Sorensen

Instruction Manual for

XT SERIES Power Supply

This manual covers models:

7-6	**60-1**
15-4	**120-0.5**
20-3	**250-0.25**
30-2	

SORENSEN WARRANTY

This unit is guaranteed for five (5) years from the date of delivery against defects in material and workmanship. This does not apply to products damaged through accident, abuse, misuse, or unauthorized repair. The manufacturer shall not be liable for any special or consequential damage of any nature. The manufacturer will repair or replace the non-conforming product or issue credit, at its option, provided the manufacturer's inspection establishes the existence of a defect. Packing, freight, insurance and other charges incurred in returning the defective products to the manufacturer will be paid by the purchaser. The manufacturer will pay return freight if the repaired unit is deemed to be under warranty. If any questions arise concerning the warranty, check with the manufacturer prior to taking any action.

When requesting information, assistance, or authorization, please state the model number and serial number of the unit, available from the label on the unit.

SAFETY WARNINGS AND CAUTIONS

Please review the following points for both personal and equipment safety while operating your power supply.

HIGH ENERGY/HIGH VOLTAGE WARNINGS

Exercise caution when using and servicing power supplies. High energy levels can be stored at the output voltage terminals on all power supplies in normal operation. In addition, potentially lethal voltages exist in the power circuit and the output connector of power supplies which are rated at 40V and over. Filter capacitors store potentially dangerous energy for some time after power is removed. Use extreme caution when biasing the output relative to the chassis due to potential high voltage levels at the output terminals.

AC SOURCE GROUNDING WARNING

Ensure the power supply is connected to a grounded AC outlet with the recommended AC input connector configured for the available line voltage as set out in the manual. There is a shock hazard if the power supply chassis and cover are not connected to an electrical ground via the safety ground in the AC input connector.

OPERATING AND SERVICE PRECAUTIONS

Operate the power supply in an environment free of flammable gases or fumes. Do not use substitute parts or make any unauthorized modifications to the power supply to ensure that its safety features are not degraded. Contact the service technician for service and repair help. Repairs must be made by experienced service technicians only.

CONFIDENTIALITY CLAUSE

The information contained in this document is confidential and is the exclusive property of the manufacturer. It may not be disclosed to any person without the express written consent of the manufacturer.

About This Manual

This manual contains user information for the XT Series DC power supply. It provides information about features and specifications, installation procedures, and basic functions testing, as well as operating procedures for using both standard and multiple supply functions. It also includes a complete set of schematics, circuit descriptions, and parts lists for the assemblies used in the supply.

The manual is designed for users who are familiar with basic electrical laws especially as they apply to the operation of power supplies. This implies a recognition of Constant Voltage and Constant Current operating modes and the control of input and output power, as well as the observance of safe techniques while making supply connections and configuration changes. The detailed schematics and circuit descriptions make it easier to troubleshoot and configure new applications.

Section 1. Features and Specifications	Describes the power supply, lists its features, and provides tables of specifications.
Section 2. Installation	Reviews safety and inspection procedures, then goes through the basic setup. Also includes directions for the testing of basic functions.
Section 3. Load Connection and Operation	Provides procedures for connecting the load, grounding, remote sensing, and for standard operation (Constant Voltage and Constant Current). Series, parallel, and split supply operation is also covered.
Section 4. Theory of Operation	Provides an explanation of the functions within each of the power supply's assemblies.
Section 5. Maintenance	Covers troubleshooting, servicing, and calibration. Lists replacement parts.
Appendix A	Contains the schematic for the supply's component assemblies.

Manual Revisions

The current release of this manual is listed below. Insert pages will update already printed manuals. Reprinted manuals may note any minor corrections and additions on the Manual Changes list (page ii). A new release of the manual is identified by a new release number and printing date and will include all of the additional or corrected information since the last release.

Release 4.2 (2001/06) - contact information change only. Technical information is current to (97/10/31).

Warnings, Cautions, and Notes

Warnings, cautions, and notes are defined and shown like this:

WARNING
Describes a potential hazard which could result in injury or death, or, a procedure which, if not performed correctly, could result in injury or death.

CAUTION
Describes a procedure which, if not performed correctly, could result in damage to data, equipment, or systems.

Note: Describes additional operating information which may affect the performance of the equipment.

Manual Changes

Nothing at this time.

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1. FEATURES AND SPECIFICATIONS

1.1 Description

The XT Series of linear, regulated DC power supplies provides reliable, high performance solutions for a wide variety of laboratory, development, and system applications. The series consists of six basic models that may be purchased as single units or combined as dual, triple, or quadruple configurations containing any combination of models. (See the chart below for a list of available models.)

Low output noise and ripple, excellent line and load regulation, and a wide variety of options, including analog, RS232 standard, or IEEE-488 controlled programming, make the XT Series the first choice in flexible DC power system design.

Table 1.1-1 XT Series Models

Model	Output Voltage	Output Current
XT 7-6	0-7V	0-6A
XT 15-4	0-15V	0-4A
XT 20-3	0-20V	0-3A
XT 30-2	0-30V	0-2A
XT 60-1	0-60V	0-1A
XT 120-0.5	0-120V	0-0.5A
XT 250-0.25	0-250V	0-0.25A

1.2 Features

- Simultaneous digital display of both voltage and current.
- Analog bar graph displays of both voltage and current make it easy to monitor transient changes.
- Ten-turn potentiometer voltage control allows high resolution setting of the output voltage.
- Current adjust potentiometer allows current limiting which is fully adjustable from zero to the rated output.
- Automatic mode crossover into current or voltage mode.
- Impedance-switched remote sensing allows the voltage at the load to be displayed without switch ambiguity.
- Optimized output connections with front panel 5-way binding posts plus rear panel barrier strip make access easy when supply is rack mounted.
- Connect multiple units in parallel or in series. Short-circuit proof outputs.
- Available in single, dual, triple, and quad outputs. Combine with HPD Series power supplies to form mixed units for applications requiring higher output power.

1.3 Options and Accessories

- Internal Analog Programming (APG) Interface for analog signal control of voltage and current, overvoltage protection (OVP), master/slave output tracking, and remote ON/OFF.
- Internal RS232 Interface for serial instrument programming using RS232 protocol.
- Internal GPIB Interface for complete remote digital programming. IEEE-488 standard.
- Single Address Multichannel (SAMI) Interface to serial link supplies at one IEEE-488 address. Complete GPIB programming.
- Optional AC input voltages. Standard is 115V. See Section 1.4.1 Electrical Specifications for a list of input options. AC input cords for use in different countries available.
- Ten-turn current potentiometer (Option M11). Rack mount kit (Option RM).
- Non-standard output configurations. Contact the manufacturer.

1.4 Specifications

Specifications are warranted for an operating ambient temperature of 0-30°C for full rated output. Above 30°C, derate output linearly to zero at 70°C. Table 1.4-2 posts maximum values. Specifications are subject to change without notice.

1.4.1 Electrical Specifications

Electrical specifications are based on the single unit configuration.

Table 1.4-1 Electrical Specifications

Models	**XT 7-6**	**XT 15-4**	**XT 20-3**	**XT 30-2**	**XT 60-1**	**XT 120-0.5**	**XT 250-0.25**
Output Ratings:							
Output Voltage	0-7V	0-15V	0-20V	0-30V	0-60V	0-120V	0-250V
Output Current	0-6A	0-4A	0-3A	0-2A	0-1A	0-0.5A	0-0.25A
Output Power	42W	60W	60W	60W	60W	60W	60W
Line Regulation [1]							
Voltage (0.01% of V max + 2mV)	2.7mV	3.5mV	4mV	5mV	8mV	14mV	27mV
Current (0.01% of I max + 250mA)	0.85mA	0.65mA	0.55mA	0.45mA	0.35mA	0.3mA	0.275mA
Load Regulation [2]							
Voltage (0.01% of V max + 2mV)	2.7mV	3.5mV	4mV	5mV	8mV	14mV	27mV
Current (0.01% of I max + 250mA)	0.85mA	0.65mA	0.55mA	0.45mA	0.35mA	0.3mA	0.275mA
Meter Accuracy							
Voltage (1% of V max + 1 count)	0.08V	0.25V	0.3V	0.4V	0.7V	2.2V	3.5V
Current (1% of I max + 1 count)	0.07A	0.05A	0.04A	0.03A	0.02A	0.006A	0.003A

[1] For input voltage variation from over the AC input voltage range, with constant rated load.
[2] For 0-100% load variation, with constant nominal line voltage.

1.4.1 Electrical Specifications (continued)

AC Input Voltages	Standard: 115Vac ±10%, 57-63Hz Option M1 (Factory-installed): 110Vac ±10%, 47-63Hz Option AC220 220Vac ±10%, 47-63Hz Option AC230 230Vac ±10%, 47-63Hz Option AC240 240Vac ±10%, 47-63Hz
AC Input Current	Single Unit: 1.2A Dual Unit: 2.4A Triple Unit: 3.6A Quad Unit: 4.8A
Output Noise and Ripple (20Hz - 20MHz)	<1mVrms (Voltage mode), <2mArms (Current mode) 250Vmodel: <5mVrms (Voltage mode), <1mArms (Current mode)
Max. Voltage Differential from O/P to safety ground	400Vdc

Additional Characteristics

Table 1.4-2 Additional Characteristics

Models	XT 7-6	XT 15-4	XT 20-3	XT 30-2	XT 60-1	XT 120-0.5	XT 250-0.25
Stability [3]							
Voltage (0.02% of V max)	1.4mV	3mV	4mV	6mV	12mV	24mV	50mV
Current (0.03% of I max)	1.8mA	1.2mA	0.9mA	0.6mA	0.3mA	0.15mA	0.075mA
Temperature Coefficient [4]							
Voltage (0.015% of V max/°C)	1.05mV	2.25mV	3mV	4.5mV	9mV	18mV	37.5mV
Current (0.02% of I max/°C)	1.2mA	0.8mA	0.6mA	0.4mA	0.2mA	0.1mA	0.05mA
Front Panel Voltage Control Resolution(0.02% of V max)	1.4mV	3mV	4mV	6mV	12mV	24mV	50mV

[3] Drift over 8 hours after 30 minute warm up.
[4] Change in output per °C change in ambient temperature, with constant line load.

Operating Ambient Temperature	0-30°C for full rated output. Above 30°C, derate output linearly to zero at 70°C.
Storage Temperature Range	-55 to +85°C
Humidity Range	0-80% RH Non-condensing
Voltage Mode Transient Response Time	<100μs recovery to 0.05% band, for ±50% load change in the range of 25% to 100% of the rated load
Front Panel Control	10-turn voltage and 1-turn current potentiometers (10-turn current control optional)
Front Panel Voltage Control Resolution	0.02% of Vmax
Agency Approvals	CSA CE marked units meet standards: EN5011 (Group 1 Class B) 1991, EN50081-1 1992, EN50082-1 1992.

1.4.2 Mechanical Specifications

Unit	Height	Width	Depth	Weight
Single	132mm (5.25in)	109mm (4.25in)	297mm (11.7in)	4.3kg (9.5lb)
Dual	132mm (5.25in)	216mm (8.5in)	297mm (11.7in)	8.1kg (17.9lb)
Triple	132mm (5.25in)	325mm (12.75in)	297mm (11.7in)	12.0kg (26.3lb)
Quad	132mm (5.25in)	436mm (17.0in)	297mm (11.7in)	16.7kg (36.7lb)

2. INSTALLATION

2.1 Introduction

This section provides inspection and installation procedures as well as some quick electrical checks you can perform to ensure that your supply is in good working order. Refer to the front and rear panel drawings in Figures 2.1-1 and 2.1-2 as needed.

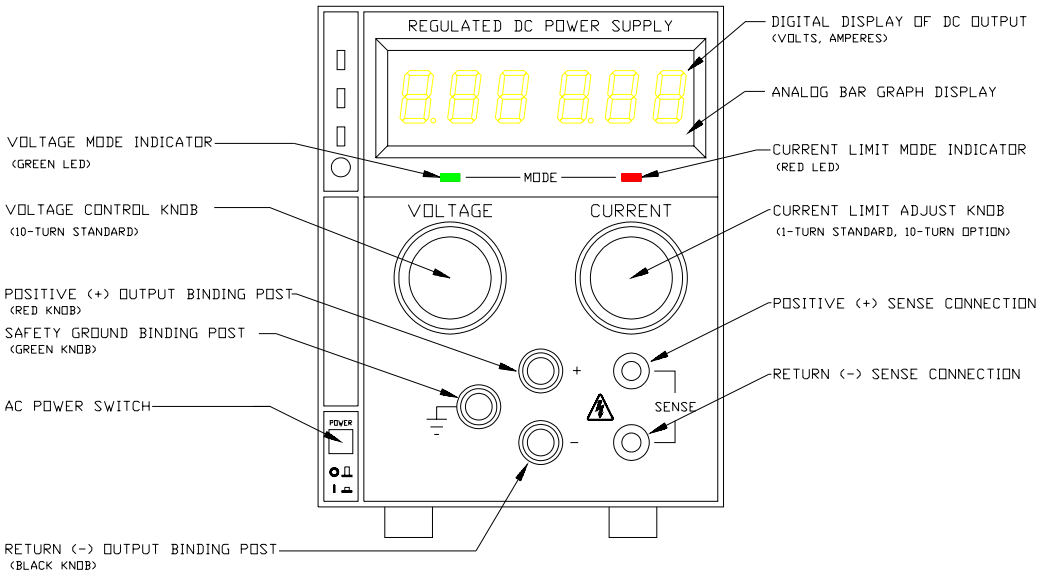

Figure 2.1-1 XT Series Supply Front Panel

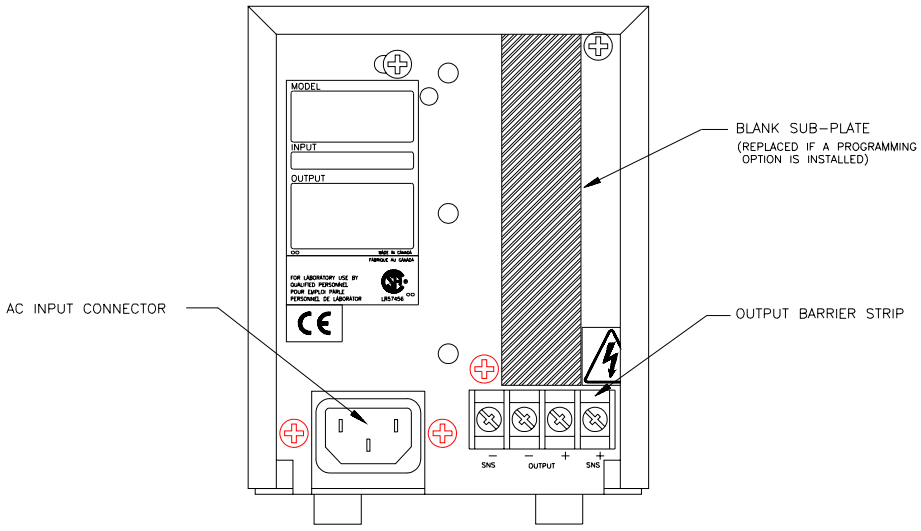

Figure 2.1-2 XT Series Supply Rear Panel

2.2 Initial Inspection

CAUTION
Follow established antistatic procedures. There are static-sensitive parts on the printed circuit boards.

The power supply comes complete with an IEC power cord set and a technical manual. Inspect the equipment for damage as follows:

1. Inspect panel and chassis for dents and other signs of obvious damage.
2. Turn front panel controls from stop to stop. Rotation should be smooth.
3. Push the power switch in to lock it on and lock it off.

If you suspect any internal damage, remove the cover and check the components and printed circuit boards then put the cover back on.

If you find any damage, save all packing materials and notify the carrier immediately. Refer to the terms of the warranty. Direct any repair problems to the manufacturer.

2.3 Indicators, Controls, and Outputs

On the front panel, a voltage mode indicator (green) is located above the voltage control knob. A current limit mode indicator (red) is located above the current limit adjust knob. The front panel voltmeter and ammeter readouts are digital. The red and black binding posts on the front panel are outputs. The green binding post is connected to chassis and line ground. This supply also provides an output barrier strip on its rear panel.

2.4 Ventilation Requirement

Whether installing the power supply on a bench or in a rack, allow a 1U (1.75″) space between units. This allows cooling air to reach the top and bottom of each supply.

2.5 Power On Procedure

1. Before connecting the unit to an AC outlet, make sure the power switch is in the extended (OFF) position and the voltage and current controls are in their fully counter clockwise positions.
2. Ensure the AC line voltage is 115V, 60Hz nominal for a supply designed with the default AC input.
3. Plug the line cord into a grounded AC outlet.
4. Set the POWER switch to ON.

The red current mode LED will light and the display reading zero.

See Section 3.5 for information about Standard Operation.

2.6 Output Biasing

WARNING
Use extreme caution when biasing the output relative to the chassis due to potential high voltage levels at the output terminals.

To bias the output voltage relative to ground, we recommend that you use a 0.01μF capacitor of sufficient voltage rating (200 to 1000V) in place of the shorting connection. You may bias the power supply outputs up to a maximum of +400Vdc with respect to line safety ground.

2.7 Initial Function Tests

2.7.1 Voltage Mode

To check voltage mode operation, proceed as follows:

1. Rotate VOLTAGE and CURRENT controls fully counter clockwise.
2. Connect a DC voltmeter, rated better than 0.5% accuracy, to the front panel binding posts (+ and -).
3. Connect the IEC power cord set to the unit, then to the specified power source.
4. Set the POWER switch to ON
5. Rotate the CURRENT control a 1/2 turn clockwise. Slowly rotate the VOLTAGE control clockwise and observe the digital displays. The control range should be from zero to the maximum rated output. Compare the test meter with the voltage display on the front panel. Observe the bar graph meter to see that it tracks as the voltage rises. Verify that the voltage mode indicator light is ON.
6. Set the POWER switch to OFF.

2.7.2 Current Mode

Then, to check current mode operation, proceed as follows:

1. Rotate VOLTAGE and CURRENT controls fully counterclockwise.
2. Rotate the VOLTAGE control a 1/2 turn clockwise.
3. Connect a DC ammeter between the front panel binding posts (+ and -). Select leads of sufficient current carrying capacity and an ammeter range compatible with the unit's rated current output. The ammeter should have an accuracy of better than 0.5%.
4. Set the POWER switch to ON.
5. Rotate the CURRENT control slowly clockwise. The control range should be from zero to the maximum rated output. Compare the test meter reading with the reading on the front panel current meter. Also check that the current bar graph display follows the rise in current and that the current mode indicator light is ON.
6. Set the POWER switch to OFF.

3. LOAD CONNECTION AND OPERATION

3.1 Introduction

This section covers:

- Single and multiple load connection
- Constant Voltage and Constant Current operating modes
- Alternate power supply configurations such as series and parallel connections

3.2 Load Connection

To obtain a stable, low noise output, pay careful attention to conductor ratings, system grounding techniques AC input, DC output, and remote sensing connections. To overcome impedance and coupling effects, use a conductor size that satisfies the current rating requirements. We recommend using larger gauge wire and short leads.

Note: Protect the power supply from positive load transients (such as back EMF from a motor) by connecting a transorb or a varistor across the output.

Connecting Multiple Loads

We recommend using the Radial Distribution method for proper connection of distributed loads. A single pair of terminals are designated as the positive and negative distribution terminals. This pair of terminals may be the power supply output terminals, the load terminals, or a distinct set of terminals specially established for distribution. Power is connected individually to each load. In this scheme, there are no ground loops and little effect of one load upon the other

Limit use of the Parallel Power Distribution method when connecting distributed loads to low current applications. For Parallel Power distribution, the leads are connected from the power supply to one load, then from that load to another load in. This method can cause DC ground loops because the voltage at each load depends on the current drawn by the other loads.

3.3 Grounding

Use only one ground return point in a power system to avoid developing paths between separate ground points.

To avoid ground loop problems, there must be only one ground return point in a power system. If the load itself is not grounded, you can ground the output binding post (which is connected to the load) to the ground safety binding post on the front of the unit.

3.4 Remote Sensing

Remote sensing shifts the regulation point of the power supply from the output terminals to the load or other distribution terminals. It compensates for voltage losses of up to a total of 0.5 volts in the power leads supplying the load.

Your power supply provides positive and negative sense connections beside the output binding posts on the front panel as well as on the output barrier strip at the rear of the unit. With remote sense leads in place, the supply regulates the displayed voltage at the sense leads termination point.

Remote Sense Lines Connected to Load

The load voltage will stay at the set value as long as the voltage drops in the power leads are less than 0.5V per line, no matter how much current is drawn.

Remote Sense Lines Not Connected to Load

The supply regulates the voltage at the output terminals when the sense lines are not connected to the load.

Notes:

1. Connect the normal power leads to the output terminals when the sense lines are connected BEFORE operating the power supply. Avoid reversing positive and negative lead connections.

2. Always use twisted pair wiring for sense lines to minimize noise effects.

3. Locate the diode in the return (negative) line when using remote sense lines which have a diode in series with the output. This stops sense line protection circuitry being turned on. The return line has approximately a 1V sense drop limit. The positive output line has a 0.5V drop.

3.5 Standard Operation

Your power supply has two basic operating modes: Constant Voltage Mode and Constant Current Mode. The operating mode depends on the combination of:

- Output voltage setting
- Output current limit setting
- Resistance of the attached load

Figure 3.5-1 Operating Modes provides a graphical representation of the relationships between these variables.

Figure 3.5-1 Operating Modes

3.5.1 Constant Voltage Mode Operation

The power supply will operate in constant voltage mode whenever the load current I_L **is less** the current limit setting I_{SET}, or: $\mathbf{I_L < I_{SET}}$ (Note: $I_L = V_{SET} / R_L$). In constant voltage mode, the power supply maintains the output voltage at the selected value (V_{SET}) while the load current I_L varies with the load requirements.

To use the power supply in Constant Voltage mode, either turn the current control to its extreme clockwise position or take the precaution of setting a desired maximum current, then set the voltage control to the desired voltage.

3.5.2 Constant Current Mode Operation

The power supply will operate in constant current mode whenever the load resistance is low enough that the load current I_L is greater than the current limit setting I_{SET}, or: $I_L > I_{SET}$. In constant current mode, the power supply maintains the output current at the selected value (I_{SET}) while the load voltage varies with the load requirements.

Setting the Current Limit

1. Connect a shorting lead across the output terminals.
2. Set the desired maximum value of current limit by turning the current control slowly clockwise to the desired level.
3. Disconnect the shorting lead from the output terminals.

The power supply automatically switches into current limiting mode (current regulation) as soon as the preset current level is reached and will not exceed this level at any voltage setting.

Operating the Supply in Constant Current Mode

1. Set the Current Limit as previously described.
2. Set the voltage control fully clockwise or to the compliance voltage of the circuit.

The red current mode LED turns on when the supply operates in current mode.

3.5.3 Automatic Mode Crossover

The automatic crossover system allows the power supply to automatically switch operating modes in response to changing load requirements. If the load changes while the power supply is operating in Constant Voltage Mode ($I_L<I_{SET}$) so that the load current (I_L) becomes **greater than** the current limit setting (I_{SET}), the power supply automatically switches to Constant Current Mode.

If you remove the additional load so that the load current is **less than** the current limit setting, the supply automatically returns to Constant Voltage Mode.

3.6 Series, Parallel, and Split Supply Operation

You can operate two or more power supplies with outputs in series or in parallel to obtain increased load voltage or current. A split supply configuration allows you to obtain two positive outputs or a positive and a negative output.

3.6.1 Series Operation

Connect power supplies in series to obtain a higher voltage single output supply. Connect the negative (-) terminal of one supply to the positive (+) terminal of the next supply. The total voltage available is the sum of the maximum voltages of each supply (add voltmeter readings).

The maximum current available to the load is equal to the current of the lowest rated supply in the string.

3.6.2 Parallel Operation

CAUTION
To parallel outputs which have overvoltage protection installed, use blocking diodes in series with the outputs.

Connect power supplies in parallel to obtain a higher current single output supply. Set all of the outputs to the same voltage before connecting the positive (+) and negative (-) terminals in parallel. The total current available is the sum of the maximum currents of each supply. The maximum voltage available at the load is equal to the voltage of the lowest rated supply. When you connect two supplies in parallel, the supply with the higher voltage setting will be in current limiting mode, while the other supply controls the output voltage.

3.6.3 Split Supply Operation

Split supply operation is used to obtain two positive voltages with a common ground, or a positive-negative supply.

Obtaining Two Positive Voltages

Connect the negative terminals of both supplies together. The positive terminals will supply the required voltages with respect to the common connection.

Obtaining a Positive-Negative Supply

Connect the negative terminal of one supply to the positive terminal of the second supply. The positive terminal of the first supply provides a positive voltage relative to the common connection. The negative terminal of the second supply provides a negative voltage. The current limits can be set independently. The maximum current available in split operation is equal to the rated output of the supplies used.

Note: The optional Analog Programming Interface has a Master/Slave Tracking feature which will allow single knob control of both supplies in a split supply configuration.

4. THEORY OF OPERATION

4.1 Introduction

This section describes the internal operation of your power supply. It starts with a description of the A2 Assembly power circuit and goes on to cover the A1 Assembly front panel. Use this information when configuring new applications or troubleshooting.

4.2 Power Circuit (A2 Assembly)

Refer to the schematic in Appendix A for the following discussion. You will find the power circuit on the A2 Assembly circuit board.

Raw Supply Section

The power switch, line fuse, and power transformer T1 apply power to the unit. The bridge rectifier CR15 provides two raw supply voltages (V and 2V applied to the collectors of power transistors Q1 and Q2 respectively) and which C16 and C18 to C20 filter.

Auxiliary Supply Section

Isolated secondary windings of T1 also provide power to bridge rectifier CR16 which supplies regulators U4 and U5. U5 and its associated components provide a +14 volt supply voltage, and U4 provides a +5 volt supply for the front panel display circuitry. CR19, and CR18 form a negative voltage doubler circuit supplying regulator U6. U6 provides a -12 volt supply voltage which is stepped down to -6.2 volts by CR17. The -6.2 volts is used to bias the display circuit ICs U102 and U104.

Pass Element Section

7-120V Models
The two raw supply voltages from T1 and CR15 provide output power, controlled by power pass transistors Q1 and Q2 and their associated driver transistors Q4 through Q6. This power stage has two modes of operation. As long as the output voltage required is less than the voltage supplied to the Q1 collector (via CR8), Q1 acts as the pass element.

As the output voltage increases, Q1 begins to saturate and its base current increases sharply. This increases the voltage at the base of Q5 so that Q6 turns on. When Q6 turns on, it supplies base current to Q2 which becomes the pass element. As Q2 becomes the pass element, Q1 is cut off. The amount of base current allowed to flow into Q4 (for a given load) by the voltage and current control circuits regulates the output current and voltage.

250V Models
For 250V models, pass elements Q1 and Q2 are *n-channel enhancement mode field transistors*.

Q4 drives Q6A to bias gates Q1 and Q2 to deliver the correct voltage/current to the output.

Shutdown and Soft Start Circuit

An external shutdown signal on option connector pin P1-9 is able to turn on Q3 and draw current away from the Q4 base via CR11, thus turning off the output of the supply. Similarly, a control ground fault (or return sense line error via U3D) will turn on Q3 via CR7 and turn off the output. Applying -12 volts to CR9 causes a reverse bias across CR10 during normal operation. However, as power is turned off, the -12 volt supply collapses quickly and Q3 is turned on via R34 and CR10. This turns off the output quickly, avoiding output transient surges on power-off.

As the power is turned on, C8 delays turn on of analog gate U1B, which in turn gates U1A on for a short period following power-on. This clamps the input to U3A pin 3 to the negative voltage set by CR3 and R13.
A negative voltage at U3A pin 3 causes U3A to go negative and turn off Q4 via CR6, turning off the output. The time constant of R14 and C8 determines how long the output is held off in this manner during power-on.

Ten Volt Reference Circuit

U2B and CR12 form a precision +10 volt reference circuit. Negative feedback maintains the zener voltage at U2B pin 6 and steps up the zener voltage by the ratio of R44 and R45 to R43. Calibration of R45 thus sets the output to a precise +10 volts which is filtered by C4 and C5. CR13 and R46 ensure normal start up on power-on. The front panel voltage and current controls R119 and R121 use the +10 volt reference and provide 0 to +10 volt adjustable levels to the voltage and current control circuits.

Voltage Control Circuit

The 0 to 10 volt signal from the voltage control (R121) is gated to U3A pin 3 via analog gate U1C. Negative feedback from the output via R8, the positive sense line, and sense resistor R122, sets U3A pin 2 at the same level as U3A pin 3. As the output increases, U3A pin 2 rises, the U3A output goes negative and CR6 draws current away from Q4, returning the output to its regulated level.

Similarly, as the output decreases, U3A pin 2 falls, the U3A output goes positive, CR6 draws less current away from Q4 and the output is returned to its regulated level. (U3B pin 14 is normally high in the voltage regulating mode.). The reference level at U3A pin 3 and the ratio of R8 to the R5 to R7 resistor string set the output level. For a 30 volt model, for example, the ratio of R8 to R5 to R7 is approximately 3:1 and a 0 to 10 volt level at U3A pin 3 results in a 0 to 30 volt level on the output, adjustable by voltage control R121.

Current Control Circuit

Current shunt R26 returns output load current from the output return to power ground. The differential amplifier circuit formed by U3C and its associated components amplifies this current information. The current level is then compared to the setting of the current limit control (R119) at U3B. U1D takes the 0 to 10 volt signal from R119 and gates it to voltage divider R18, R20, and R33 which provides a reference at U3B pin 12.

As the output current exceeds the setting of the current control, U3B pin 13 rises above U3B pin 12, causing U3B to go negative and turning off Q4. This decreases the output until the load current is equal to the regulated level set by R119.

Mode Monitoring Circuit

During voltage mode operation, CR6 is forward biased, while CR6 is reverse biased during current mode operation. Comparator U2A provides a mode indication level at pin 1 by sensing the polarity of the voltage across CR6. This level is used to turn on either the green voltage mode LED (DS131) or the red current mode LED (DS130) on the front panel.

Output Circuit

Connector lines J1-1 through J1-4 connect the output power to the front panel binding posts. The positive and negative sense points for the voltage control circuit are located at J2-8 and J2-9 respectively. It is at these sense points that U3A maintains voltage regulation, so that remote sensing is possible by connecting the positive and negative sense lines to the desired regulation points.

When the sense lines are not connected, R122 and R125 provide default sensing at the power output binding posts. R27 provides the output pre-loading needed to maintain operation of the pass element circuit during light load conditions. CR1 and F1 protect the power supply against reverse biases incorrectly applied to the output.

Return Sense Buffer

U3D buffers the return sense line to provide a buffered control ground point for the voltage control circuit. This allows the proper operation of the output sense protection circuit (Q101 and associated resistors).

Metering Outputs

Resistor divider R23, R24, and R25 provides a calibrated current monitoring signal to the front panel current display circuit. Similarly, resistor divider R5, R6, and R7 provides a calibrated voltage monitoring signal to the front panel voltage display circuit.

Remote Programming Capability

The option connector lines P2-9 and P2-8 may switch the 0 to 10 volt levels from the current and the voltage controls out of the circuit by turning off analog gates U1C and U1A. An option board uses lines P2-1 and P2-2 to remote program the voltage and current control circuits with selected 0 to 10 volt programming levels.

Model Identification

The A2 board also provides model information required by an option board at connector lines P3-4 through P3-7. A coded combination of shorted links at points A, B, and C identifies each model. Logic circuitry on the option board decodes this combination.

4.3 Meter Circuit (A1 Assembly)

Refer to the schematic in Appendix A for the following discussion. You will find the meter circuit on the A1 assembly circuit board.

Voltage Display

The analog input signal from the A2 power board is divided down so that 1mV between P102-7 and P102-5 represents 1 volt at the output of the power supply. R128 and C114 filter this reduced voltage to remove noise and then provide the input to U104, a 3½ digit analog to digital converter. U104 converts the input voltage to a three digit readout on the seven segment LED displays DS104 through DS106. The conversion rate is approximately 3 times per second. (This rate is determined by the value of C106.).

The reference voltage from pin 35 to pin 36 of U104 determines the full scale accuracy of the meter. The 10 volt reference on the A2 board provides the reference voltage via the divider R129, R130, and R131. The bar graph driver IC (U103) and LEDs DS117 through DS126 display transient changes in the output voltage. R104 and R113 determine the full scale reference voltage which corresponds to all ten LEDs being lit.

Current Display

The current metering function is identical to the voltage metering previously described. U102 performs the analog to digital conversion which DS101 through DS103 then display. U101 drives the current bar graph LEDs DS107 through DS116 which display the transient events.

Output and Sense Lines

R122 and R125 connect the remote sense lines internally to the main output terminals.

5. MAINTENANCE

WARNING

Always disconnect power and discharge circuits before replacing components. When servicing the supply, ensure another person with first aid and resuscitation certification is present. Ensure only experienced technical personnel make any repairs.

Use proper static control techniques to avoid damage to front panel display drivers and other static-sensitive parts.

Be sure to isolate the power supply from the input line with an isolation transformer when using grounded test equipment, such as an oscilloscope, in the primary circuit.

5.1 Introduction

This section provides troubleshooting, servicing, and calibration procedures in addition to the parts lists. Use the troubleshooting data in conjunction with the schematics in Appendix A and with the circuit descriptions in Section 4. Refer to the specifications in Section 1 when calibrating your power supply.

5.2 Units Under Warranty

Return units requiring repair during their warranty period to the manufacturer for service. Unauthorized repairs performed by any one other than the manufacturer during the warranty period may void the warranty. Direct any questions regarding the warranty or any repairs to the manufacturer.

5.3 Periodic Servicing

Whenever you remove a unit from service, clean it by using Naphtha or an equivalent solvent on metal surfaces. Use a weak solution of soap and warm water on the front panel. Use compressed air (at 5 psi) to blow dust from in and around components.

5.4 Test Equipment

You may need the following test equipment when servicing or calibrating your power supply:

1. Oscilloscope, dual trace, 20-200MHz bandwidth.
2. Digital multimeter, 4 ½ digit accuracy.
3. True RMS voltmeter (Hewlett Packard HP-3403C or Fluke 8840-09).
4. Line isolation transformer, 500VA.

5.5 Troubleshooting

WARNING

Potentially lethal voltages exist in the power circuit (on the A2 Assembly PCB). Troubleshoot with care after familiarizing yourself with circuit operation and use appropriate high voltage testing techniques. Assign service and repair to experienced technical personnel only. Remember that filter capacitors can store potentially dangerous energy for some time after you turn off the power. Discharge large filter capacitors with suitable resistors for your personal safety and for the protection of components during repair work. Line potentials are present throughout the A2 circuit. Isolate the power supply from the line with an isolation transformer when using grounded test equipment in the power circuit.

Use the circuit descriptions in Section 4 and the schematic in this section as troubleshooting aids.

5.5.1 Blown Fuses

Always replace fuses with the same type and rating as those originally installed. A blown fuse almost invariably indicates other faulty components which you should identify and replace before you install a new fuse. If possible, troubleshoot and identify faulty components **with power removed**. Look particularly for isolation faults in inductors and transformers and for drain-source shorts in the power-FET devices.

A blown line fuse indicates likely failure of the power bridge rectifier, power transistors Q1 and Q2, and transistors Q3 through Q6, while a blown output fuse indicates likely failure of Q1, Q2, C1, and CR1.

Replace power transistors with identical parts, not with substitutes.

5.6 Calibration

You will not normally need to recalibrate your power supply unless you replace entire assemblies while repairing the supply. But when necessary, you calibrate your power supply using selected resistors on the printed circuit boards for the A1 Front Panel and A2 Power Assembly. These calibration resistors allow you to trim such critical parameters as the reference voltage and front panel display accuracy. Refer to the specifications in Section 1 when calibrating.

The calibration resistors are mounted in component lead sockets on 0.5" centers and you can replace them easily, using needle nose pliers. Some are 1% metal film resistors to ensure low temperature drift of the related parameter, so you should not replace them with standard 5% ¼W resistors. We have listed these calibration resistors and other calibration components by assembly in the following sections.

5.6.1 Front Panel Assembly (A1) Calibration

Table 5.6-1 Calibration (A1)

A1 Calibration Resistor	Parameter Affected
R103	Current bar graph full scale level
R104	Voltage bar graph full scale level
R130	Voltage display accuracy

5.6.2 Power Assembly (A2) Calibration

Table 5.6-2 Calibration (A2)	
A2 Calibration Resistor	**Parameter Affected**
R18	Maximum output current. Set for 5% above rated output current.
R23	Current display accuracy
R38	Pass element crossover. Factory set.
R45	+10 volt reference level. Set for most accurate voltage display.

5.7 Replacement Parts

This section provides schematic drawings and parts lists for the following assemblies:

- Front Panel Assembly (A1)
- Power Assembly (A2)
- Chassis Assembly

The schematic diagram for the A1 and A2 Assemblies is inserted in Appendix A as a reference for configuration and troubleshooting.

Most assemblies consist of parts common to all model assemblies as well as parts which are model-specific, or differential. You can order each of the parts and assemblies listed, whether complete, common, or differential.

5.7.1 Parts Replacement and Modifications

To ensure the safety features are not degraded, do not use substitute parts or make any unauthorized modifications to the power supply. For service and repair help, contact the factory.

5.7.2 Ordering Parts

Order parts from the manufacturer. Use the parts numbers from the assembly parts lists in this section. For service and inquiries call the manufacturer.

Please include the power supply's model number and serial number with your order.

5.7.3 Front Panel Assembly (A1) Replacement Parts

Table 5.7-1 A1 Front Panel Assembly Common Parts		
Designation	**Description**	**Part Number**
Complete Assembly	A1 PCB Assembly (Specify model.)	X2-6xxx-A1
C101,102	10μF 50V 2.mm Electrolytic Radial Capacitor 5x11	CL-100C-50
C103,105,107,108, 109,112,118,119	0.1μF 50V Z5U +80% to -20% 2.5mm Ceramic Radial Capacitor	CC-104D-09
C104,106	100pF 100v X7R 10% 2.5mm Ceramic Radial Capacitor	CB-101D-16
C110,111,114,115	47nF 50V Z5U +80% to -20% 2.5mm Ceramic Radial Capacitor	CC-473D-09
C113,116,117	0.1μF 100V MF 10% 10mm Radial Capacitor	CD-104J-16
DS101-106	7 Segment 13.5mm Orange Display	DS-1131-07
DS107-126, 127,130	Red Rectangle LED 2.5mm x 5.0mm	DS-5556-R6
DS128	Yellow Rectangle LED 2.5mm x 5.0mm	DS-0384-Y6
DS129,131	Green Rectangle LED 2.5mm x 5.0mm	DS-0394-G6
P101,102,104	9 pin male 0.1" Friction Lock	MC-0903-MC
PCB	Bare A1 Printed Circuit Board Rev H	PC-6001-H
R105,110	5.11k 1% ¼W MF Resistor	R-5111-41
R106,107,111,112	2.74k 1% ¼W MF Resistor	R-2741-41
R108,113,117,130	Select and install in Test	R-TEST
For R108,113,130	Socket 0.025" Component Lead , 0.052 Mount Hole	MC-5315-MS
R109,116,126,128	100k 1% ¼W MF Resistor	R-1003-41
R119	5k 1T 1/2W 20% Panel Mount ¼" Shaft	RP-5001-18
R120,127	475k 1% ¼W MF Resistor	R-4753-41
For R121	Internal Lock Washer 0.6 x 0.415 x 0.022	MW-1220-08
R125	22.1k 1% ¼W Resistor	R-2212-41
R129	8.25k 1% ¼W Resistor	R-8251-41
R131	1k 1% ¼W MF Resistor	R-1001-41
U101,103	18 pin DIP LM3914N Bar Graph Driver	UD-3914-N
U102,104	7107 CMOS 3.5 Digit A/D LED Driver	UD-7107-C
	40 pin DIL IC Socket .1" x .6"	MC-0040-IC

Note: Check Section 5.7.5 Chassis Assembly for front panel hardware not listed here.

5.7.3 Front Panel Assembly (A1) Replacement Parts

Table 5.7-2 A1 Front Panel Assembly Differential Parts		
Designation	**Description**	**Part Number**
	7 Volts	
C117	0.1μF 250V MF 10% 10mm Radial Capacitor	CD-104J-26
Q101	MPS-A92 PB 300V 500mA 625mW	QN-MPSA-92
R101,102A	365Ω ¼W 1% Resistor	R-3650-41
R103	1.5k ¼W 1% Resistor	R-1501-41
R104	1.8kW 5% ¼W CF Resistor	R-1801
R114	39.2k ¼W 1% Resistor	R-3922-41
R115	100k 1T ¼W 10% Cermet Trimpot	RC-1003-49
R122	150Ω ¼W 1% MF Resistor	R-1500-41
R123,124	22.1k ¼W 1% Resistor	R-2212-41
	15 Volts	
C117	0.1μF 250V MF 10% 10mm Radial Capacitor	CD-104J-26
Q101	MPS-A92 PB 300V 500mA 625mW	QN-MPSA-92
R101,102	365Ω ¼W 1% Resistor	R-3650-41
R103	825Ω ¼W 1% Resistor	R-8250-41
R104	270Ω ¼W 5% Resistor	R-2700
R114	16.2k ¼W 1% Resistor	R-1622-41
R115	100k 1T ¼W 10% Cermet Trimpot	RC-1003-49
R122	150Ω ¼W 1% MF Resistor	R-1500-41
R123,124	22.1k ¼W 1% Resistor	R-2212-41
	20 Volts	
C117	0.1μF 250V MF 10% 10mm Radial Capacitor	CD-104J-26
Q101	MPS-A92 PB 300V 500mA 625mW	QN-MPSA-92
R101,102	365Ω ¼W 1% Resistor	R-3650-41
R103	619Ω ¼W 1% Resistor	R-6190-41
R104	392Ω ¼W 1% Resistor	R-3920-41
R114	12.1kW ¼W 1% Resistor	R-1212-41
R115	100k 1T ¼W 10% Cermet Trimpot	RC-1003-49
R122	150Ω ¼W 1% MF Resistor	R-1500-41
R123,124	22.1k ¼W 1% Resistor	R-2212-41
	30 Volts	
C117	0.1μF 250V MF 10% 10mm Radial Capacitor	CD-104J-26
Q101	MPS-A92 PB 300V 500mA 625mW	QN-MPSA-92
R101,102	365Ω ¼W 1% Resistor	R-3650-41
R103	392Ω ¼W 1% Resistor	R-3920-41
R104	619Ω ¼W 1% Resistor	R-6190-41
R114	7.5k ¼W 5% CF Resistor	R-7501
R115	100k 1T ¼W 10% Cermet Trimpot	RC-1003-49
R122	150Ω ¼W 1% MF Resistor	R-1500-41
R123,124	22.1k ¼W 1% Resistor	R-2212-41
Continued on next page.		

5.7.3 Front Panel Assembly (A1) Replacement Parts

Table 5.7-2 A1 Front Panel Assembly Differential Parts (continued)		
Designation	**Description**	**Part Number**
	60 Volts	
C117	0.1μF 250V MF 10% 10mm Radial Capacitor	CD-104J-26
Q101	MPS-A92 PB 300V 500mA 625mW	QN-MPSA-92
R101,102	365Ω ¼W 1% Resistor	R-3650-41
R103	180Ω ¼W 5% CF Resistor	R-1800
R104	1.5k ¼W 1% Resistor	R-1501-41
R114	36kΩ ¼W 5% CF Resistor	R-3602
R115	1M 1T ¼W 10% Cermet Trimpot	RC-1004-49
R122	150Ω ¼W 1% MF Resistor	R-1500-41
R123,124	22.1k ¼W 1% Resistor	R-2212-41
	120 Volts	
C117	0.1μF 250V MF 10% 10mm Radial Capacitor	CD-104J-26
Q101	MPS-A92 PB 300V 500mA 625mW	QN-MPSA-92
R103	1.1k ¼W 1% MF Resistor	R-1101-41
R104	221Ω ¼W 1% MF Resistor	R-2210-41
R114	18.2k ¼W 1% Resistor	R-1822-41
R115	Trimpot 1M 1T ¼W 10% Cermet Trimpot	RC-1004-49
R122	150Ω ¼W 1% MF Resistor	R-1500-41
R123,124	22.1k ¼W 1% Resistor	R-2212-41
	250 Volts	
C117	10nF 400Vdc MF 10% 10mm Radial	CD-103J-46
Q101	2N6520 PB 350V 0.5A 625mW TO 92	QJ-6250
R122	1k ¼W 1% MF Resistor	R-1001-41
R123,124	243k ¼W 1% MF Resistor	R-2433-41
R103,104	511Ω ¼W 1% MF Resistor	R-5110-41
R114	8.25k ¼W 1% MF Resistor	R-8251-41
R115	Trimpot 1M 1T ¼W 10% Cermet Trimpot	RC-1004-49

5.7.4 Power Assembly (A2) Replacement Parts

Table 5.7-3 A2 Power Assembly Common Parts

Designation	Description	Part Number
Complete Assembly	A2 PCB Assembly (Specify model.)	X2-6xxx-A2
C2	1nF 100V X7R 10% 5mm Ceramic Radial Capacitor	CB-102F-16
C3	10µF 25V Tantalum 20% 2.5mm	CJ-100D-25
C4,15,17,27	10µF 50V 2mm Electrolytic Radial Capacitor	CL-100C-50
C5,6,9,10,25	0.1µF 50V X7R 10% 5mm Ceramic Capacitor	CB-104F-06
C7,8	47nF 50V X7R 10% Ceramic Radial Capacitor	CB-473F-06
C12	100pF 100V Z5F 10% 5.0mm Cer Rad	CB-101F-16
C12A	Capacitor Empty Location	C-EMPT
C14,31	4.7nF 100V X7R 10% 5.0mm Cer Rad	CB-472F-16
C16A	33µF 25V 2.5mm 20% El Rad 6.3x11	CL-330D-25
C23	2200µF 16V 13x25, 5mm Electrolytic Radial Capacitor	CL-222F-16
C24	1µF 250V MF 10% 15mm Radial	CD-105L-26
C26	220µF 35V 5mm Electrolytic Radial Capacitor	CL-221F-35
C29,30	470µF 35V 13x25, 5mm 20% Electrolytic Radial Capacitor	CL-471F-35
C31,14	4.7nF 100V X7R 10% 5mm Ceramic Radial Capacitor	CB-472F-16
CR1	1N5402 Case 267-02 200V 3A	CR-5402
CR 6A, 11A11B	Diode Empty Location	CR-EMPT
CR3,4,6,7,10,11,13,20	1N4148 UR D035 75V 300mA	CR-4148
CR16	200V 1A Bridge Rectifier 4 PIN DIL	CR-8012
CR8A	0Ω Jumper,¼" Resistor size	R-000
CR9	1N5240A Z D0-35 10V 10% 500mW	CR-5240-A
CR12	1N825A VZ D0-35 6.2V 400mW	CR-0825-A
CR16	4 pin DIL 200V 1A Bridge Rectifier	CR-B012
CR17	1N4735A ZENER D041 6.2V 1W	CR-4735-A
CR18,19	1N4005 R DO41 600V 1A	CR-4005
F1	7A Fast 125V 3AG Fuse	F1-0700-F
For F1	3AG Tin Plate Brass PC Mount Fuseclip	MC-3001-FC
F2	1/8A 125V Pico	F1-0012-F2
J1,2P1,2,3	9 pin Male 0.1" Friction Lock	MC-0903-MC
Bare PCB	Bare A2 PCB Rev D	PC-6002-D
Q1,2	TO3 Transistor Socket	MC-0TO3-QS
Q3	2N3904 NB 40V 200mA 350mV T92	QJ-3904
Q5,6	MPS-A92 PB 300V 500mA 625mW TO-92	QN-MPSA-92
Q6A,7	Empty Transistor Location	Q-EMPT
R1	825Ω ¼W 1%	R-8250-41
R4A	Resistor Empty Position	R-EMPT
R9,10,22,32,50	100k ¼W 1% MF	R-1003-41
R-8A	0Ω Jumper,¼" Resistor size	R-000
R11,33,43	10k ¼W 1%	R-1002-41
R12,19	Resistor Empty Location	R-EMPT
R13,48	1.5k ¼W 1%	R-1501-41
R14-17	475k ¼W 1% MF	R-4753-41
R14A	Resistor Empty Position	R-EMPT
R17A,21	4.75k ¼W 1%	R-4751-41
R18,23,38,45,38	Select and Install in Test	R-TEST
For R18,23,38,45	0.025" Comp. Lead Socket, 0.052" Mounting Hole	MC-5315-MS
R20	6.65k ¼W 1% MF	R-6651-41
R25,28,29,35,36,37	1k ¼W 1% MF	R-1001-41
R28A	Resistor Empty Position	R-EMPT
R30	20k ¼W 1%	R-2002-41
R31,49	150Ω ¼W 1% MF	R-1500-41
R36A	Resistor Empty Position	R-EMPT

Continued on next page.

5.7.4 Power Assembly (A2) Replacement Parts

TABLE 5.7-3 A2 Power Assembly Common Parts (continued)		
Designation	**Description**	**Part Number**
R37A	2k ¼W 1% MF	R-2001-41
R37B	Resistor Empty Position	R-EMPT
R40,51	392Ω ¼W 1%	R-3920-41
R41	130Ω ¼W 5% CF	R-1300
R42,46	511Ω ¼W 1%	R-5110-41
R44	4.99kΩ ¼W 1% MF	R-4991-41
R47	100Ω ¼W 1% MF	R-1000-41
R52	475Ω ¼W 1% MF	R-4750-41
U1	14 pin 4066B Quad Analog Gate	UC-4066-BN
For U1,3	14 pin DIL IC Socket	MC-0014-IC
For U1,U3	IC Socket, DIL 14 PIN	MC-0014-IC
U2	8 pin DIP LM358 Dual OP Amp	UA-0358-N
For U2	8 pin DIL IC Socket	MC-0008-IC
U3	14 pin DIP LF347N Q Jft OP Amp	UA-0347-N
U4,5	317 3Term 1.5A POS Adj Reg TO-220	UR-0317-T
U4 Heatsink	TO220 Vertical PCB Mount, Tinned tabs	HS-6238-TT
U5 Heatsink	TO220 Heatsink, Black Clip-on, 1"H x 0.8"W	HS-6043
U6	LM7912CT-12V 31 Reg TO-220	UR-7912-T
W1	Resistor Empty Position	R-EMPT
W2	0Ω Jumper,¼" Resistor size	R-000

Table 5.7-4 A2 Power Assembly Differential Parts		
Designation	**Description**	**Part Number**
	7 Volts	
C1 Output Cap	100μF 63V 10x20, 5mm 20% El Rad Capacitor	CL-101F-63
C2A,12	100pF 100V Z5F 10% 5mm Cer Rad Capacitor	CB-101F-16
C11,13	47pF 100V X7R 10% 5mm Radial Capacitor	CB-470F-16
C15A	1nF 100V X7R 10% 5mm Cer Rad Capacitor	CB-102F-16
C16,18	10μF 50V 2mm El Rad Capacitor	CL-100C-50
C19-22	22,000μF 10V 35Dx30L 10mm Snap in	CL-223J-25
CR8	200V 16A Dual UFast Rectifier	CR-1620-UD
CR 8 Heatsink	TO220 Heatsink, Black Clip-on, 1"H x 0.8"W	HS-6043
CR15	Bridge Rectifier 200V 8A	CR-B082
	Repairable Thermal Adhesive	AT-7099-R
	Thermal Adhesive Activator	AT-7100-A
"-" Connect to CR15	#18 Tew Stranded Blue	WT-0118-BL
"+" Connect to CR15	#18 Tew Stranded Red	WT-0118-RD
"AC" Connect to CR15	#18 Tew Stranded Yellow	WT-0118-YL
Q4	2N5550 N 140V .2A .6W TO-92	QJ-5550
R2,3	14.3k ¼W 1% MF	R-1432-41
R4	16.9k ¼W 1%	R-1692-41
R5, 39	1kΩ ¼W 1% MF	R-1001-41
R6	6.19kΩ ¼W 1%	R-6191-41
R7	1.33kΩ ¼W 1% MF	R-1331-41
R8	1.47kΩ ¼W 1% MF	R-1471-41
R24	140Ω ¼W 1% MF	R-1400-41
R26	0.12Ω 7W 5% WW	RW-R120-7
R27	39Ω 5W 5% WW	RW-39R0-5
Continued on next page.		

5.7.4 Power Assembly (A2) Replacement Parts

Table 5.7-4 A2 Power Assembly Differential Parts

	15 Volts	
C1	100µF 63V 10x20, 5mm 20% El Rad Capacitor	CL-101F-63
C2A	22pF 100V X7R 10% 5mm Radial Capacitor	CB-220F-16
C3A	100pF 100V Z5 10% 5.00mm Cer Rad	CB-101F-16
C,11,13	47pF 100V X7R 10% 5mm Radial Capacitor	CB-470F-16
C15A	1nF 100V X7R 10% 5mm Cer Rad Capacitor	CB-102F-16
C16,18	10µF 50V 2mm El Rad Capacitor	CL-100C-50
C19	Capacitor Empty Location	C-EMPT
C20,21,22	15,000µF 16V 10mm El Rad Capacitor	CL-153J-16
CR8	200V 16A Dual UFAST Rectifier	CR-1620-UD
CR 8 Heatsink	TO220 Heatsink, Black Clip-On, 1"H x 0.8"W	HS-6043
CR1A,1B,21,21A	Diode Empty Location	CR-EMPT
CR15 Mounting	Repairable Thermal Adhesive (17099)	AT-7099-R
CR15A,B,C,D	Bridge Rectifier 200V 8A	CR-B082
"-" Connect to CR15	#18 Tew Stranded Blue	WT-0118-BL
"+" Connect to CR15	#18 Tew Stranded Red	WT-0118-RD
"AC" Connect to CR15	#18 Tew Stranded Yellow	WT-0118-YL
Q4	2N5550 N 140V .2A .6W TO-92	QJ-5550
R2,3	9.53kΩ ¼W 1% MF	R-9531-41
R4	10MΩ ¼W 5%	R-1005
R5	1k Ω ¼W 1% MF	R-1001-41
R6	32.4k ¼W 1%	R-3242-41
R7	30.1k ¼W 1% MF	R-3012-41
R8	36.5k ¼W 1% MF	R-3652-41
R24	140Ω ¼W 1% MF	R-1400-41
R26	0.12Ω 7W 5% WW	RW-R120-7
R27	100Ω 5W 5% WW	RW-1000-5
R34	100k ¼W 1% MF	R-1003-41
	20 Volts	
C1	100µF 63V 10x20, 5mm 20% El Rad Capacitor	CL-101F-63
C2A	22pF 100V X7R 10% 5mm Radial Capacitor	CB-220F-16
C,11,13	47pF 100V X7R 10% 5mm Radial Capacitor	CB-470F-16
C12	100pF 100V X7R 10% 5mm Radial Capacitor	CB-101F-16
CR1A,1B,21,21A	Diode Empty Location	CR-EMPT
C15A	1nF 100V X7R 10% 5mm Cer Rad Capacitor	CB-102F-16
C16,18	10µF 50V 2mm El Rad Capacitor	CL-100C-50
C19	Capacitor Empty Location	C-EMPT
C20,21	15000µF 25V 10mm El Rad Capacitor	CL-153J-25
CR8	XX-751 Rectifier 100V 6A	CR-0751-MR
CR15	Bridge Rectifier 200V 8A	CR-B082
"-" Connect to CR15	#18 Tew Stranded Blue (300 metres)	WT-0118-BL
"+" Connect to CR 15	#18 Tew Stranded Red (300 metres)	WT-0118-RD
"AC" Connect to CR15	#18 Tew Stranded Yellow (300 metres)	WT-0118-YL
Q4	2N5550 N 140V .2A .6W TO-92	QJ-5550
R5	1kΩ ¼W 1% MF	R-1001-41
R6	23.7k ¼W 1%	R-2372-41
R7	22.6k ¼W 1% MF	R-2262-41
R8	52.3kΩ ¼W 1% MF	R-5232-41
R24	909Ω ¼W 1% MF	R-9090-41
R26	0.2Ω 5W 5% WW	RW-R200-5
R27	200Ω 5W 10% WW	RW-2000-59
R34	100k ¼W 1% MF	R-1003-41
R39	2k ¼W 1% MF	R-2001-41

Continued on next page.

5.7.4 Power Assembly (A2) Replacement Parts

TABLE 5.7-4 A2 Power Assembly Differential Parts (continued)		
Designation	**Description**	**Part Number**
	30 Volts	
C1	33μF 100V 5mm 20% El Rad Capacitor	CL-330F-76
C2A	22pF 100V X7R 10% 5mm Radial Capacitor	CB-220F-16
C3A	47pF 100V X7R 10% 5mm Radial Capacitor	CB-470F-16
C11,12	100pF 100V X7R 10% 5mm Radial Capacitor	CB-101F-16
C15A	1nF 100V X7R 10% 5.0mm Cer Rad	CB-102F-16
C16,18	10μF 50V 2mm El Rad Capacitor	CL-100C-50
C19,22	Capacitor Empty Location	C-EMPT
C20,21	10000μF 25V 10mm El Rad Capacitor	CL-103J-25
CR8,15A-15D	1N5402 CASE 267-02 200V 3A	CR-5402
CR1A,1B,21,21A	Diode Empty Location	CR-EMPT
Q4	2N5550 N 140V .2A .6W TO-92	QJ-5550
R2,3	7.68k ¼W 1% MF	R-7681-41
R4	10M ¼W 5%	R-1005
R5	1kΩ ¼W 1% MF	R-1001-41
R6	15.8k ¼W 1%	R-1582-41
R7	15k ¼W 1% MF	R-1502-41
R8	68.1k ¼W 1% MF	R-6812-41
R24	909Ω ¼W 1% MF	R-9090-41
R26	0.2Ω 5W 5% WW	RW-R200-5
R27	470Ω 5W 5% WW	RW-4700-5
R34	100k ¼W 1% MF	R-1003-41
R39	2k ¼W 1% MF	
	60 Volts	
C1 Output Cap	10μF 100V 3.5mm El Rad Capacitor	CL-100E-76
C2A	22pF 100V X7R 10% 5mm Radial Capacitor	CB-220F-16
C11,13	47pF 100V X7R 10% 5mm Radial Capacitor	CB-470F-16
C15A	470pF 100V X7R 10% 5mm Cer Rad Capacitor	CB-471-16
C16,18	10μF 50V 2mm El Rad Capacitor	CL-100C-50
C20,21	3,300μF 50V 10mm El Rad Capacitor	CL-332J-50
CR8	1N4005 R D041 600V 1A	CR-4005
Q4	2N5550 N 140V .2A .6W TO-92	QJ-5550
R4	10MΩ ¼W 5%	R-1005
R5	1kΩ ¼W 1% MF	R-1001-41
R6	7.32k ¼W 1%	R-7321-41
R7	7.5kΩ ¼W 1% MF	R-7501-41
R8	84.5k ¼W 1% MF	R-8452-41
R24	909Ω ¼W 1% MF	R-9090-41
R26	0.2Ω 5W 5% WW	RW-R200-5
R27	2k 5W 5% WW	RW-2001-5
R34,50	100k ¼W 1% MF	R-1003-41
R39	2k ¼W 1% MF	R-2001-41
	Continued on next page.	

5.7.4 Power Assembly (A2) Replacement Parts

TABLE 5.7-4 A2 Power Assembly Differential Parts (continued)		
Designation	**Description**	**Part Number**
	120 Volts	
C1 Output Cap	3.3μF 160V 5mm El Rad Capacitor	CL-3U3F-78
C2A,19,22	Capacitor Empty Location	C-EMPT
C3A, 11	100pF 100V X7R 10% 5mm Radial Capacitor	CB-101F-16
C13	220pF 100V X7R 10% 5mm Radial Capacitor	CB-221F-16
C15A	470pF 100V 10% 5.0mm Cer Rad NPO	CB-471F-16
C15A C14A	2.2nF 100V X7R 10% 5mm Cer Rad Capacitor	CB-222F-16
C16,18	10μF 100V 2mm El Rad Capacitor	CL-100E-76
C20,21	1000μF 100V 10mm El Rad Capacitor	CL-102J-76
CR1A,1B	MUR140 UR D05 400V 1A	CR-01140-UR
CR8,15A,15B, 15C,15D	1N4005 R D041 600V 1A	CR-4005
CR21	1N4372A Z Case3.0V 400mW	CR-4372-A
CR21A	1N5231B Z D0204 5.1V 5% .5W	CR-5231-B
Q4	MPSA42 NB 300V 500mA	QN-MPSA-42
R2,3	11.3kΩ ¼W 1% MF	R-1132-41
R4	10MΩ ¼W 5%	R-1005
R5	1.05k ¼W 1% MF	R-1051-41
R6,7	42.2k ¼W 1%	R-4222-41
R8	953k ¼W 1% MF	R-9533-41
R24	140Ω ¼W 1% MF	R-1400-41
R26 (Current Shunt)	1.2Ω 5W 5% WW	RW-1R20-5
R27	10k 5W 5% WW	RW-1002-5
R29A between Q1 &Q2 emitters, skt pins	2Ω5W 5% WW	RW-2R00-5
R34	200k ¼W 1% MF	R-2003-41
R39	2k ¼W 1% MF	R-2001-41
Mount T1, H/S	#8-32 x 5/16" Kep Nut	MN-832K-10
	250 Volts	
R24	909Ω 1/4W 1% MF	R-9090-41
R26	2Ω 5W 5% WW	RW-2R00-5
R27	36kΩ 5W 5% WW	RW-3602-5
R13, 28, 48	1.50kΩ 1/4W 1%	R-1501-41
R28A,W1	0Ω jumper, ¼W resistor size	R-0000
R14A, 29,35,37,W2	Empty Position	R-EMPT
R34	825kΩ 1/4W 1%	R-8253-41
R36	15k 1/4W 1% MF	R-1502-41
R36A, 47	100Ω 1/4W 1% MF	R-1000-41
R37A	2k 1/4W 1% MF	R-2001-41
R37B	5.62k 1/4W 1%	R-5621-41
R18, 23, 38, 45	Select and Install in Test	R-TEST
R39, 50	240k 1W 5% MF	RA-2403-1

5.7.5 Chassis Assembly Replacement Parts

Table 5.7-5 Chassis Assembly		
Designation	**Description**	**Part Number**
AC Wiring	2.5A Slow 250V 3AG fuse	F2-0250-S
For AC I/P Connector	#4-40 x 5/16" Philips Pan Screw Stainless Steel	MS-4P28-05MS
Barrier Strip	Fast-On Female ¼" x .032" AWG 18-22	MC-0251-F0
Wire Assembly		
	9 PIN Female MTA 0.1" #22 Wire	MC-0922-MC
	0.10" x 4" Cable Ties (1000 pieces/package)	MI-1004-CT
	0.25" Female Fast-On Nylon Insulator	MI-4804-F0
	#18 TEW Stranded, Black	WT-0118-BK
	#18 TEW Stranded Green-Yellow (300 meters)	WT-0118-GY
	#18 TEW Stranded, White	WT-0118-WT
	#22 TEW Stranded, Black (300 metres)	WT-0122-BK
	#22 TEW Stranded, Blue (300 metres)	WT-0122-BL
	#22 TEW Stranded, Orange (300 metres)	WT-0122-OR
	#22 TEW Stranded, Red (300 metres)	WT-0122-RD
For Barrier Strip	Sense Label	LA-6300-SNS
For Barrier Strip	Speed Nut for .312 shaft	MN-31SN-12
For Ground Stud (20), Fuse Block Mtg. (1)	#6-32x ¼" Kep Nut Stainless Steel	MN-632Z-08
Handle	Handle Webbing, Black, 1" Nylon	SP-6HND-BK
For Handle	Handle ClampClip	SM-60HC-AA
For Handle	Black 1" Nylon Handle Webbing	MH-656E-BK
For Handle Clips	# 6-32 x 3/16" Philips Pan Stainless Steel	MS-6P28-03
	Label, Power Cord Warning Bilingual (Specify series.)	LA-6300-CPSN
For Mounting Switch	#4-40x¼" Undercut FLTHD Philips Stainless Steel	MS-4P30-04
For Switch Bracket and AC Input Connector	#4-40 x ¼" Kep Nut Steel/Cad	MN-440Z-08
Power Cord	125V 10A NA Plug to IEC 320 Power Cord	WP-1725-00
Power Switch	SPST 15A 125V Pushbutton Switch	SW-1116-BN1M
	Power Switch Bracket	SM-60SB-CA
	Switch Push Rod, Black Molded Plastic	SP-6001-03FB
For Power Switch	#8 Ring Tongue	MC-8305-RT
	Fuseblock, 3AG Tin-Plate Brass Spadeplug	MC-3000-FBT
	Mate N Lock Socket Housing	MC-3550-ML
	Mate N Lock 3 pin Capacitor Housing	MI-4801-ML
	IEC320 AC Input Connector, 0.25" FO	MC-IEC3-FO
	Fast-on FM ¼" x 0.032" AWG 10-16	MC-0250-FO
	Fast-on FM ¼" x 0.032" AWG 18-22	MC-0251-FO
	0.10"x14" Cable Ties	MI-1004-CT
For Fast-on	0.25" Female Fast-on Insulator, Nylon	MI-4804-FO
	Transformer (Specify model.)	T2-6xxx

APPENDIX A

ASSEMBLY SCHEMATIC

A1 Assembly (Front Panel) and A2 Assembly (Power Circuit)

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