

# **Sorensen**

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## **Instruction Manual for**

## **XT SERIES Power Supply**

**This manual covers models:**

**7-6  
15-4  
20-3  
30-2**

**60-1  
120-0.5  
250-0.25**

## **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.

|   |   |
|---|---|
| <b>Section 1. Features and Specifications</b>   | Describes the power supply, lists its features, and provides tables of specifications.  |
| <b>Section 2. Installation</b>                  | Reviews safety and inspection procedures, then goes through the basic setup. Also includes directions for the testing of basic functions.   |
| <b>Section 3. Load Connection and Operation</b> | 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. |
| <b>Section 4. Theory of Operation</b>           | Provides an explanation of the functions within each of the power supply's assemblies.  |
| <b>Section 5. Maintenance</b>                   | Covers troubleshooting, servicing, and calibration. Lists replacement parts.  |
| <b>Appendix A</b>                               | 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:

|   |
|---|
| <b>WARNING</b>  |
| 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. |

|   |
|---|
| <b>CAUTION</b>  |
| 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.

| 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<br>7-6 | XT<br>15-4 | XT<br>20-3 | XT<br>30-2 | XT<br>60-1 | XT<br>120-0.5 | XT<br>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 <sup>1</sup>          |           |            |            |            |            |               |                |
| 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 <sup>2</sup>          |           |            |            |            |            |               |                |
| 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         |

<sup>1</sup> For input voltage variation from over the AC input voltage range, with constant rated load.

<sup>2</sup> For 0-100% load variation, with constant nominal line voltage.

**1.4.1 Electrical Specifications (continued)**

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

**Additional Characteristics**

| <b>Models</b>  | <b>XT<br/>7-6</b> | <b>XT<br/>15-4</b> | <b>XT<br/>20-3</b> | <b>XT<br/>30-2</b> | <b>XT<br/>60-1</b> | <b>XT<br/>120-0.5</b> | <b>XT<br/>250-0.25</b> |
|--|-------------------|--------------------|--------------------|--------------------|--------------------|-----------------------|------------------------|
| Stability <sup>3</sup>                                 |                   |                    |                    |                    |                    |                       |                        |
| 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 <sup>4</sup>                   |                   |                    |                    |                    |                    |                       |                        |
| Voltage (0.015% of V max/ $^{\circ}$ C)                | 1.05mV            | 2.25mV             | 3mV                | 4.5mV              | 9mV                | 18mV                  | 37.5mV                 |
| Current (0.02% of I max/ $^{\circ}$ 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                   |

<sup>3</sup> Drift over 8 hours after 30 minute warm up.

<sup>4</sup> Change in output per  $^{\circ}$ C change in ambient temperature, with constant line load.

|  |  |
|--|--|
| Operating Ambient Temperature          | 0-30 $^{\circ}$ C for full rated output. Above 30 $^{\circ}$ C, derate output linearly to zero at 70 $^{\circ}$ C. |
| Storage Temperature Range              | -55 to +85 $^{\circ}$ C  |
| Humidity Range                         | 0-80% RH Non-condensing  |
| Voltage Mode Transient Response Time   | <100 $\mu$ s recovery to 0.05% band, for $\pm$ 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<br>CE marked units meet standards: EN5011 (Group 1 Class B) 1991, EN50081-1 1992, EN50082-1 1992.              |

**1.4.2 Mechanical Specifications**

| <b>Unit</b> | <b>Height</b>  | <b>Width</b>    | <b>Depth</b>   | <b>Weight</b>   |
|-------------|----------------|-----------------|----------------|-----------------|
| 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.

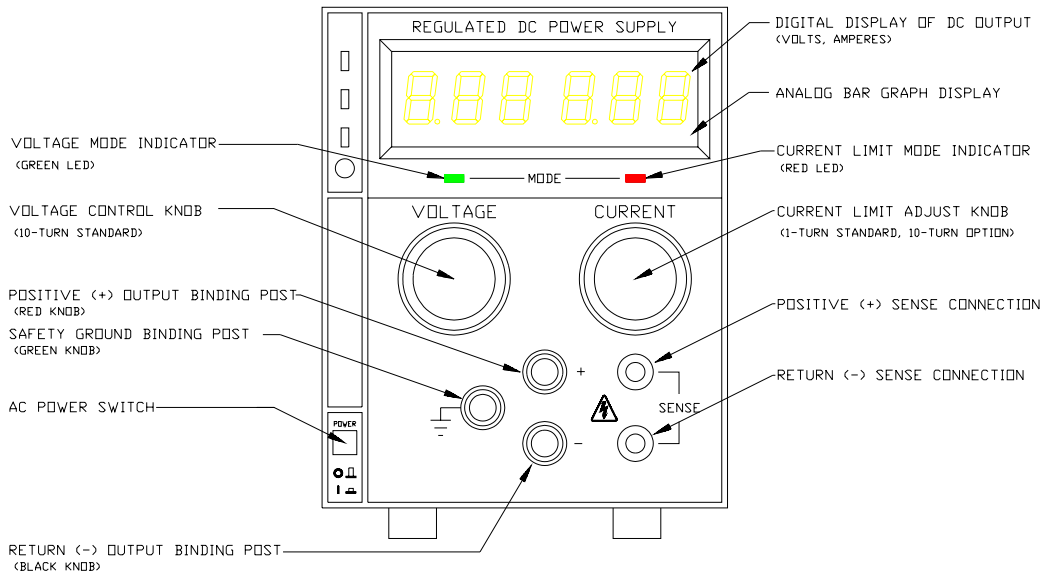


Figure 2.1-1 XT Series Supply Front Panel

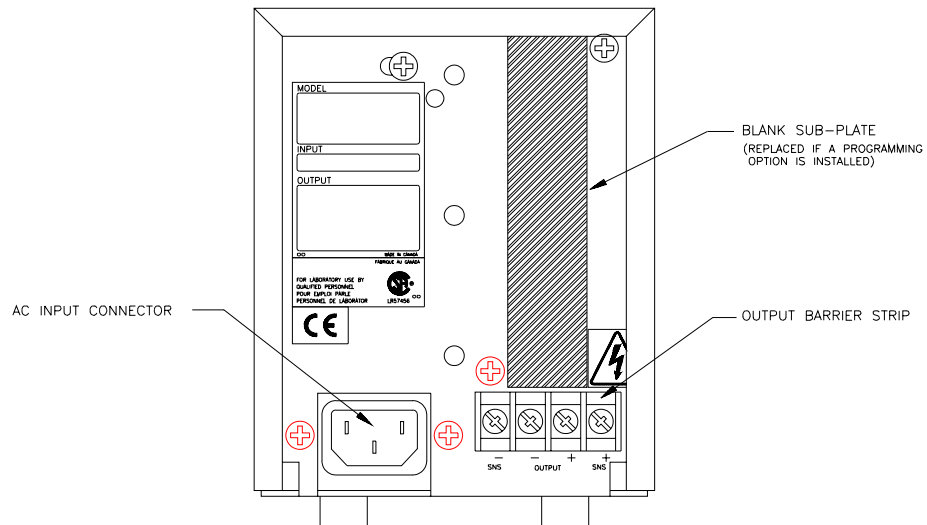


Figure 2.1-2 XT Series Supply Rear Panel

## 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 0.01 $\mu$ F 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:  $I_L < I_{SET}$  (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

| 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**

| <b>Table 5.7-1 A1 Front Panel Assembly Common Parts</b> |   |                    |
|---|---|--------------------|
| <b>Designation</b>                                      | <b>Description</b>  | <b>Part Number</b> |
| Complete Assembly                                       | A1 PCB Assembly (Specify model.)                          | X2-6xxx-A1         |
| C101,102  | 10µF 50V 2.5mm Electrolytic Radial Capacitor 5x11         | CL-100C-50         |
| C103,105,107,108,<br>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 |
| <b>7 Volts</b>   |   |             |
| C117   | 0.1 $\mu$ F 250V MF 10% 10mm Radial Capacitor | CD-104J-26  |
| Q101   | MPS-A92 PB 300V 500mA 625mW                   | QN-MPSA-92  |
| R101,102A  | 365 $\Omega$ 1/4W 1% Resistor                 | R-3650-41   |
| R103   | 1.5k 1/4W 1% Resistor                         | R-1501-41   |
| R104   | 1.8kW 5% 1/4W CF Resistor                     | R-1801      |
| R114   | 39.2k 1/4W 1% Resistor                        | R-3922-41   |
| R115   | 100k 1T 1/4W 10% Cermet Trimpot               | RC-1003-49  |
| R122   | 150 $\Omega$ 1/4W 1% MF Resistor              | R-1500-41   |
| R123,124   | 22.1k 1/4W 1% Resistor                        | R-2212-41   |
| <b>15 Volts</b>  |   |             |
| C117   | 0.1 $\mu$ F 250V MF 10% 10mm Radial Capacitor | CD-104J-26  |
| Q101   | MPS-A92 PB 300V 500mA 625mW                   | QN-MPSA-92  |
| R101,102   | 365 $\Omega$ 1/4W 1% Resistor                 | R-3650-41   |
| R103   | 825 $\Omega$ 1/4W 1% Resistor                 | R-8250-41   |
| R104   | 270 $\Omega$ 1/4W 5% Resistor                 | R-2700      |
| R114   | 16.2k 1/4W 1% Resistor                        | R-1622-41   |
| R115   | 100k 1T 1/4W 10% Cermet Trimpot               | RC-1003-49  |
| R122   | 150 $\Omega$ 1/4W 1% MF Resistor              | R-1500-41   |
| R123,124   | 22.1k 1/4W 1% Resistor                        | R-2212-41   |
| <b>20 Volts</b>  |   |             |
| C117   | 0.1 $\mu$ F 250V MF 10% 10mm Radial Capacitor | CD-104J-26  |
| Q101   | MPS-A92 PB 300V 500mA 625mW                   | QN-MPSA-92  |
| R101,102   | 365 $\Omega$ 1/4W 1% Resistor                 | R-3650-41   |
| R103   | 619 $\Omega$ 1/4W 1% Resistor                 | R-6190-41   |
| R104   | 392 $\Omega$ 1/4W 1% Resistor                 | R-3920-41   |
| R114   | 12.1kW 1/4W 1% Resistor                       | R-1212-41   |
| R115   | 100k 1T 1/4W 10% Cermet Trimpot               | RC-1003-49  |
| R122   | 150 $\Omega$ 1/4W 1% MF Resistor              | R-1500-41   |
| R123,124   | 22.1k 1/4W 1% Resistor                        | R-2212-41   |
| <b>30 Volts</b>  |   |             |
| C117   | 0.1 $\mu$ F 250V MF 10% 10mm Radial Capacitor | CD-104J-26  |
| Q101   | MPS-A92 PB 300V 500mA 625mW                   | QN-MPSA-92  |
| R101,102   | 365 $\Omega$ 1/4W 1% Resistor                 | R-3650-41   |
| R103   | 392 $\Omega$ 1/4W 1% Resistor                 | R-3920-41   |
| R104   | 619 $\Omega$ 1/4W 1% Resistor                 | R-6190-41   |
| R114   | 7.5k 1/4W 5% CF Resistor                      | R-7501      |
| R115   | 100k 1T 1/4W 10% Cermet Trimpot               | RC-1003-49  |
| R122   | 150 $\Omega$ 1/4W 1% MF Resistor              | R-1500-41   |
| R123,124   | 22.1k 1/4W 1% Resistor                        | R-2212-41   |
| <b>Continued on next page.</b>                         |   |             |

5.7.3 Front Panel Assembly (A1) Replacement Parts

| Table 5.7-2 A1 Front Panel Assembly Differential Parts (continued) |   |             |
|--|---|-------------|
| Designation  | Description                             | Part Number |
| <b>60 Volts</b>  |   |             |
| 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   |
| <b>120 Volts</b>   |   |             |
| 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   |
| <b>250 Volts</b>   |   |             |
| 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   | 10 $\mu$ F 25V Tantalum 20% 2.5mm                            | CJ-100D-25  |
| C4,15,17,27                                | 10 $\mu$ F 50V 2mm Electrolytic Radial Capacitor             | CL-100C-50  |
| C5,6,9,10,25                               | 0.1 $\mu$ F 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                                       | 33 $\mu$ F 25V 2.5mm 20% EI Rad 6.3x11                       | CL-330D-25  |
| C23  | 2200 $\mu$ F 16V 13x25, 5mm Electrolytic Radial Capacitor    | CL-222F-16  |
| C24  | 1 $\mu$ F 250V MF 10% 15mm Radial                            | CD-105L-26  |
| C26  | 220 $\mu$ F 35V 5mm Electrolytic Radial Capacitor            | CL-221F-35  |
| C29,30                                     | 470 $\mu$ F 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                                       | 0 $\Omega$ Jumper, 1/4" 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   | 825 $\Omega$ 1/4W 1%   | R-8250-41   |
| R4A  | Resistor Empty Position                                      | R-EMPT      |
| R9,10,22,32,50                             | 100k 1/4W 1% MF  | R-1003-41   |
| R-8A                                       | 0 $\Omega$ Jumper, 1/4" Resistor size                        | R-000       |
| R11,33,43                                  | 10k 1/4W 1%  | R-1002-41   |
| R12,19                                     | Resistor Empty Location                                      | R-EMPT      |
| R13,48                                     | 1.5k 1/4W 1%   | R-1501-41   |
| R14-17                                     | 475k 1/4W 1% MF  | R-4753-41   |
| R14A                                       | Resistor Empty Position                                      | R-EMPT      |
| R17A,21                                    | 4.75k 1/4W 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 1/4W 1% MF   | R-6651-41   |
| R25,28,29,35,36,37                         | 1k 1/4W 1% MF  | R-1001-41   |
| R28A                                       | Resistor Empty Position                                      | R-EMPT      |
| R30  | 20k 1/4W 1%  | R-2002-41   |
| R31,49                                     | 150 $\Omega$ 1/4W 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 |
| <b>7 Volts</b>                                   |  |             |
| C1 Output Cap                                    | 100µF 63V 10x20, 5mm 20% EI 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 EI 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   |
| <b>Continued on next page.</b>                   |  |             |

## 5.7.4 Power Assembly (A2) Replacement Parts

| Table 5.7-4 A2 Power Assembly Differential Parts |   |            |
|--|---|------------|
| <b>15 Volts</b>                                  |   |            |
| C1   | 100 $\mu$ F 63V 10x20, 5mm 20% EI 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   | 10 $\mu$ F 50V 2mm EI Rad Capacitor             | CL-100C-50 |
| C19  | Capacitor Empty Location                        | C-EMPT     |
| C20,21,22  | 15,000 $\mu$ F 16V 10mm EI 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   | 9.53k $\Omega$ 1/4W 1% MF                       | R-9531-41  |
| R4   | 10M $\Omega$ 1/4W 5%                            | R-1005     |
| R5   | 1k $\Omega$ 1/4W 1% MF                          | R-1001-41  |
| R6   | 32.4k 1/4W 1%                                   | R-3242-41  |
| R7   | 30.1k 1/4W 1% MF                                | R-3012-41  |
| R8   | 36.5k 1/4W 1% MF                                | R-3652-41  |
| R24  | 140 $\Omega$ 1/4W 1% MF                         | R-1400-41  |
| R26  | 0.12 $\Omega$ 7W 5% WW                          | RW-R120-7  |
| R27  | 100 $\Omega$ 5W 5% WW                           | RW-1000-5  |
| R34  | 100k 1/4W 1% MF                                 | R-1003-41  |
| <b>20 Volts</b>                                  |   |            |
| C1   | 100 $\mu$ F 63V 10x20, 5mm 20% EI 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   | 10 $\mu$ F 50V 2mm EI Rad Capacitor             | CL-100C-50 |
| C19  | Capacitor Empty Location                        | C-EMPT     |
| C20,21   | 15000 $\mu$ F 25V 10mm EI 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   | 1k $\Omega$ 1/4W 1% MF                          | R-1001-41  |
| R6   | 23.7k 1/4W 1%                                   | R-2372-41  |
| R7   | 22.6k 1/4W 1% MF                                | R-2262-41  |
| R8   | 52.3k $\Omega$ 1/4W 1% MF                       | R-5232-41  |
| R24  | 909 $\Omega$ 1/4W 1% MF                         | R-9090-41  |
| R26  | 0.2 $\Omega$ 5W 5% WW                           | RW-R200-5  |
| R27  | 200 $\Omega$ 5W 10% WW                          | RW-2000-59 |
| R34  | 100k 1/4W 1% MF                                 | R-1003-41  |
| R39  | 2k 1/4W 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 |
| <b>30 Volts</b>  |  |             |
| C1   | 33 $\mu$ F 100V 5mm 20% EI 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   | 10 $\mu$ F 50V 2mm EI Rad Capacitor      | CL-100C-50  |
| C19,22   | Capacitor Empty Location                 | C-EMPT      |
| C20,21   | 10000 $\mu$ F 25V 10mm EI 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 $\frac{1}{4}$ W 1% MF              | R-7681-41   |
| R4   | 10M $\frac{1}{4}$ W 5%                   | R-1005      |
| R5   | 1k $\Omega$ $\frac{1}{4}$ W 1% MF        | R-1001-41   |
| R6   | 15.8k $\frac{1}{4}$ W 1%                 | R-1582-41   |
| R7   | 15k $\frac{1}{4}$ W 1% MF                | R-1502-41   |
| R8   | 68.1k $\frac{1}{4}$ W 1% MF              | R-6812-41   |
| R24  | 909 $\Omega$ $\frac{1}{4}$ W 1% MF       | R-9090-41   |
| R26  | 0.2 $\Omega$ 5W 5% WW                    | RW-R200-5   |
| R27  | 470 $\Omega$ 5W 5% WW                    | RW-4700-5   |
| R34  | 100k $\frac{1}{4}$ W 1% MF               | R-1003-41   |
| R39  | 2k $\frac{1}{4}$ W 1% MF                 |             |
| <b>60 Volts</b>  |  |             |
| C1 Output Cap  | 10 $\mu$ F 100V 3.5mm EI 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   | 10 $\mu$ F 50V 2mm EI Rad Capacitor      | CL-100C-50  |
| C20,21   | 3,300 $\mu$ F 50V 10mm EI Rad Capacitor  | CL-332J-50  |
| CR8  | 1N4005 R D041 600V 1A                    | CR-4005     |
| Q4   | 2N5550 N 140V .2A .6W TO-92              | QJ-5550     |
| R4   | 10M $\Omega$ $\frac{1}{4}$ W 5%          | R-1005      |
| R5   | 1k $\Omega$ $\frac{1}{4}$ W 1% MF        | R-1001-41   |
| R6   | 7.32k $\frac{1}{4}$ W 1%                 | R-7321-41   |
| R7   | 7.5k $\Omega$ $\frac{1}{4}$ W 1% MF      | R-7501-41   |
| R8   | 84.5k $\frac{1}{4}$ W 1% MF              | R-8452-41   |
| R24  | 909 $\Omega$ $\frac{1}{4}$ W 1% MF       | R-9090-41   |
| R26  | 0.2 $\Omega$ 5W 5% WW                    | RW-R200-5   |
| R27  | 2k 5W 5% WW                              | RW-2001-5   |
| R34,50   | 100k $\frac{1}{4}$ W 1% MF               | R-1003-41   |
| R39  | 2k $\frac{1}{4}$ W 1% MF                 | R-2001-41   |
| <b>Continued on next page.</b>                               |  |             |

## 5.7.4 Power Assembly (A2) Replacement Parts

| TABLE 5.7-4 A2 Power Assembly Differential Parts (continued) |  |             |
|--|--|-------------|
| Designation  | Description                              | Part Number |
| <b>120 Volts</b>   |  |             |
| C1 Output Cap  | 3.3 $\mu$ F 160V 5mm EI 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   | 10 $\mu$ F 100V 2mm EI Rad Capacitor     | CL-100E-76  |
| C20,21   | 1000 $\mu$ F 100V 10mm EI 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   | 11.3k $\Omega$ 1/4W 1% MF                | R-1132-41   |
| R4   | 10M $\Omega$ 1/4W 5%                     | R-1005      |
| R5   | 1.05k 1/4W 1% MF                         | R-1051-41   |
| R6,7   | 42.2k 1/4W 1%                            | R-4222-41   |
| R8   | 953k 1/4W 1% MF                          | R-9533-41   |
| R24  | 140 $\Omega$ 1/4W 1% MF                  | R-1400-41   |
| R26 (Current Shunt)  | 1.2 $\Omega$ 5W 5% WW                    | RW-1R20-5   |
| R27  | 10k 5W 5% WW                             | RW-1002-5   |
| R29A between Q1 &Q2 emitters, skt pins                       | 2 $\Omega$ 5W 5% WW                      | RW-2R00-5   |
| R34  | 200k 1/4W 1% MF                          | R-2003-41   |
| R39  | 2k 1/4W 1% MF                            | R-2001-41   |
| Mount T1, H/S  | #8-32 x 5/16" Kep Nut                    | MN-832K-10  |
| <b>250 Volts</b>   |  |             |
| R24  | 909 $\Omega$ 1/4W 1% MF                  | R-9090-41   |
| R26  | 2 $\Omega$ 5W 5% WW                      | RW-2R00-5   |
| R27  | 36k $\Omega$ 5W 5% WW                    | RW-3602-5   |
| R13, 28, 48  | 1.50k $\Omega$ 1/4W 1%                   | R-1501-41   |
| R28A,W1  | 0 $\Omega$ jumper, 1/4W resistor size    | R-0000      |
| R14A, 29,35,37,W2  | Empty Position                           | R-EMPT      |
| R34  | 825k $\Omega$ 1/4W 1%                    | R-8253-41   |
| R36  | 15k 1/4W 1% MF                           | R-1502-41   |
| R36A, 47   | 100 $\Omega$ 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 1/4" 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),<br>Fuse Block Mtg. (1) | #6-32x 1/4" 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                          | #4-40x1/4" Undercut FLTHD Philips Stainless Steel     | MS-4P30-04   |
| For Switch Bracket and<br>AC Input Connector | #4-40 x 1/4" 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 1/4" x 0.032" AWG 10-16                    | MC-0250-FO   |
|  | Fast-on FM 1/4" 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-F0   |
|  | Transformer (Specify model.)                          | T2-6xxx      |

**APPENDIX A**  
**ASSEMBLY SCHEMATIC**

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

Sorensen Company  
9250 Brown Deer Road  
San Diego, CA USA 92121

Toll Free (USA) 1-800-525-2024  
Sales Support: (858) 450-0085  
FAX: (858) 458-0267

E-Mail: [sales@sorensen.com](mailto:sales@sorensen.com)  
Website: [www.sorensen.com](http://www.sorensen.com)

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