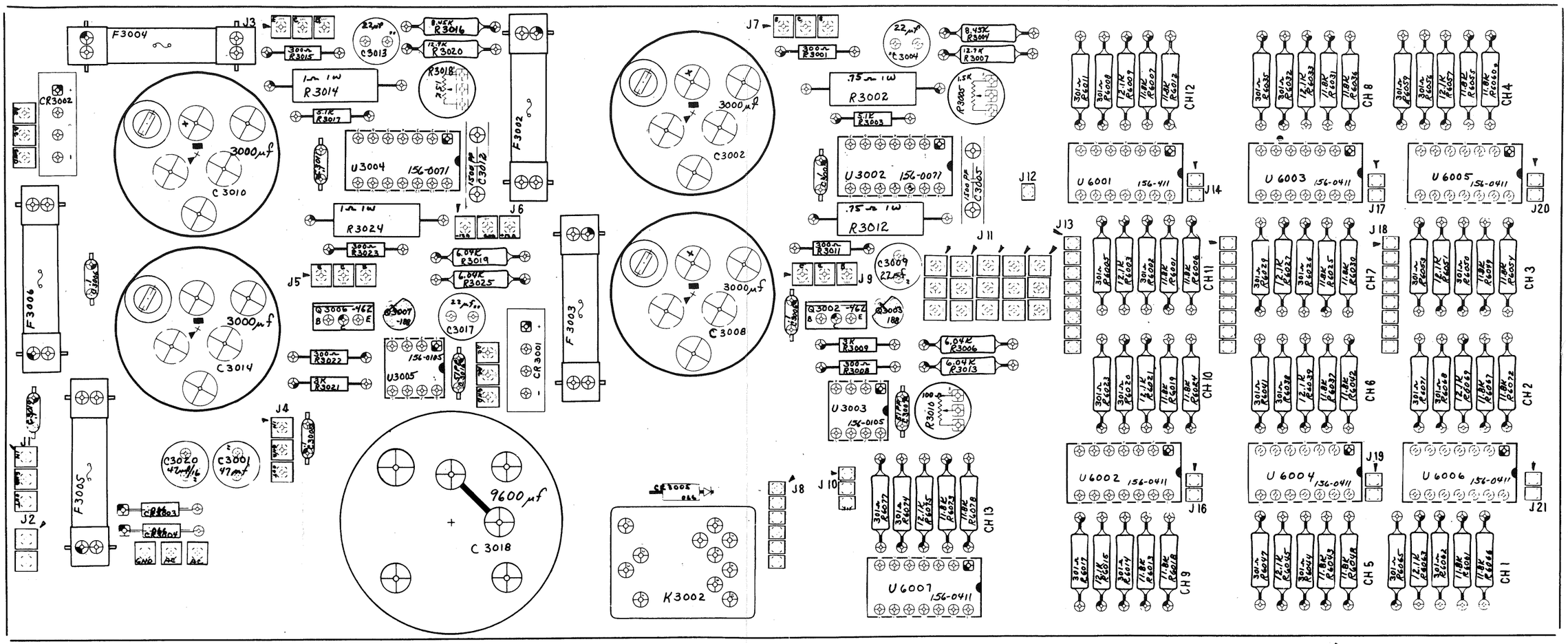
Component Loaction Diagram
LOWER PANEL BD. 670-6050-00



067-0883-99

LOWER PANEL BOARD 2

REV B 3-79



Component Location Diagram
POWER SUPPLY BD. 670-6049-00

REAR PANEL

LINE FILTER LF3001

LINE
NEUTRAL

S3001 OFF ON

1A F3001

P/O 670-6049-00

K3002 A NO 1

J8-6 J8-5

8-14

8-2

FAN FM 3001

S3003 (REAR PANEL) 110V 220V

S3003 220V 110V

P/O 670-6049-00

K3002 B NO 2

J8-2 J8-3

8-3

8-19

FAN FM 3002

OFF ON S3001 (REAR PANEL)

SHIELD BLACK

P/O 670-6049-00

-12V B

CR3005 K3002

P8

P/O P3 (REAR PANEL)

34

1/6

S3002 (MAIN BD ASSY)

H

T3001 (CHASSIS)

BROWN

BLACK

BROWN

AC + CR 3001 -0488 AC -

WHITE

BROWN

RED

AC + CR 3002 -0488 AC -

ORANGE

YELLOW

GREEN

CR3003 -0066

CR3004 -0066

C3018 9600

C3019 .1

C3020 47

F3005 1A

U3001 7805 -0077 H

Q3001 -0373 H

P2120-1

P4 P2 P7

C3000 .1

C3001 47

+5V B

+21V B

1A F3002

C3002 3000

C3003 .1

R3001 300

R3002 .75(1W)

+12V B

J11-1

P4007-6 4

A20 5

J825 J125 1

N/C

U3002 723C -0071 14 PIN DIP

6.9V

R3003 5.1K

R3004 8.45K

R3005 1.50K

R3007 12.7K

C3004 22 25V

R3006 6.04K

J11-2

N/C

J825 J125 1 2

P2120-2

P4007-8 4

C3005 1500pf

C3006 .1 50V

C3007 51pf

R3008 300

R3009 3K

U3003 LM301 -0105

0V

R3010 100 BAL

C3008 3000

C3009 22 25V

R3013 6.04K

N/C

J825 J125 1 4

P4007-9

B20 5

Q3002 -0462

Q3003 -0188

R3011 300

R3012 .75 (1W)

-12V B

J11-3

1A F3003

-21V B

P9

Q3004 -0373

Q 3005 -0373 H

P3

P6

+21V A

1A F3004

R3014 1.2k 1W

+12 V A

P4007-1 4

R3015 300

U3004 723 -0071 14 PIN DIP

R3016 8.45K

R3017 5.1K

C3011 .1

R3018 1.5K

C3012 1500pf

R3019 6.04K

R3020 12.7K

C3013 22

COMMON

P4007-3 4

C3014 3000

C3015 .1

C3016 51pf

R3021 3K

U3005 LM301 -0105

-21V A

R3022 300

C3017 22

Q3006 -0462

Q3007 -0188

R3023 300

R3024 1.2k 1W

R3025 6.04K

1A F3006

+5V A

-12 V A

P4007-5 4

P1 P2 P5

P/O 670-6049-00

7805 U3006

P4007-1 4

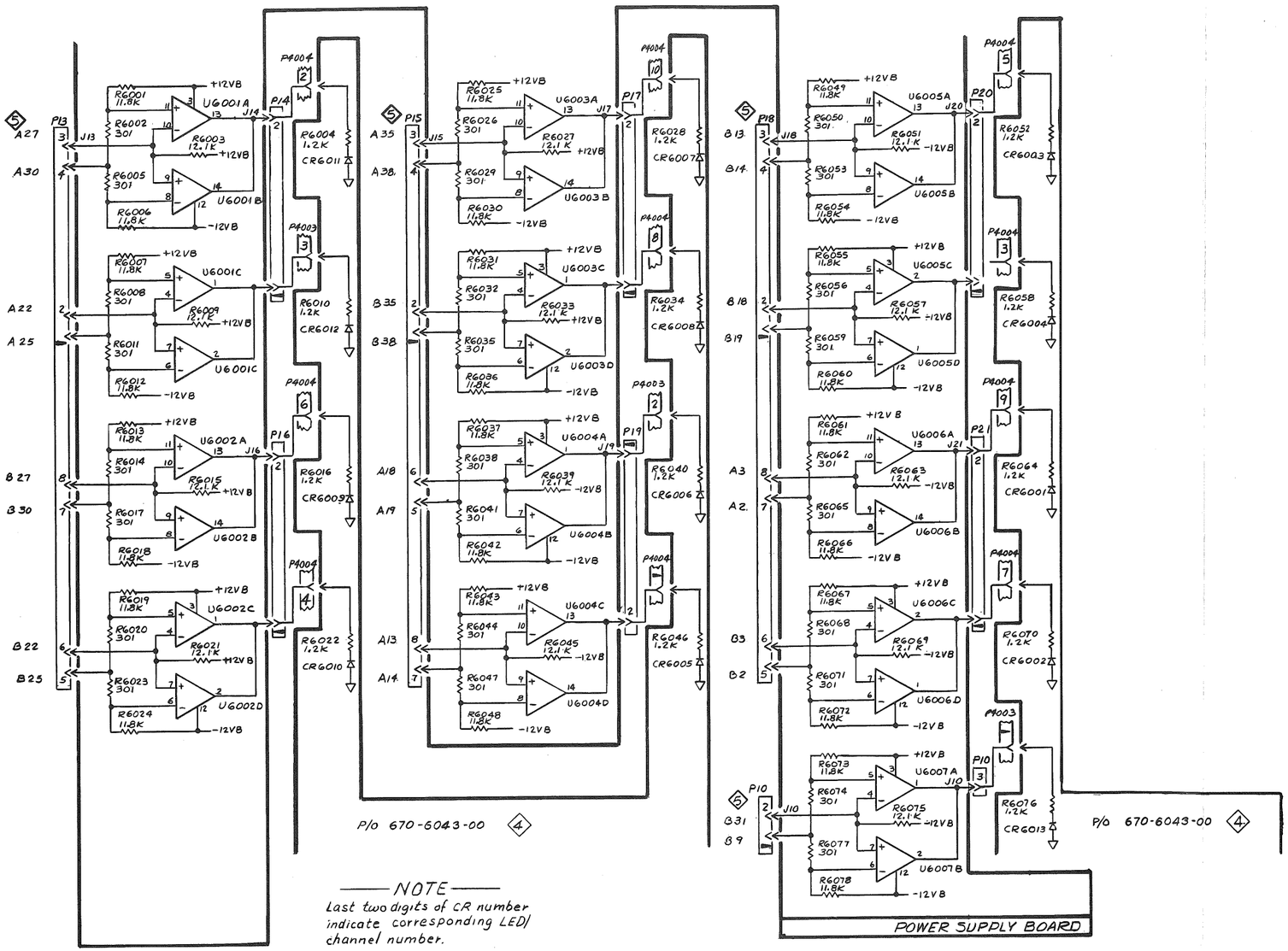
Q3008 -0373

U3001 & U3006, Q3001, Q3004 Q3005 & Q3008 HEATSUNK FROM 670-6049-00 ARE PHYSICALLY LOCATED ON THE POWER SUPPLY CHASSIS.

POWER SUPPLY 3a

REV D 9-79

067-0883-99



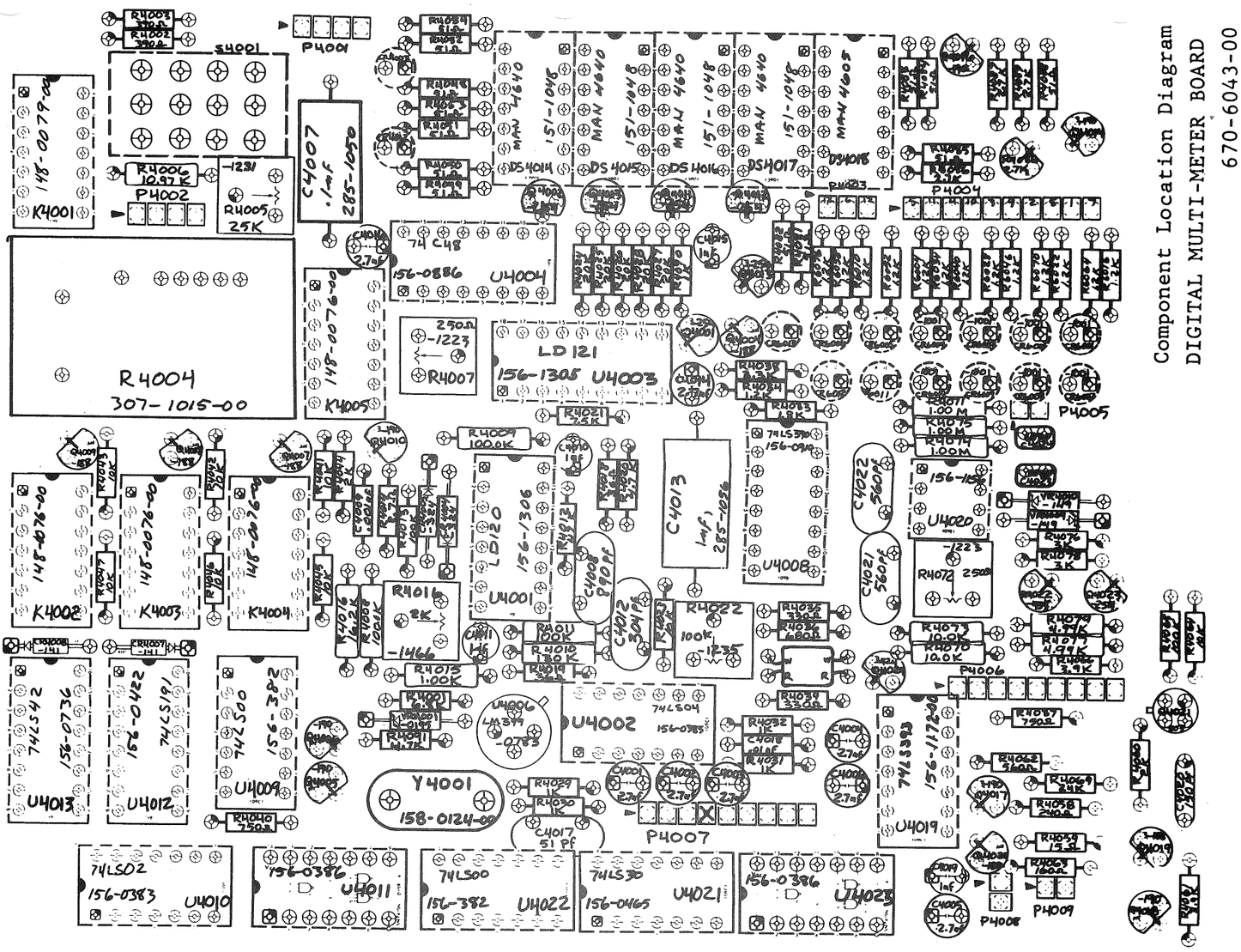
NOTE

Last two digits of CR number indicate corresponding LED/ channel number.

067-0883-99

PARTIAL POWER SUPPLY 3b

REV C, 6-79


Component Location Diagram
DIGITAL MULTI-METER BOARD
670-6043-00
SW001
P4001
P4002
P4004
P4005
P4006
P4007
P4008
P4009
K4001
K4002
K4003
K4004
K4005
R4004
307-1015-00
C4007
.1mf
285-1050
LD120
156-1306
U4001
LD121
156-1305
U4003
74C48
156-0886
U4004
C4013
1mf
285-1056
U4008
U4020
U4002
U4019
U4013
U4012
U4009
U4010
U4011
U4022
U4021
U4023
Y4001
158-0124-00
DS4014
DS4015
DS4016
DS4017
DS4018
MAN 4640
MAN 4610
MAN 4005
151-1048

P4007
N/C
J6-3
J2-1
J6-2
J6-1
J11-1
P2121-3
J11-2
J11-3
+12V A
+5V A
-12V A
+12V B
+5V B
-12V B
C4002
C4001
C4003
2.7μf (6)
C4004
C4005
C4006
CHOP ENABLE
RIPPLE OUT -
RIPPLE OUT +
P4001
P4002
C4007 .1
S4001D
S4001A
VOLTAGE/CURRENT
HEATSINK GROUND NEAR THERMAL SWITCH
R4004
900K 90K 9K 900Ω 90Ω 10Ω
9M
K4002
K4003
K4004
K4005
R4001 6.8K
VR4001 5.1V
CR4002 V-LED
CR4003 I-LED
R4002 390
R4003 390
S4001B
R4005 I OFF SET 25K
R4006 10.97K
R4007 250 I GAIN
R4009 100.00K
R4010 30.05K
R4011 100.00K
C4008 820pf
R4012 47K
K4001 K1
R4008 100.0K
CR4004
CR4005
R4013 100K
C4009 .001
R4014 2.7
R4015 1.00K
R4016 2K V GAIN
R4017 14.2K
U4006
C4010
C4011
R4018 36
R4019 36
R4020 4.7K
C4012 304pf
C4013 1μf
R4022 100K
U4002A
V OFF SET
R4023 10K
R4021 7.5K
U4001 LD 120 (16 PIN DIP) A-D CONVERTER
LSD
MSD
U4003 LD 121 (18 PIN DIP) A-D CONVERTER
PIN 4 U4011C
PIN 10 U4022A
PIN 9 U4011B
PIN 13 U4023A
Q4001
C4014 2.7μf
C4015 1μf
R4024 20K (5)
R4025
R4026
R4027
R4028
1.5V
BCD OUTPUT LINES
C4016 2.7
U4004 74C48 BCD-7 SEGMENT DECODER
R4048 51 (7)
R4049
R4050
R4051
R4052
R4053
R4054
Q4002
Q4003
Q4011
Q4012
Q4013
Q4014
Q4015
Q4016
DS4014 MAN-4640
DS4015
DS4016
DS4017
DS4018 MAN-4603
R4081 51
R4082 51
R4083 51
R4084 51
R4085 51
R4086 2.7K
R4087 2.7K
R4088 51
R4089 2.7K
R4090 1K
R4091 4.7K
Y4001 2.4576 mHz
245.76 KHz
÷10
÷100
U4008 74LS390 CLOCK
R4029 1K
R4030 1K
R4031 1K
R4032 1K
C4017 51pf
C4018 .01
U4002 B
U4002 C
U4002 D
T4001
+2 -2 (+5VB ONLY ON CHOP MODE)
R4035 330
R4036 680
R4037 750
R4039 330
C4019
÷256 U4019 COUNTER
Q4024
Q4017
Q4018
Q4019
Q4020
Q4021
R4058 240
R4059 15
R4060 2K
R4061 3.9K
R4062 560
R4063 160
R4064 10K
R4065 100K
C4020 150pf
R4066 3.9K
R4069 24K N/C
R4033 1.8K
R4034 1.2K
Q4004
R4038 3.3K
-12V A
Q4005
Q4006
R4040 750
U4009A (LS00)
U4009B
U4009C
U4009D
U4010A (LS02)
U4010B
U4010C
U4010D
U4011A (LS10)
OVERFLOW INHIBIT
UNDERFLOW INHIBIT
UNDER
OVER
U4012 74LS191 U/D COUNTER
CLK
E
U/D
QB
QA
U4013 74LS42 BCD-DECADE DECODER
Q3 Q2 Q1 Q0
Q4007
Q4008
Q4009
Q4010
R4041 10K
R4042 10K
R4043 10K
R4044 2K
R4045 10K
R4046 10K
R4047 10K
K4001
K4002
K4003
K4004
K4005
CR4007
CR4008
J4002
P4008
SYNC 96 Hz
P/O P4006 10F
EXT IN
J4003
P4005
CURRENT LIMIT
S4067
S4010
8R ROTOR
1R STATOR
8R STATOR
P4009
P2121-1
P2121-2
CURRENT ADJUST
R4067A 5K
R4068 12K
R4067B 5K
R4080 150K
EXTERNAL INPUT AMPLIFIER
C4021 560pf
R4070 10.0K
R4074 1.00M
R4076 3K
R4077 4.99K
C4023 1.0pf
R4071 1.00M
R4072 250
C4022 560pf
R4073 10.0K
C4024 1.0pf
R4075 1.00M
R4078 3K
R4079 4.99K
U4020
VR4009 10V
VR4010 10V
Q4022
Q4023
U4021 (LS 30)
U4003-1 (D2)
U4003-17 (D4)
U4003-18 (D3)
U4022A
U4022B
U4022C
U4023A
U4023B
U4011B
U4011C
PIN 16 LD121 D5
S4001C
P/O P4006 1R ROTOR
VOLTAGE/CURRENT
P/O 670-6043-00
F = FLOATING GROUND
067-0883-99
DIGITAL MULTI-METER BOARD 4
REV C 7-79

PARTIAL INTERCONNECT BD

CARD EDGE CONNECTIONS

PARTIAL INTERCONNECT BD

CH 13

R-LOAD

R5096 .1Ω

* REAR PANEL CONNECTOR
= USER SELECTED
= SOLDER PADS

CHAN 1 | CHAN 2 | CHAN 3 | CHAN 4 | CHAN 5 | CHAN 6

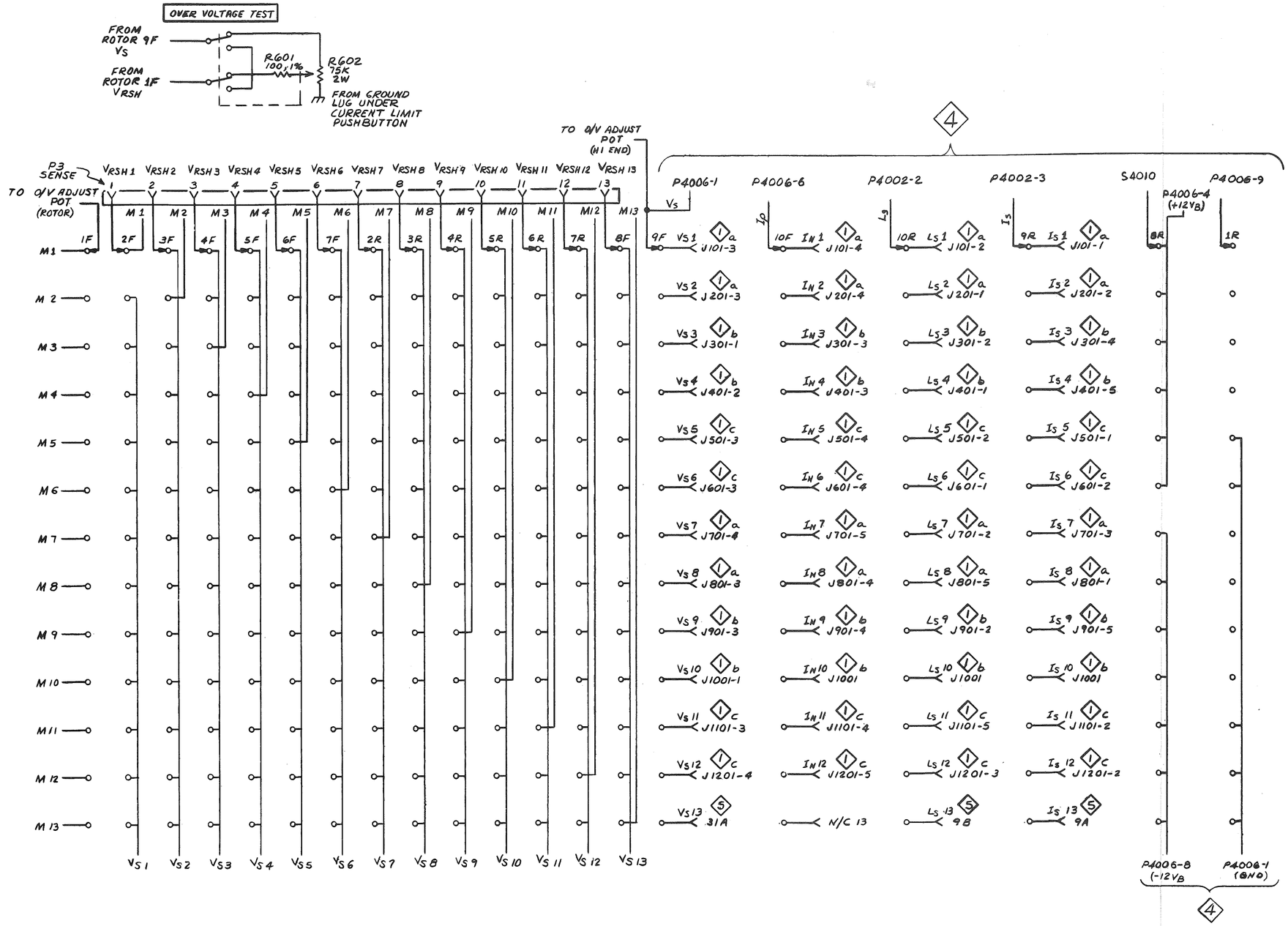
CHAN 7 | CHAN 8 | CHAN 9 | CHAN 10 | CHAN 11 | CHAN 12

P/O 670-6047-00

P/O 670-6051-00
INTERCONNECT BD

067-0883-99

PLUG-IN MODULE
PROGRAM BOARD 5
REV C 6-79



067-0883-99

CHANNEL SELECT & OVERVOLTAGE TEST SWITCHES 6

REV B 6-79

APPENDIX A

PROGRAMMING PLUG-IN MODULE

General

The following paragraphs describe the Programming plug-in module (unprogrammed) Tektronix part number 067-0919-99, that is included with the Universal Load Unit.

This module is a 2.48" X 4.54" X 13.5" metal framework box enclosing a circuit board. The module's front surface is featureless except for a pull-to-release handle. The edge connector on the circuit board protrudes from the rear of the module and is used as the electrical mating connector when the plug-in is installed into the Universal Load Unit.

The Programming Plug-in module may be modified to program a Load Unit to facilitate performance checking the power supplies in a specific Tektronix instrument. This modification process includes the selection of four precision resistors for each supply to be tested. A guide to program resistor selection with specific examples is given in the following pages.

This appendix also includes a schematic diagram, a component location diagram and a complete parts list of the Programming Plug-in module.

PROGRAM RESISTOR SELECTION

Introduction

Each of the twelve active channels of the Universal Load Unit has associated with it four selectable precision resistors. The Comparison and Desensitizing resistors control the operation of the OUT-OF-REGULATION indicators, while the High and Low resistors control the loading levels.

Each channel is programmed to produce a high or low load, depending on the positions of the CHOP/SWITCH control, the HI/LOW/INDividual LOAD SELECT control, and (in the INDividual position) the individual MAX/MIN switches. Depending on whether the Constant Current or Resistive modes of power supply loading are desired, either the R_P or the R_F High and Low resistors (but not both) are selected. The High and Low resistors need not be selected in the same mode, however. For example, an R_{PH} and an R_{FL} may be used in the same channnel if a high constant current load and a low resistive load were desired.

Channel 13 only has two selectable resistors associated with it, R-Comparison and R-Load. R_{Load} is a direct load resistor whose value is determined by dividing the power supply voltage by the desired load current. R_{Comp} is the same as in the other twelve channels, except that it must have a positive input.

Equations

The following equations govern the operation of the Comparator circuits which provide input to the OUT-OF-REGULATION indicators:

$$R_{Comp}(\text{in k ohms}) = V_s$$

$$\% \text{ Tolerance (nominal)} = \frac{30}{V_s} + 2.5$$

$$R_{Des} = \frac{30}{\% \text{ Tol.} - \frac{30}{V_s} - 2.5}$$

Where: R_{Comp} = Comparator Resistor

V_S = Supply Voltage

% Tolerance Nominal = % Tolerance with no "R_{Des}" used

R_{Des} = Desensitizing Resistor

The following equations define the relationships betweeen the High and Low resistor values, the voltage of the power supply being loaded and the desired High and Low load currents:

High Current Cells - $$R_p(\text{in k ohms}) = \frac{249}{I_S}$$

$$R_f(\text{in k ohms}) = 24.9\left(\frac{V_S}{I_S} - .01\right)$$

Medium Current Cells - $$R_p(\text{in k ohms}) = \frac{100}{I_S}$$

$$R_f(\text{in k ohms}) = 10\left(\frac{V_S}{I_S} - .01\right)$$

Low Current Cells - $$R_p(\text{in k ohms}) = \frac{20}{I_S}$$

$$R_f(\text{in k ohms}) = 2\left(\frac{V_S}{I_S} - .1\right)$$

Channel 13 - $$R_{Load}(\text{in ohms}) = \frac{V_S}{I_S}$$

Where:

R_p = Resistor value for a constant current load

R_f = Resistor value for a constant resistance load

R_{Load} = Resistor value for channel 13

V_s = Supply voltage

I_s = Desired load current

Getting Started

When programming a Universal Load Unit for multiple supplies, start with those which require the largest load or which have the highest voltages, as they generally pose the biggest problems.

To ascertain the limitations of a given cell, consult the appropriate Safe Operating Area Curve (at the end of this procedure). These graphs illustrate which combinations of current and voltage a given cell can handle without exceeding its power dissipation capacity.

If no cell can handle the desired current alone, cells may be paralleled to achieve the desired load.

Paralleling Two Cells

Before two cells may be paralleled, at least two conditions must exist: both cells must be of the same polarity and both cells must be operated within the permissible regions of their Safe Operating Area Curves.

It is also important to attempt to share the load so that both cells are operating at about the same percentage of their full power capability. Also, if any cell is to be operated above 80% of its capacity, the fans must be allowed to run full time. (Remove the jumper at the P3 sense connector to cause the fan to run constantly).

The rotary switch will sense the same total applied voltage in either cell's position, but senses current only for that individual cell. Hence, it will be necessary to add the currents measured for each cell to find the total current for that power supply. The OVER VOLTAGE TEST control will only function in conjuntion with the one cell which is being sensed.

WARNING

Do **not** parallel remote sense lines. The voltage may be sensed on either line, but not on both. Failure to heed this warning can lead to catastrophic failure of the instruments involved.

Channel 13

Channel 13 should **only** be used with **positive supplies** whose output is **less than 350 volts.** It must be used when a supply exceeds the Safe Operating Area Curve for the low current cell. Maximum current is **1A** and maximum power is **10W.**

An Example

A hypothetical power supply has the following outputs and load requirements:

Supply Voltage	Low I (Amps)	High I (Amps)	Mode
+15.0	1.0	3.0	Constant I
+50.0	0.39	0.8	Constant I
-5.2	20.8	32.4	Resistive
+130	0.022	---	Resistive

The -5.2 volt supply should attract our attention first because it has the largest current requirement. Consulting the Safe Operating Area Curve for high current cells, we find that the maximum safe operating current at 5.2 Volts is about 23 Amps, while we need to be able to handle 32.4 Amps. By consulting the Safe Operating Area Curve for medium current cells, we learn that the remaining 9.4 Amps will not require an additional high current cell, but will fit within the 10 Amps available in a medium current cell at 5.2 Volts.

Medium current cells have a maximum power capacity of 52W at 5.2 volts, while high current cells have a maximum current capacity of about 120W at 5.2 volts. The total power capacity available at 5.2 volts is then 172W. We need 5.2V x 32.4A = 168.5W. Each cell should then be operated at

about 98% of capacity (168.5/172). Putting 10 amps in the medium cell and 22.4 amps through the high current cell is an adequately equal division of the power. This represents 100% and 97% capacity respectively, and will necessitate the removal of the jumper between P3-16 and P3-36 to provide continuous cooling fan operation. The relevant equations follow:

Cell 8, High Current:

$$R_{fl8} = 24.9\left(\frac{V_s}{I_s} - .01\right) = 24.9\left(\frac{5.2}{20.8} - .01\right) = 5.98k$$

$$R_{fh8} = 24.9\left(\frac{V_s}{I_s} - .01\right) = 24.9\left(\frac{5.2}{22.4} - .01\right) = 5.53k$$

Cell 9, Medium Current:

$$R_{fl9} = 10\left(\frac{V_s}{I_s} - .01\right) = 10\left(\frac{5.2}{5.0} - .01\right) = 10.3k$$

$$R_{fh9} = 10\left(\frac{V_s}{I_s} - .01\right) = 10\left(\frac{5.2}{10} - .01\right) = 5.1k$$

Comparison Resistors:

$$R_{Comp8} = R_{Comp9} = V_s = 5.2k$$

Out-of-Regulation Tolerance:

$$\%\ \text{Tol (no } R_{Des}) = \frac{30}{V_s} + 2.5 = \frac{30}{5.2} + 2.5 = 8.3\%$$

For now, let us assume that this OUT-OF-REGULATION tolerance is satisfactory. When it is not, refer to the section of this appendix (below) entitled "Desensitizing".

Returning to our example, the +130 volt supply, as a relatively high voltage and low current power supply, may require special treatment and should be examined next. Examination of the Safe Operating Area Curve for Low Current Cells discloses that these cells can supply a load of 0.2 amps at their limit of 160 volts. Our requirement is only for 0.022 amps, however, and this may require a different analysis. The equations for current accuracy follow:

Current Accuracy (low and medium cells) = $\pm$ 1.0% $\pm$ 0.25% x $I_{cell\ max}$

Current Accuracy (high current cells) = $\pm$ 1.0% $\pm$ 0.5% x $I_{cell\ max}$

Specifically, in our case:

Current Accuracy (low cell) = $\pm$(0.022A x 1%) $\pm$(0.25% x 2A) = $\pm$ 0.00522A

Expressed as a percentage of the desired current this is:

$$\%\ \text{Current Accuracy} = \frac{0.00522}{0.022A} = \pm\ 24\%$$

At such low currents the percentage accuracy has become intolerable and we would be better off using a simple direct load resistor rather than a low current cell. Substituting into the channel 13 equations, we have:

$$R_{Load}(\text{in ohms}) = \frac{V_S}{I_S} = \frac{130}{.022} = 5909\ \text{ohms}$$

$$R_{Comp13} = V_S = 130k$$

The +15 volt supply will require a medium current cell, since its high current requirement exceeds the capacity of a low current cell. Note that the requirement is for a constant current, rather than a resistive, load. Therefore, we will be substituting into equations of the constant current form:

$$R_{pl3} = \frac{100}{I_S} = \frac{100}{1.0} = 100k$$

$$R_{ph3} = \frac{100}{I_s} = \frac{100}{3.0} = 33.3k$$

$$R_{Comp3} = V_s = 15.0k$$

$$\%\ Tol\ (no\ R_{Des}) = \frac{30}{V_s} + 2.5 = \frac{30}{15.0} + 2.5 = 4.5\%$$

The remaining power supply, +50 volts, with its low current requirement, should go to a low current channel, say 5. Again constant current loading is called for and the equations are:

$$R_{pl5} = \frac{20}{I_s} = \frac{20}{0.039} = 51.3k$$

$$R_{ph5} = \frac{20}{I_s} = \frac{20}{0.8} = 25.0k$$

$$R_{Comp5} = V_s = 50.0k$$

$$\%\ Tol\ (no\ R_{Des}) = \frac{30}{V_s} + 2.5 = \frac{30}{50.0} + 2.5 = 3.1\%$$

Desensitizing

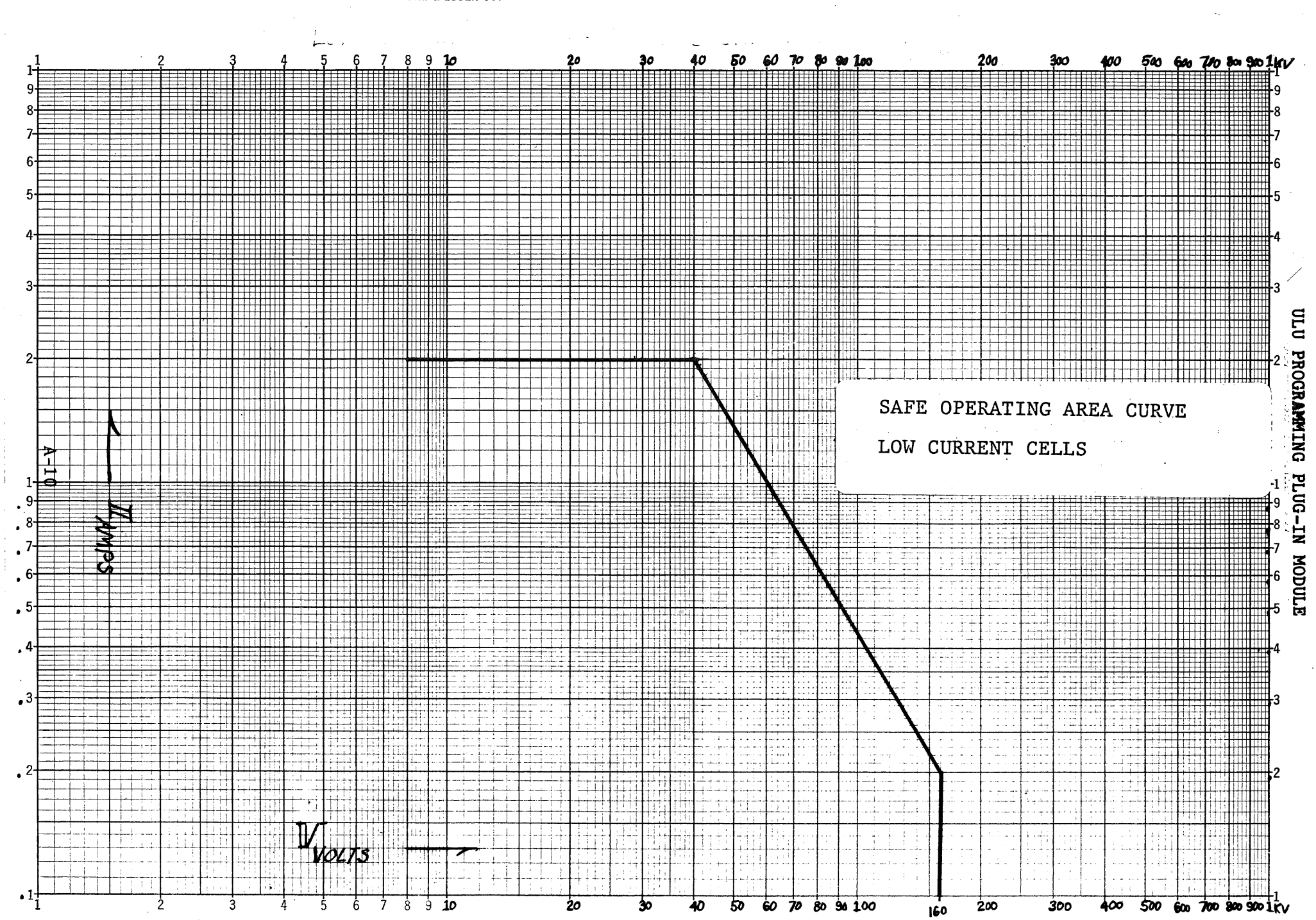
If the Out-of-Regulation tolerance generated by the comparison circuitry is inadequate, the tolerance window can be opened by using R_{Des}. In fact, channels which are not being used can have their OUT-OF-REGULATION indicators disabled by the installation of shorts in the R_{Des} location of those channels.

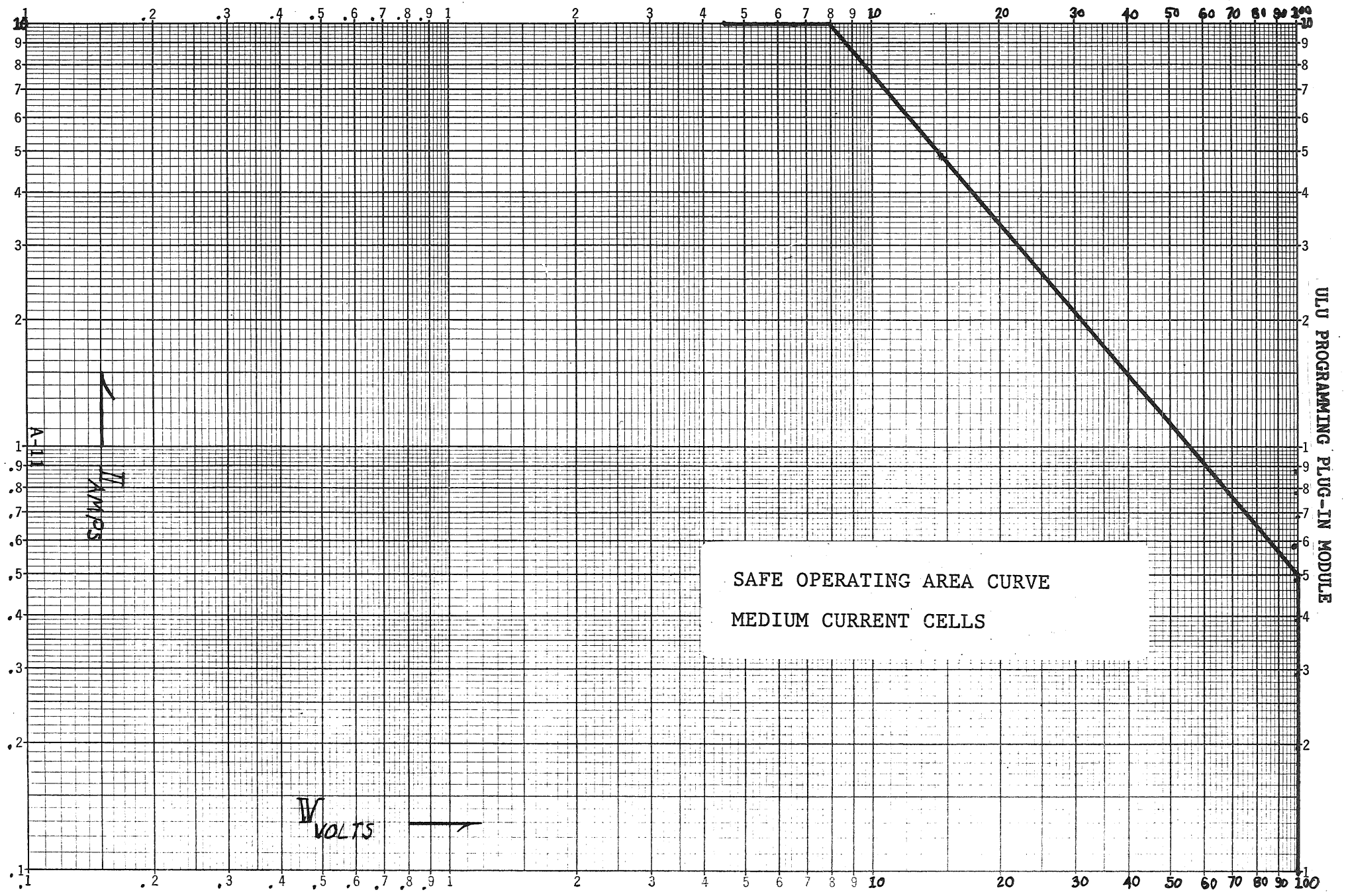
The following equation indicates how the value of the desensitizing resistor is related to the supply voltage and the desired tolerance percentage:

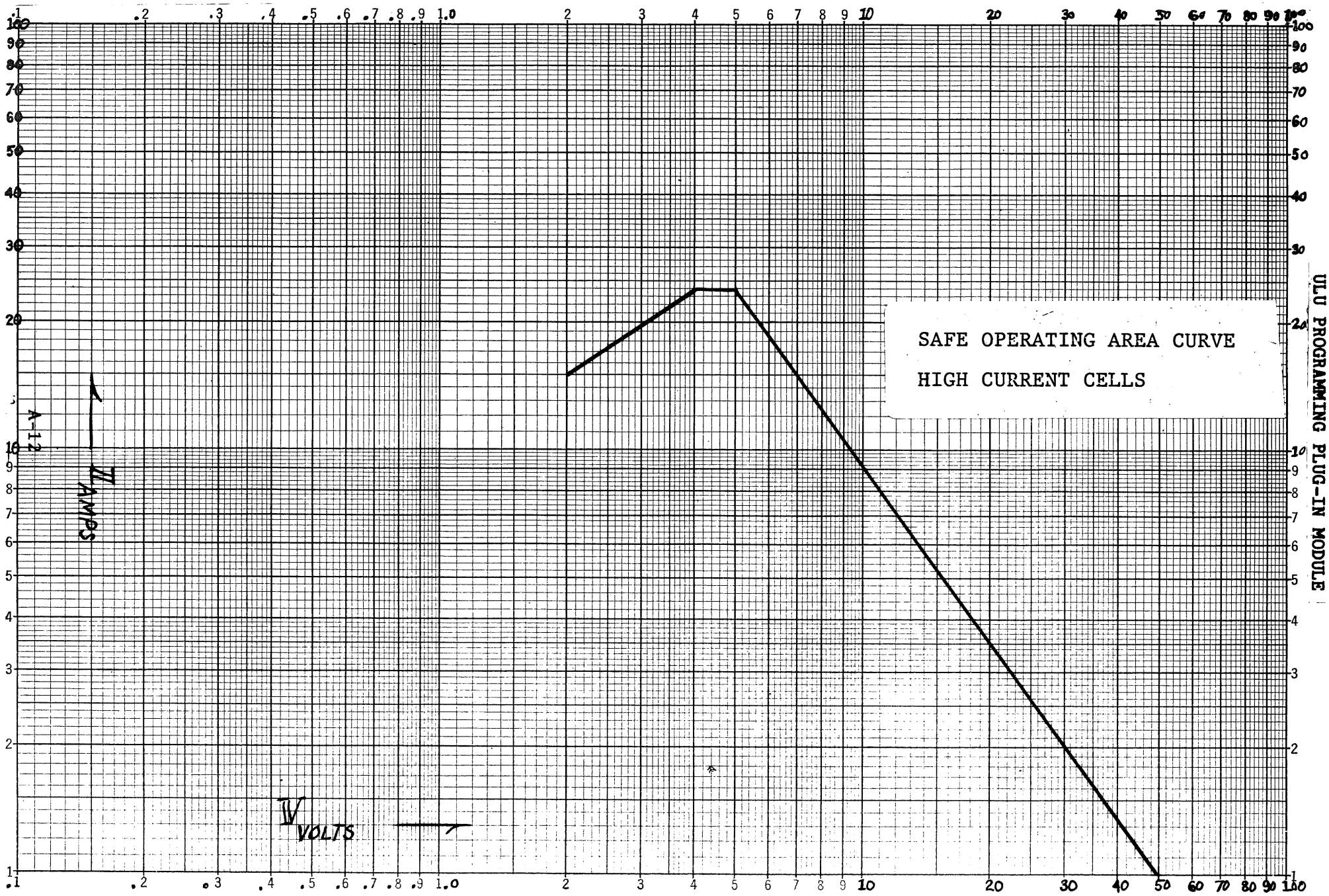
$$R_{Des} = \frac{30}{\%\ Tol. - \frac{30}{V_s} - 2.5}$$

In the example above the nominal percentage tolerance of the comparison circuitry in channel five was calculated to be 3.1%. If that were inappropriate to that +50 volt supply, and a tolerance of 10% were desired instead, we would substitute those values to obtain:

$$R_{Des5} = \frac{30}{10 - \frac{30}{50.0} - 2.5} = 4.35k$$


SAFE OPERATING AREA CURVE
LOW CURRENT CELLS
I AMPS
V VOLTS
A-10
ULU PROGRAMMING PLUG-IN MODULE
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1KV
160


SAFE OPERATING AREA CURVE
MEDIUM CURRENT CELLS
I AMPS
V VOLTS
A-11
ULU PROGRAMMING PLUG-IN MODULE


SAFE OPERATING AREA CURVE
HIGH CURRENT CELLS
I AMPS
V VOLTS
A-12
ULU PROGRAMMING PLUG-IN MODULE

REPLACEABLE PARTS LIST

PROGRAMMING PLUG-IN (UNPROGRAMMED) CHASSIS ASSEMBLY

067-0919-99

Tektronix Part No.	Quantity	Description
670-6047-00	1	ECB, Programming plug-in, Unprogrammed (Complete)
131-0097-00	2	CONNECTOR, Female, 32 Contact
131-0293-00	1	CONNECTOR, Male, 36 Contact
200-0551-00	1	COVER, Plug-in ext, Plastic
333-1367-00	1	PANEL, Front
386-1447-47	1	SUBPANEL, Front
386-1402-04	1	SUBPANEL, Rear
386-3657-01	1	SUPPORT, Plug-in
426-0499-07	1	FRONT SECTION, Plug-in, Bottom
426-0505-07	1	FRONT SECTION, Plug-in, Top
337-1064-04	2	SHIELD, Elec, Plug-in Side
348-0235-00	2	SHIELD GASKET, Elec.
366-1058-00	1	KNOB, Gray, 0.625 x 0.255 x 0.485 in.
105-0075-00	1	BOLT, Latch
105-0076-02	1	RELEASE BAR, Latch
214-1095-00	1	PIN, Spring, 0.187 L x 0.1 OD, Stl-Cd-Pl
214-1280-00	1	SPRING, Helical, Music Wire
214-1054-00	1	SPRING, Flat
214-1061-00	1	CONTACT, Elec, Cu-Be
211-0105-00	6	SCREW, 4-40 x 0.188, Flathead
211-0116-00	6	SCREW, 4-40 x 0.312, Double Sems
213-0192-00	7	SCREW, 6-32 x 0.500, Fillisterhead
220-0547-01	6	NUT, 4-40
334-3663-01	1	MARKER, I.D.
334-1378-00	1	MARKER, I.D., Ser. No.
004-0748-00	1	BOX, Shipping, 19.55 x 9.0 x 9.55 in.
004-0241-00	2	CUSHION MATL, Pkg, 1/2
004-0243-00	1	CUSHION MATL, Pkg, End Cap, Front
004-0242-00	1	CUSHION MATL, Pkg, End Cap, Rear

ELECTRICAL PARTS LIST

PROGRAMMING CIRCUIT BOARD (UNPROGRAMMED)

670-6047-00

Circuit No.	Tektronix Part No.	Description
	670-6047-00	ECB, Programming plug-in, Unprogrammed (Complete)
CR5001, 5002, 5005, 5006, 5010, 5011, 5015, 5016, 5020, 5021, 5025, 5026, 5030, 5031, 5035, 5036, 5040, 5041, 5045, 5046, 5050, 5051, 5055, 5056	152-0141-02	DIODE, 1N4152, Signal, Si.
Q5011, 5012, 5021, 5022, 5031, 5032, 5041, 5042, 5051, 5052, 5061, 5062, 5071, 5072, 5081, 5082, 5091, 5092, 5101, 5102, 5111, 5112, 5121, 5122	151-0188-00	TRANSISTOR, 2N3906, Signal, PNP, Si.
Q5013, 5014, 5023, 5024, 5033, 5034, 5043, 5044, 5053, 5054, 5063, 5064, 5073, 5074, 5083, 5084, 5093, 5094, 5103, 5104, 5013, 5014,	151-0190-00	TRANSISTOR, 2N3904, Signal, NPN, Si.

ELECTRICAL PARTS LIST

PROGRAMMING CIRCUIT BOARD (UNPROGRAMMED) (Cont.)

670-6047-00

Circuit No.	Tektronix Part No.	Description
5123, 5124		
Q5015, 5016, 5025, 5026, 5035, 5036, 5045, 5046, 5055, 5056, 5065, 5066, 5077, 5078, 5087, 5088, 5097, 5098, 5107, 5108, 5117, 5118, 5127, 5128	151-0443-00	TRANSISTOR, MPSA92, Signal, PNP, Si.
Q5017, 5018, 5027, 5028, 5037, 5038, 5047, 5048, 5057, 5058, 5067, 5068, 5075, 5076, 5085, 5086, 5095, 5096, 5105, 5106, 5115, 5116, 5125, 5126	151-0444-00	TRANSISTOR, MPSA42, Signal, NPN, Si.
R5001, 5002, 5018, 5019, 5035, 5036, 5051, 5052, 5066, 5067, 5081, 5082, 5109, 5111, 5125, 5127, 5141, 5143, 5157, 5159, 5173, 5175, 5189, 5191	321-0289-00	RESISTOR, 10.0K, 1/8W, 1%, Mtl. Flm.

ELECTRICAL PARTS LIST

PROGRAMMING CIRCUIT BOARD (UNPROGRAMMED) (Cont.)

670-6047-00

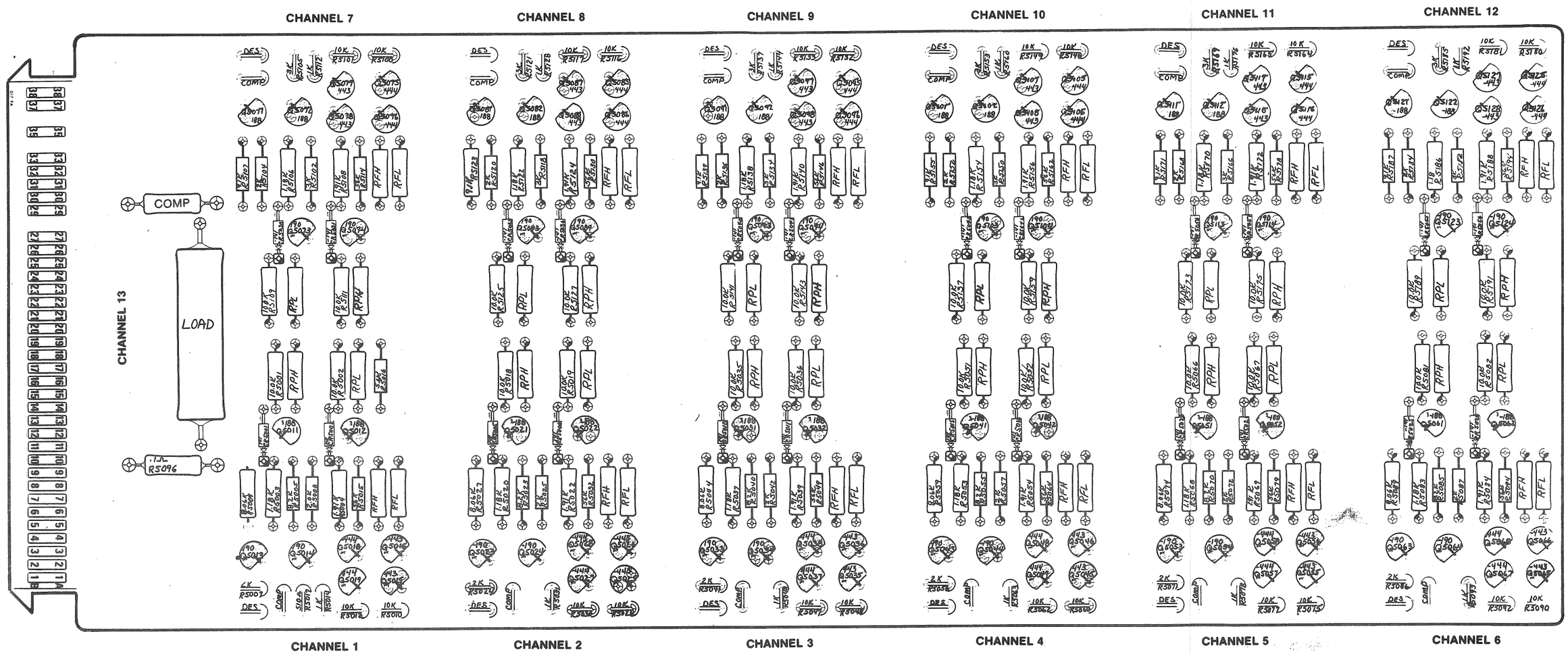
Circuit No.	Tektronix Part No.	Description
R5003, 5020, 5037, 5053, 5068, 5083, 5106, 5122, 5138, 5154, 5170, 5186	321-0200-00	RESISTOR, 1.18K, 1/8W, 1%, Mtl. Flm.
R5004, 5022, 5039, 5054, 5069, 5084, 5108, 5124, 5140, 5156, 5172, 5188	321-0220-00	RESISTOR, 1.91K, 1/8W, 1%, Mtl. Flm.
R5005, 5023, 5040, 5055, 5070, 5085	315-0822-00	RESISTOR, 8.2K, 1/4W, 5%, Carbon
R5007, 5024, 5041, 5056, 5071, 5086, 5104, 5120 5136, 5152, 5168, 5184	315-0202-00	RESISTOR, 2K, 1/4W, 5%, Carbon
R5008, 5025, 5042, 5057, 5072, 5087,	321-0222-00	RESISTOR, 2.00K, 1/8W, 1%, Mtl. Flm.
R5009, 5027, 5049, 5059, 5074, 5089	321-0280-00	RESISTOR, 8.06K, 1/8W, 1%, Mtl. Flm.
R5010, 5012, 5028, 5030, 5045, 5047, 5060, 5062, 5075, 5077, 5090, 5092, 5100, 5101, 5116, 5117, 5132, 5133,	315-0103-00	RESISTOR, 10K, 1/4W, 5%, Carbon

ELECTRICAL PARTS LIST

PROGRAMMING CIRCUIT BOARD (UNPROGRAMMED) (Cont.)

670-6047-00

Circuit No.	Tektronix Part No.	Description
5148, 5149, 5164, 5165, 5180, 5181		
R5014, 5031, 5048, 5063, 5078, 5093, 5112, 5128, 5144, 5160, 5176, 5192	315-0102-00	RESISTOR, 1K, 1/4W, 5%, Carbon
R5016	315-0562-00	RESISTOR, 5.6K, 1/4W, 5%, Carbon
R5017	315-0511-00	RESISTOR, 510, 1/4W, 5%, Carbon
R5032, 5049, 5064, 5079, 5094, 5114, 5130, 5146, 5162, 5178, 5194, 5015	315-0563-00	RESISTOR, 56K, 1/4W, 5%, Carbon
R5096	308-0643-00	RESISTOR, .1 ohm, 3W, 3%, WW
R5102, 5105, 5118, 5121, 5134, 5137, 5150, 5153, 5166, 5169, 5182, 5185	315-0302-00	RESISTOR, 3K, 1/4W, 5%, Carbon
R5107, 5123, 5139, 5155, 5171, 5178	315-0912-00	RESISTOR, 9.1k, 1/4W, 5%, Carbon



Component Location Diagram
PROGRAM BOARD 670-6047-00,
670-6418-00 & 670-6419-00