Sorensen

DCR-T SERIES

10 KW
Power Supplies

Instruction Manual

Manual covers DCR-T models:

16-625T	110-90T
32-310T	160-62T
55-180T	300-33T
80-125T	600-16T

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SORENSEN COMPANY LIMITED WARRANTY

All DCR-T Series power supplies manufactured by SORENSEN COMPANY are 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. SORENSEN 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. If any questions arise concerning the warranty, check with SORENSEN prior to taking any action.

When information, assistance or authorization is required, refer to the model and serial number on the back of the unit.

Model: ______________________________

Serial Number: ______________________

SECTION 1
INTRODUCTION

1.1 INTRODUCTION

This manual contains operation and maintenance data on the 10 kilowatt (10KW) units of the DCR-T Series Sorensen Power Supplies. It is intended to familiarize the user with the function of the unit, to introduce the varied applications to which the unit may be adapted, and to furnish sufficient maintenance data to assure long operating life.

Six major sections form the manual divisions. Section 1 contains a brief functional description of the DCR-T series power supplies along with complete unit specifications. Initial inspection and checkout procedures are outlined in Section 2. Operating instructions, including methods for adapting units to various applications, comprise Section 3. Sections 4 and 5 provide the principles of operation and maintenance procedures respectively. System drawings and the replacement parts lists are included in Section 6.

1.2 DESCRIPTION

1.2.1 General

The DCR-T series is designed for either rack or floor mounting, and to provide stable, highly regulated dc outputs from a wide range of three phase input voltages and frequencies. (For complete unit specifications refer to Table 1-1.) The series exhibits excellent transient response and low ripple in both voltage regulating and current limiting modes. Other design features include: provisions for remote programming, remote sensing, and series and parallel operation. Increased versatility is also provided by the use of an industrial control technique for main power disconnect and line protection. This feature facilitates the remote control of the line power to the supply.

A variety of Sorensen power supply application notes are available through your Sorensen Service Representative. These notes detail many hook-up configurations available to meet most power supply applications.

1.2.2 Automatic Crossover

There are two basic operating modes: voltage and current. In the voltage mode, the voltage is held constant while the current varies with the load. In the current mode, the voltage varies and current is held constant. The automatic crossover feature enables the unit to switch operating modes as a function of load requirements. If, for example, load currents attempt to increase above a preset current limit, the unit will switch operation automatically from the voltage to the current mode. In this mode, the current will be regulated at the value preset on the front panel. If load requirements are lowered, a return to the voltage regulating mode will occur automatically.

1.2.3 Remote Sensing

Terminals located on the rear-mounted connector (J-2) offer a means of extending a unit's regulating point from the output terminals to the load. This effectively compensates for variations in the load lead voltage drop. Section 3 outlines the connections for remote sensing.

1.2.4 Series Operation

For applications requiring output voltages higher than a single unit can provide, DCR-T power supplies may be connected in series (see Section 3). Regulation in series operation is the sum of the regulations for all units.

1.2.5 Parallel Operation

Parallel operation may be used to service those applications requiring an output current higher than a single unit can provide. DCR-T power supplies may be direct paralleled with no limit to the number of units which can be paralleled. However, the regulation will deteriorate, and will be the sum of the regulations for the individual settings plus the output voltage differences between units at no load.

1.2.6 Remote Programming

Output voltage or current of DCR-T power supplies may be remotely programmed in either the voltage or current mode by resistance or voltage signal. Details and consideration are given in Section 3.

1.2.7 Failure Protection

In addition to the constant limiting protection provided by automatic crossover and the current regulator, the DCR-T power supply incorporates several other protection systems. Loss of one input phase drops the output to zero and energizes an indicator lamp on the control panel. Thermal overload, usually resulting from a cooling fan failure, will also drop the output to zero and energize an indicator lamp on the front panel. The main power components are protected by a thermal overload relay working in conjunction with a contactor to provide mechanical disconnect of the AC line to the main power components. (See Section 2 for complete input wiring requirements.) Control circuitry is protected by rear mounted fuses and an internal fuse.

In the event of an overvoltage condition at the output, such as a failure in the power supply or an externally induced condition, the adjustable overvoltage protection (OVP) will drop the output to zero and disconnect the AC power from the main power components. Protection against the effects of overloads and internal short circuits is also provided.

1.3 OPTIONAL MODIFICATIONS

1.3.1 Chassis Slide Kit

The sides of the DCR-T have inserts which allow attachment of slide rails. Consult the factory for information on this optional Chassis Slide Kit.

1.4 SPECIFICATIONS

See Table 1-1 for complete specifications on the DCR-T 10KW series power supply.

Table 1-1 Specifications

DCR-T SPECIFICATIONS
10K WATT SERIES

DCRT Model	OUTPUT POWER				Constant Voltage Mode					Temp. Coeff. Voltage mV/°C	Voltage Drift % Eo Max. (Typ.)	Programming Constants Voltage Mode	
	Voltage (Vdc)	Current (Adc)			Regulation Line & Load mV[1]	Ripple (PARD)		Resolution	Transient Response Time ms (Typ.)				
		50°C	60°C	70°C		mV rms	mV p-p					Ohms/V	V/V
16-625T5	0-16	625	531	375	8-16	30	100	Note 4	40	3.2	.05	625	Note 4
32-310T5	0-32	310	264	186	16-32	20	120	Note 4	40	6.4	.05	313	Note 4
55-180T5	0-55	180	153	108	27-55	20	120	Note 4	40	11.0	.05	182	Note 4
80-125T5	0-80	125	106	75	40-80	20	120	Note 4	40	16.0	.05	125	Note 4
110-90T5	0-110	90	77	54	55-110	40	140	Note 4	40	22.0	.05	91	Note 4
160-62T5	0-160	62	53	37	80-160	60	180	Note 4	40	32.0	.05	63	Note 4
300-33T5	0-300	33	28	20	150-300	100	300	Note 4	40	60.0	.05	33	Note 4
600-16T5	0-600	16	14	9.6	300-600	150	600	Note 4	40	120.0	.05	17	Note 4

NOTE 1: Regulation range as stated 0.1% of voltage or current, or stated range, whichever is greater.

NOTE 4: Contact factory.

COMMON SPECIFICATIONS

DC OUPUT CONSTANT VOLTAGE MODE:

Voltage Regulation: Line Load combined: All models 0.1% of the voltage setting or specification in table, whichever is greater.
Temperature Coefficient: 0.2%/°C of Eo max.
Voltage Signal Programming: 100 mV per 1% of rated output. (0-10V for 0-100% of rated output.)
Resistive Programming: 100 ohms per 1% of rated output. (0-10) k ohms for 0-100% of rated output.)
Stability: 0.1% Eo max. for 8 hours after 30 minute warm up with fixed line, load and temperature.
Remote Sensing: 3 to 10V max. drop + line. 0.75V max. drop - line.
Transient Response: 40 ms (typical) to return to ± 1% band for a step load change of 50% to 100% or 100% to 50% of full load.

INPUT:

T1 - 208 Vac ± 10% @ 60Hz.
T2 - 380 Vac ± 10% @ 50Hz.
T3 - 405 Vac ± 10% @ 50Hz.
T4 - 440 Vac ± 10% @ 60Hz.
T5 - 480 Vac ± 10% @ 60Hz.

OPERATING DATA:

Efficiency: 60% to 80% of full rated output depending on model.
Series Operation: 200 Vdc maximum; consult factory for series operation of more than 2 units.
Parallel Operation: Direct paralleling of any number of units.
Overvoltage Protection: Standard.
Ambient Operating Temperature Range: 0 to 70°C.
Storage Temperature Range: -45°C to +70°C.
Cooling: Forced Air.

Table 1-1 Specifications Cont'd

DCR-T SPECIFICATIONS
10KW SERIES

DCRT Model	Constant Current Mode			Temp Coeff Current mV/°C	Current Drift % Eo Max. (Typ.)	Programming Constants Current Mode		Standard Input Power (3 phase, 60 ± 1 hz)		Power Factor (Typ.)		Efficiency[3] %	Case Size
	Regulation mA[1]	Ripple (PARD) mA rms	Resolution (Typ.)			Ohms/V	V/V	Voltage Vac	Current Aac (Max.)[2]	Lead	Lag		
16-625T5	312-625	2000	Note 4	250	.05	16.0	Note 4	432-528	24.3	.9	.2	60	III
32-310T5	155-310	1500	Note 4	124	.05	32.0	Note 4	432-528	23.9	.9	.2	61	III
55-180T5	90-180	900	Note 4	72	.05	56.0	Note 4	432-528	23.1	.9	.2	63	III
80-125T5	62-125	900	Note 4	50	.05	80.0	Note 4	432-528	22.8	.9	.2	64	III
110-90T5	45-90	800	Note 4	36	.05	111.0	Note 4	432-528	22.4	.9	.2	65	III
160-62T5	31-62	480	Note 4	25	.05	161.0	Note 4	1432-528	22.4	.9	.2	66	III
300-33T5	16-33	240	Note 4	13	.05	303.0	Note 4	432-528	21.8	.9	.2	67	III
600-16T5	8-16	120	Note 4	6	.05	625.0	Note 4	432-528	21.8	.9	.2	67	III

NOTE 1: Regulation range is 0.1% of voltage or current, or stated range, whichever is greater.

NOTE 2: Line current at min. line voltage.

NOTE 3: Efficiency taken at max. power out and nominal ac volts input.

NOTE 4: Contact factory.

COMMON SPECIFICATIONS

CONSTANT CURRENT MODE:

Current Regulation: Line and load combined: All models 0.1% Io max. of the output current setting or specification in table, whichever is greater.
Temperature Coefficient: 0.04%/°C of Io max.
Current Signal Programming: 100 mV per 1% of rated output. (0-10V for 0-100% of rated output.)
Resistive Programming: 100 ohms per 1% of rated output. (0-10 kohms for 0-100% of rated load.)
Stability: 0.2% Io max. for 8 hours after 30 minute warm up with fixed line, load and temperature.

DCRT ACCESSORIES:

Chassis Slides: Part No. 1060247-1 (Optional).
Digital Programmer: Available for all models in DCRT Series. IEEE-488 Interface to GPIP Bus. Order Model 488 MICRO-DAP.

OPTIONAL EQUIPMENT:

OVP: OVP shutdown is standard.
Option: SCR crowbar M5.

METERING:

Digital: Standard
Analog: add M52

DCRT INPUT VOLTAGE			
T1	208V	60HZ	STD. U.S. VOLTAGE
T2	380V	50HZ	STD. CONTINENTAL EUROPE VOLTAGE
T3	415V	50HZ	STD. BRITISH ISLES VOLTAGE
T5	480V	60HZ	STD. U.S. VOLTAGE

CASE SIZE	DIMENSIONS IN. (mm)			WEIGHT lb. (kg)
	HEIGHT	WIDTH	LENGTH	
III	12.25(311.2)	19(482.6)	24(609.6)	310(682)

SECTION 2
INSTALLATION

2.1 GENERAL

After unpacking, general inspection and preliminary checkout procedures should be performed to assure that the unit is in proper working order. These consist of visually checking for damage, and performing an electrical check. If it is determined that the unit has been damaged, the carrier should be notified immediately. Repair problems should be directed to the nearest Sorensen representative, or to the factory.

2.2 INSPECTION

Proceed as follows to inspect for damage incurred during shipment:

A. Check meter faces for cracked or broken glass. Check analog meter for zero indication. Use zero adjust to bring indicator to zero, if necessary. Zero set is inside of the unit on the rear of the meter.

B. Look for cracked or broken lenses on the indicator lights.

C. Rotate the VOLTAGE and CURRENT potentiometers.

D. Remove the top cover and check to make sure that all printed circuit card plugs are firmly in place.

E. Remove the front panel (if already in place) and check that the controls and card plugs are firmly in place.

F. Check remote plug (P1) to insure that the remote AC control jumpers are in place.

If any optional equipment (refer to Section 1.3) has been purchased with the unit, assure that all parts are accounted for and that no damage has occurred in shipment. (Optional parts are normally shipped loose in the packaging carton.)

2.3 OPTIONAL EQUIPMENT INSTALLATION

The unit is shipped in ready to use condition. If optional accessories have been purchased, however, they must be installed at destination. The following sections detail the installation of optional equipment.

2.3.1 Chassis Slide Kit

Extend the Slide Rail and mount the rail to the DCR-T side panel inserts (4 each) with the #10-32 screws provided. Note that all but one of the mounting holes are accessible when the slide rail is fully extended. Close the inner portion of the rail approximately halfway to access the remaining mounting hole. Make certain that all four mounting inserts are used.

2.4 MECHANICAL INSTALLATION

The DCR-T series power supply is shipped ready for floor or bench use. If the unit is to be rack mounted, the eye hooks on the top and the feet on the bottom must be removed. If chassis slides are used, they should be attached to the unit prior to mounting in the rack. To access the rack mounting flanges used for bolting the unit into the rack, remove the four allen-head screws and the front cover plate. Re-attachment of the front cover plate after rack mounting will hide the mounting hardware and give an attractive flush look to the installation. As these power supplies have a relatively large mass, they should be mounted at or near the bottom of the rack.

2.5 GENERAL PRECAUTIONS

WARNING

This unit requires a 3 pole, wall-mounted, fused disconnect switch with the proper current limiting fuse for safe operation.

DO NOT turn on the wall switch until AC and DC wires are attached to the DCR-T unit.

Accidental shorts or hand contact inside the DCR-T can cause burns or electrical shock.

All DCR-T units must be hard-wired for fixed installation. The following precautions should be taken when connecting power supplies to an AC main. The latest NEC should be consulted and followed when wiring a DCR-T with the electrical mains.

2.5.1 AC Line Protection

All Sorensen power supplies are designed with a mechanical disconnect and overload protection. The components most often used are circuit breakers or fused switches. With the DCR-T series, Sorensen has introduced a system of mechanical disconnect for ac protection which has been used for years in industrial controls. All Sorensen power supplies, including the DCR-T, require careful coordination of the AC mains connections with the AC line protection system within the unit. This will insure not only that an AC fault will be cleared, but that the AC line protection system will not be damaged by the fault.

The following components are required for a complete AC line protection system:

MAIN DISCONNECT SWITCH - Customer-installed 3 pole, wall-mounted fused disconnect switch. The main disconnect switch mechanically removes the AC lead wires and the unit from the AC mains.

MAIN SHORT CIRCUIT PROTECTION - Customer-installed main short circuit protection (usually a fuse). The ratings of the short circuit protection should be large enough to handle the units attached. The let-through current of the short circuit protection shall be below the lowest ratings of any one unit attached and below the rating of the unit lead-in wire.

UNIT AC OVERLOAD PROTECTION - Included in all Sorensen power supplies. Mechanically connects and disconnects as much of the wiring within the unit as is possible. Prevents the AC line (from the main AC disconnect to the unit) from causing damage within the unit should a fault occur. Acts as a safety feature preventing shock or burns due to a possible fault within the unit.

The following table specifies the maximum fault current which Sorensen three phase power supplies can safely clear. Use this table to size current limiting fuses for these supplies.

UNIT	MAX. LET-THRU CURRENT
DCR-T-10KW	2500 AMPS

2.6 ELECTRICAL INSTALLATION

CAUTION

Read wiring WARNING on page 2-2 before starting wiring. Unit is phase sensitive. Test input phase per para. 2.7.

Follow these steps in wiring:

1 Check phase rotation at the main disconnect switch (see Section 2.7). Mark terminals 2 - 3 - 4 to correspond to line A, line B and line C, respectively.

2 Identify the proper safety ground at the wall switch. (The neutral and/ or a separate ground may be provided. Check the power company and local codes for a proper connection.)

3 Label four wires for the input connection. Wires 2 - 3 - 4 are connected to the three phase terminals, and wire 1 is connected to the safety ground terminal.

4 Connect the 4 wires to the DCR-T ac input terminals which are marked GND-0A-0B-0C.

IMPORTANT SAFETY PRECAUTION

Wire 1 must be connected to the CHASSIS GROUND terminal to provide a ground for the DCR-T chassis frame.

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5 Connect the two dc output wires. Label these wires (+) and (-).

2.7 PHASE ROTATION CHECK

The DCR-T is a phase rotation sensitive unit. To check rotation, proceed as follows:

A. Connect unit as indicated in paragraph 2.6.

B. Turn CURRENT and VOLTAGE control pots fully counterclockwise (zero out).

C. Turn ON/OFF switch to STAND-BY.

D. Press START button.

E. Turn CURRENT control several degrees clockwise.

F. Turn VOLTAGE control slowly clockwise until full voltage is reached.

G. If at any point the unit makes sharp noises and voltmeter jumps, turn unit off. Two AC lines are probably reversed. Reverse any two AC input lines.

2.8 INITIAL CHECKOUT

2.8.1 Voltage Mode

NOTE

Sense leads from P2 may not be connected. The unit will perform adequately without sense leads because internal safety circuits. However, regulation capability will be impaired. (See paragraph 3.2

To perform a check of voltage mode operation, proceed as follows:

A. Assure that proper input connections have been made. Refer to Section 2.5, 2.6 and 2.7.

B. Turn VOLTAGE and CURRENT controls fully counterclockwise.

NOTE

See Figure 3-1 for location of controls and indicators.

C. Set ON/OFF switch to STAND-BY mode. Amber STAND-BY lamp will be illuminated.

D. Press START button, note sound of fan. Green ON lamp will be illuminated.

E. Turn VOLTAGE and CURRENT control slowly clockwise and observe the unit voltmeter. The pointer should move upscale.

F. Press STOP button. Unit will return to the STAND-BY mode.

2.8.2 Current Mode

To check operation of the unit in the current mode, proceed as follows:

A. Turn VOLTAGE and CURRENT controls fully counterclockwise.

B. Connect a heavy gauge wire across the output terminals. One of the intended output leads is recommended for this purpose.

C. Set ON/OFF switch to STAND-BY. Amber STAND-BY light will be illuminated.

D. Press START button, note sound of fan. Green ON lamp will be illuminated.

E. Rotate VOLTAGE control about 30° from the left hand stop and observe output meters. Both should be zero.

F. In small increments, raise CURRENT control while observing the ammeter. If current does not increase, rotate the VOLTAGE adjustment another 30°.

G. Press STOP button. Unit will return to the STAND-BY mode.

H. Remove shorting wire from the output terminals.

Table 2.1 MAXIMUM LINE CURRENT
5 K W

	Amps RMs					
Line Voltage	**208**	**220**	**385**	**415**	**480**	**560**
UNIT						
16-625T	53	50	28	26	23	20
32-310T	52	49	28	26	23	19
55-180T	48	46	26	24	21	18
80-125T	46	43	25	23	20	17
110-90T	48	46	26	24	21	18
160-62T	45	43	24	23	20	17
300-33T	42	40	23	21	18	16
600-16T	41	39	22	21	18	15

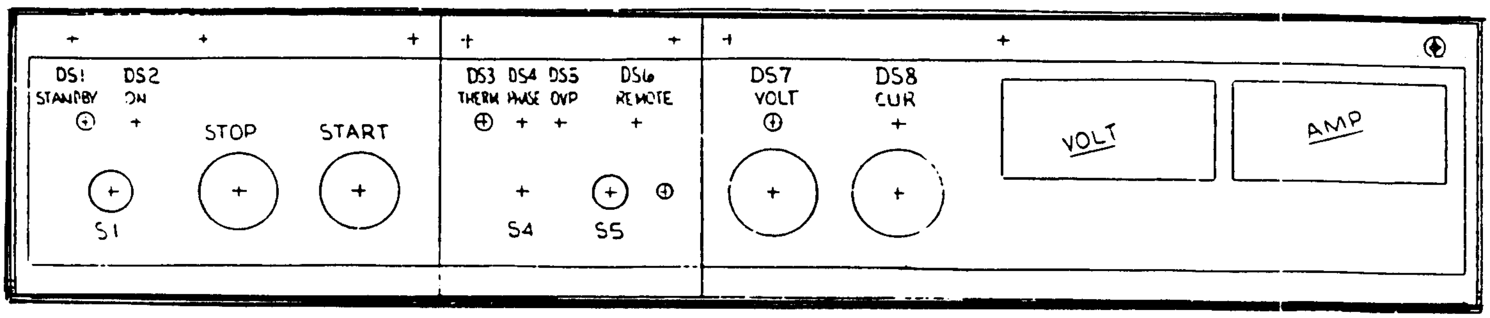
SECTION 3
OPERATION

3.1 GENERAL

This section provides a tabular listing of the unit's controls and indicators along with a brief description of their function. Physical location of the controls and indicators is shown in Figure 3.1. The physical location of the rear panel terminals and connectors is shown in Figure 3.2.

Table 3.1 CONTROLS AND INDICATORS.

Control/ Indicator	Function
On/Off Switch	Energizes control circuitry and provides power for contactor disconnect. Puts unit in Stand-By.
Stand-By Lamp	Indicates unit is in Stand-By.
STOP Button	Causes contactor to be pulled in. Contactor is held energized through the STOP button, the overload auxiliary contacts, the contactor auxiliary contact, and a triac on the Control PCB.
ON Lamp	Indicates Main Power ON.
Phase Indicator	Indicates loss of an ac line.
Thermal Indicator	Indicates an overtemperature condition.
OVP Indicator	Indicates that the OVP has been activated.
Reset Button	Brings output to zero. Resets the unit after OVP or thermal shutdown without recycling.
OVP Adjust Button	OVP Adjustment control.
REM Indicator	Indicates unit is in remote operation. ON when in remote operation. Flashes if a remote line is open.
Voltage Control	Multi-turn pot to set output voltage.
Volt Mode Indicator	Indicates when unit is in the voltage regulating mode.
Current Control	Multi-turn pot to set output current.
Current Mode Indicator	Indicates when unit is in the current regulating mode.
Unit Ammeter	An ammeter connected to a shunt in the negative leg of the unit output. Indicates output current.
Unit Voltmeter	A voltmeter connected internally across the SENSE



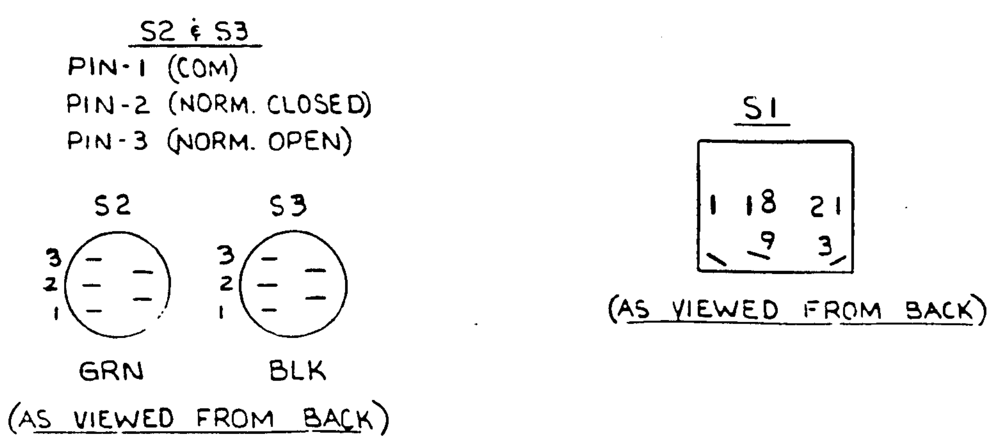
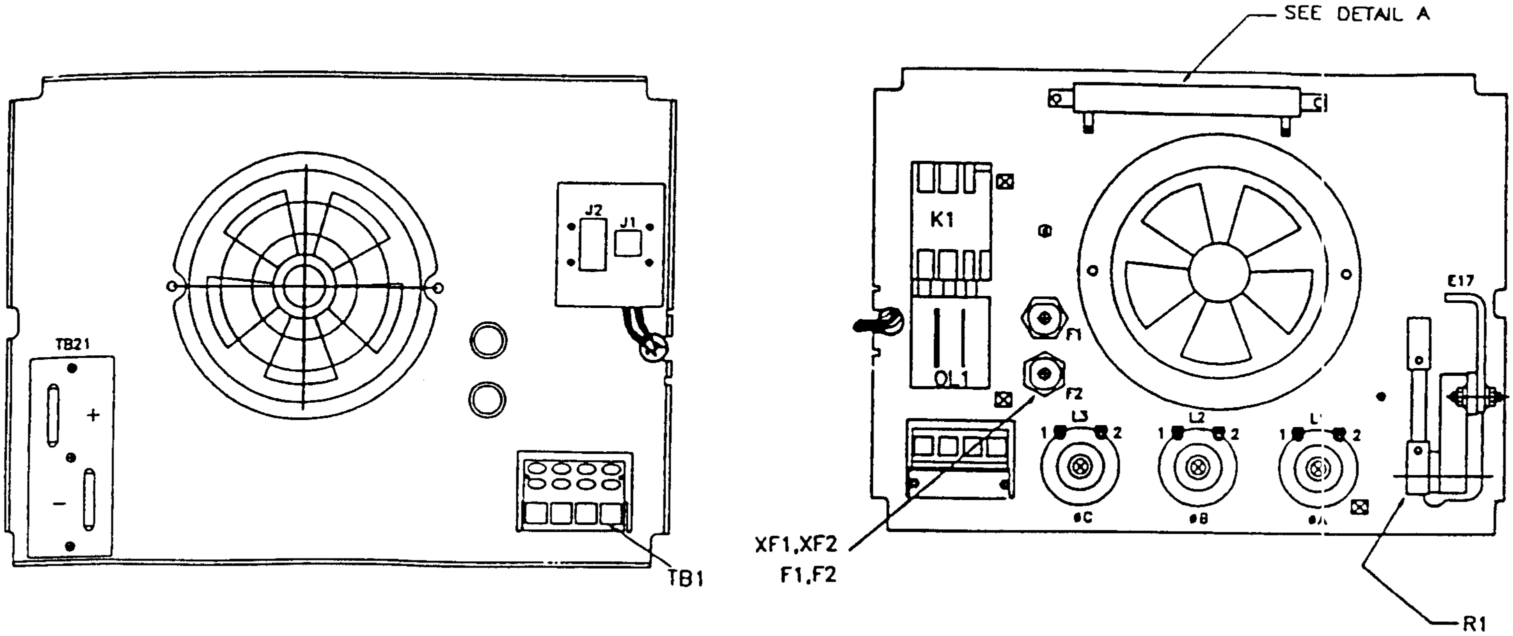
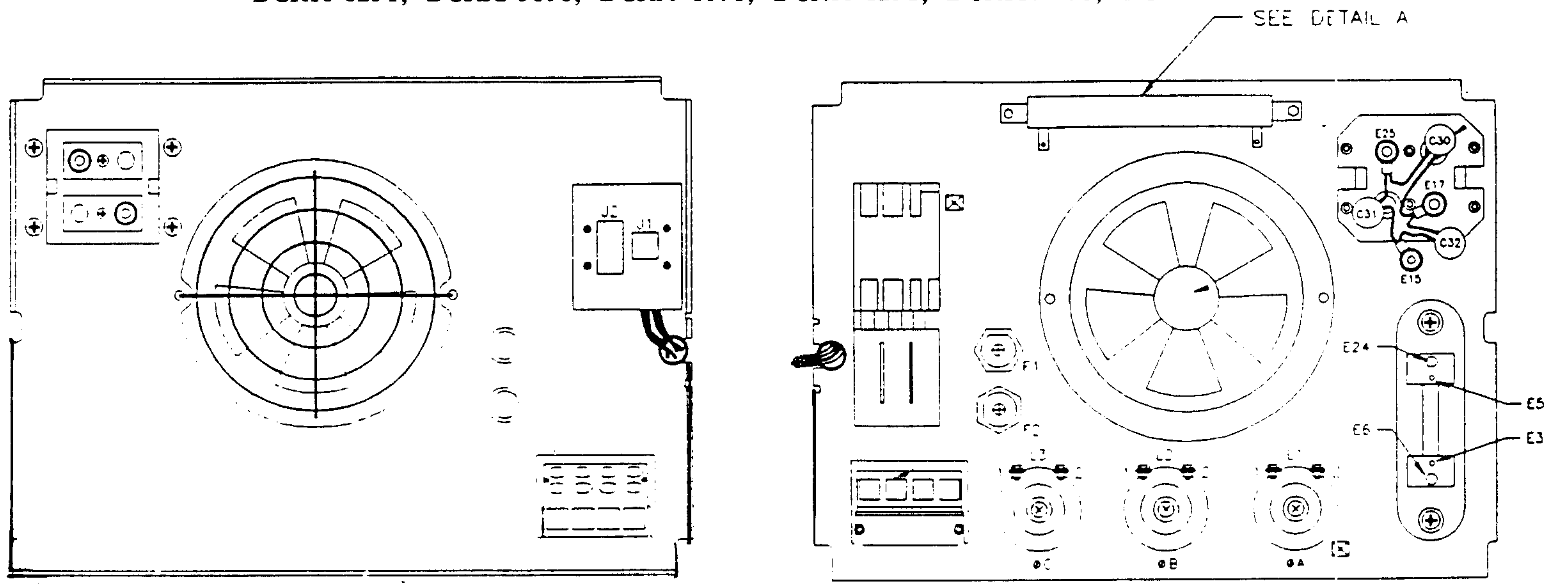


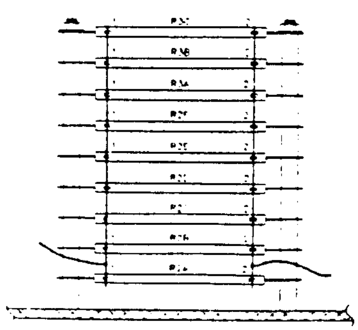
Figure 3.1 Typical Controls and Indicators



DCR16-625T, DCR32-310T, DCR55-180T, DCR80-125T, DCR110-90T, DCR160-62T



DCR300-33T, DCR600-16T



J2 PROGRAM AND SENSE

- -1 LC
- -2 LOGIC GND
- -3 RESET
- -4 OVP IND
- -5 THERMAL IND
- -6 PHASE IND
- -7 OPERATOR REMOTE IND
- -8 REMOTE/LOCAL
- -9 (+) OUTPUT
- -10 (-) OUTPUT
- -11 VIRTUAL GND
- -12 REMOTE OVP SET
- -13 REMOTE CURRENT SET
- -14 REMOTE VOLTAGE SET
- -15 SHUTDOWN
- -16 REMOTE VOLTAGE MTR
- -17 REMOTE AMP MTR
- -18 MODE PLS
- -19 MODE DRIVE
- -20 MODE IND
- -21 SENSE (+)
- -22 SENSE (-)

J1 REMOTE AC CONTROL

- -1 COM
- -2 STOP
- -3 START

Note: For proper crimping, use Molex tooling HTR-1719-C for J1, J2 pins or Amp tool 5879962. Use 18-24 Awg wire.

Figure 3.2 Rear Panel Terminals and Connectors

This section also provides instructions for adapting the supplies to of their varied applications. Included are procedures to be followed for conversion to: remote sensing operation; voltage, current and programming modes; and series and parallel operation. Also included are procedures for use of the various remote control and remote indicator features of the power supply.

NOTE

Throughout the following discussion, voltage and current levels will be expressed in percentages of full scale label values. This is necessary due to the large variety of outputs available in the DCRT Series. Full scale label values are determined by the model number, (e.g.) DCR16-625T5 is 16 volts and 625 amps full scale, DCR55-180T5 is 55 volts and 180 amps, etc.

3.2 LOCAL SENSING

The supplies are shipped without the sense leads connected. The supplies are protected against open sense leads. To realize specified performance of the unit, however, the sense leads must be connected. Local sensing simply means that the sensing circuit is connected across the unit output terminals and not at the load. For applications where the voltage drop in the load wires is prohibitive, use remote sensing (paragraph 3.5). Figure 3.3 illustrates the local sensing configuration of remote connector (J-2). The mating connector housing, strain relief and connector pins are included with the DCRT unit. Connector pins will accept #18 through #24 AWG insulated wire.

NOTE

Care must be exercised when connecting sense leads. Reversing the connections will result in damage to the unit.

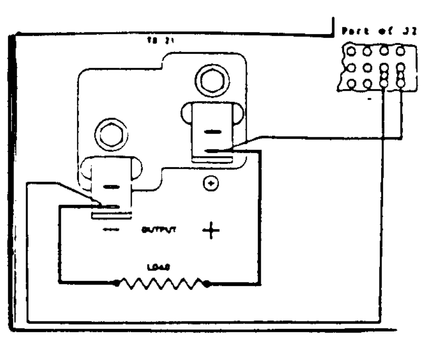


Figure 3.3 Local Sensing Configuration

3.3 VOLTAGE MODE

To put the unit in voltage mode operation, proceed as follows:

A. Rotate the VOLTAGE and CURRENT control potentiometers fully counterclockwise.

B. With the main disconnect switch OFF, connect the three phase input leads as indicated in Section 2.6

C. Set ON/OFF switch to ON. Stand-By lamp should be illuminated.

D. Press START button. ON lamp should illuminate.

E. Rotate VOLTAGE control until the unit voltmeter indicates the desired output voltage.

NOTE

To prevent random firing of the SCR's, for voltage outputs below 5% of maximum rated output voltage, it is recommended that a bleeder resistor be connected across the output of sufficient value to draw approximately 10% of rated output current. For example, for a DCR16-310 below .8V use a bleeder to draw approximately a 31.0A load. This would be approximately .026 ohms (use a 100 watt rating).

F. Set ON/OFF switch to OFF, and set the main disconnect switch to OFF.

G. Connect load to the unit terminals on the rear of the unit.

H. Set CURRENT control to a value at least 10% above the actual load current.

NOTE

Regulation falls off if output current is within 10% of limiting value. Current mode indicator begins to glow when current output is within approximately 10% of limiting value.

I Set the Main Disconnect switch to ON and the ON/OFF switch to ON.

J Press START button. The ON lamp will light and the unit will be in voltage operation mode.

NOTE

With the unit in the voltage mode, an increase in load current requirements above the value set in step H will cause an automatic crossover to current mode (current limiting) operation.

3.4 CURRENT MODE

To operate the unit in current mode, proceed as follows:

A. Rotate the VOLTAGE and CURRENT controls fully counterclockwise.

B. With the Main Disconnect switch OFF, connect three phase input as indicated in Section 2.6

C. Set ON/OFF switch to ON. Stand-By lamp should illuminate.

D. Press START button. ON lamp should illuminate.

E. Rotate VOLTAGE control until unit voltmeter indicates a level 10% above the desired dynamic voltage.

NOTE

Current regulation falls off if the dynamic (compliance) voltage is within 5% of the voltage limiting value.

F. Set ON/OFF switch to OFF, and set the Main Disconnect switch to OFF.

G. Connect load lines to unit output terminals on the rear of the unit.

H. Set the Main Disconnect switch to ON and the ON/OFF switch to ON.

I Press START button. ON lamp will light, and the unit is in voltage mode operation.

J Turn CURRENT control to desired current regulating value. CURRENT MODE lamp will light and the unit is in current mode operation.

NOTE

If dynamic (compliance) voltage rises above limit set in step "E", the unit automatically crosses over to voltage mode operation. (Current mode light goes off.)

3.5 REMOTE SENSE

In the remote sensing mode, voltage regulation is at the load rather than at the unit output terminals, thus correcting for voltage drops in the load leads.

NOTE

A 10% of E_O maximum voltage drop lead is the maximum for which remote sensing will compensate. To avoid exceeding the rated maximum unit voltage, the maximum load voltage (as read on the panel voltmeter) must be less than the rated maximum by the sum total of the drops. Example: If each load line drops 3 volts, (6 volts total), then on a 55 volt rated unit, the DCR55-90T, the voltmeter reading must not exceed 55 - 6 = 49 volts.

To adapt a unit for remote sense operation, proceed as follows:

A. Set unit ON/OFF switch to OFF and the Main Disconnect switch to OFF.

B. Remove the local sense leads from both the output terminals and J2 mating connector, if already connected.

C. Install the remote sense leads to plus and minus SENSE terminals in J2 using the J2 mating connector provided. Note which lead is connected to the plus terminal (remote sensing configuration is shown in Figure 3.4).

NOTE

Care must be exercised when connecting sense leads. Reversing the connections will result in damage to the unit.

NOTE

Use a twisted or shielded pair of wires for the remote sensing leads. Sensing current is approximately 1.0 mA.

D. Connect the lead from the positive sense terminal to the positive load terminal, and connect the negative sense lead to the negative load terminal.

E. Reset current limit per paragraph 3.3.

F. If the unit is being placed on-line for the first time or is being returned to service following a maintenance check, etc., proceed as outlined in paragraph 3.3 or 3.4. Otherwise, set the Main Disconnect switch to ON, set the unit ON/OFF switch to ON and press the START button. POWER ON indicator light will illuminate and the unit supplies the load.

3.6 OVERVOLTAGE PROTECTION (OVP)

The OVP circuit protects the load by limiting the output voltage to a preset value. Load protection is accomplished by bringing the output current and voltage to zero and opening the contactor which brings the unit to a Stand-By mode when the preset OVP value is reached. The unit is shipped with the OVP factory set at 10 to 15% of the maximum output voltage.

To set the OVP at another value, proceed as follows:

NOTE

To avoid nuisance tripping of the OVP circuit, the preset value should be set at 10% minimum above the operating output voltage.

A. Set the unit for operation as outlined in paragraph 3.3 or 3.4.

B. To read the OVP set value on the front panel voltmeter, simply press the OVP set switch.

C. Set the desired OVP value using the front panel OVP Adjust Control while depressing the OVP set switch.

D. At any time, the OVP set value may be read without affecting the normal operation of the unit.

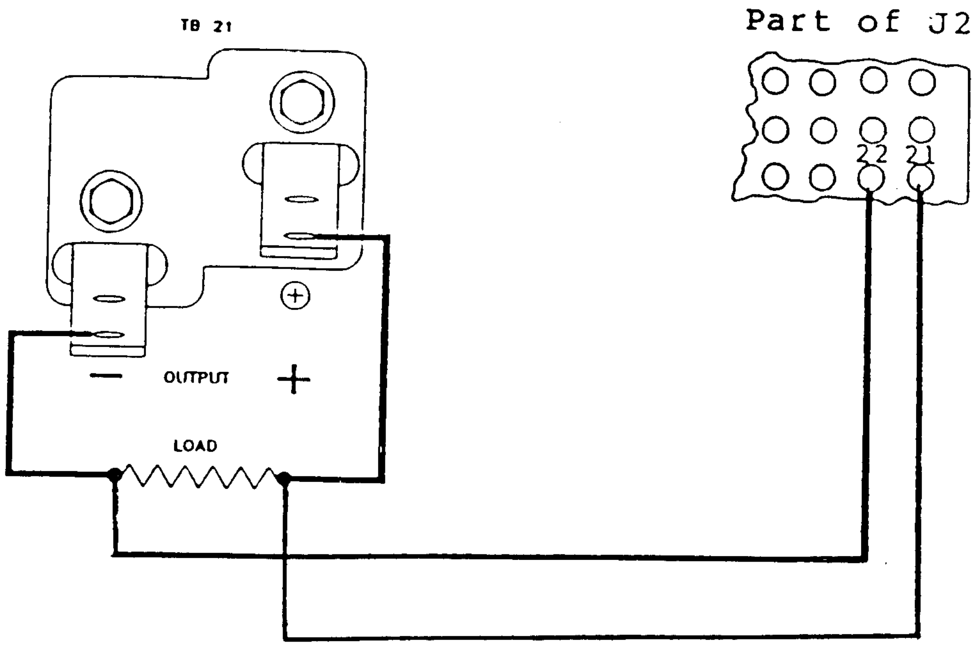


Figure 3.4 Remote Sensing Configuration

NOTE

When unit is set for external programming, both voltage and current settings must be externally programmed. Both front panel output adjustment controls are disabled. If either programming line is open, the unit output will go to zero and the front panel Remote Indicator Lamp will flash. The OVP is unaffected.

3.7 RESET

The front panel RESET switch is used to clear those faults which latch the unit in the zero output state. These faults are: OVP shutdown, thermal shutdown and phase loss. The thermal indicator light will illuminate when the RESET is depressed and the unit output voltage and current will go to zero. When the RESET switch is released, the unit will soft start and return to the preset operating conditions.

To RESET the unit after a fault has occurred, proceed as follows:

1 <u>OVP SHUTDOWN:</u> After an OVP fault, the unit will be in Stand-By mode and the OVP indicator lamp will be illuminated. Press the RESET switch. The OVP indicator lamp will go off, and the unit can be re-started by pressing the START switch.

2 <u>THERMAL SHUTDOWN:</u> Should the thermal shutdown circuit activate, check first to make sure the unit cooling fan is operating. Fan failure is the primary cause of a thermal shutdown fault. Allow approximately 10 minutes time with the cooling fan operating before resetting the unit. Press the RESET switch and release. The thermal indicator will go off and the unit output voltage and current will return to the preset operating conditions.

3 <u>PHASE LOSS:</u> The loss of one input phase line will latch the output voltage and current to zero. The unit can only be reset when the phase has been restored to the unit. When the lost phase has been restored, press and release the RESET switch. The PHASE indicator will go off and the unit output voltage and current will return to the preset operating conditions.

3.8 EXTERNAL RESISTANCE PROGRAMMING

The unit output voltage, current and OVP set points may be resistance-programmed remotely to a predetermined regulated value. Three 1 mA precision current sources are provided, one each for programming voltage, current and OVP set. External resistance programming is accomplished by connecting a resistance from the current source output to V_{GEN} (J2 pin 11).

External Resistance Programming Constants are:

10,000 Ohms for 100% Output Setting.
1,000 Ohms for 10% Output Setting.
100 Ohms for 1% Output Setting.

3.8.1 Voltage and Current Mode

Remote programming sensitivity varies according to the full scale voltage and current output of the unit. Table 1-1 lists the proper ohms/volt and ohms/amp for each model. For example, a DCR32-310T has a 32 volt full scale output. The ohms/volt sensitivity from Table 1-1 is 313 ohms/volt. For a certain voltage output, therefore, the voltage value to be programmed must be multiplied by the ohms per volt sensitivity to arrive at the correct value for programming resistance.

Example for programming a 25 volt output from a 32 volt full scale unit: (25) X (313 ohms) = (7825 ohms)

Current output programming is accomplished in the same manner. For example, the DCR32-310T has a 310 Amp full scale output. The ohms/amp sensitivity from Table 1-1 is 32 ohms/amp.

Example for programming a 300 amp output: (300) X (32 ohms) = (9600 ohms)

NOTE

The resistor used should have a low temperature coefficient (±30 PPM) to maintain the units rated temperature characteristics as well as stability. Programming current is about 1 mA. Use a 1% resistor with a wattage rating of 1/8W or larger.

To adapt the unit to external resistance programming, proceed as follows:

A. Set unit ON/OFF switch to OFF and Main Disconnect switch to OFF.

B. Connect jumper wire from J2 pin 2 (Logic Ground) to J2 pin 8 (Remote/ Local).

C. Connect both voltage and current programming resistors. (See Figure 3.5 for diagram of programming connections.) The voltage programming resistor is connected from J2 pin 14 (Remote Voltage Set) to J2 pin 11 (Virtual Ground). The current programming resistor is connected from J2 pin 13 (Remote Current Set) to J2 pin 11.

D. Set the Main Disconnect switch to ON and set the ON/OFF switch to ON. The Remote Indicator Lamp on the front panel will illuminate. Press the START button. The unit will regulate to the values set by the external programming resistors.

NOTE

If remote programming is to be discontinued, remove the programming device, and disconnect the jumper from J2 pin 2 to J2 pin 8.

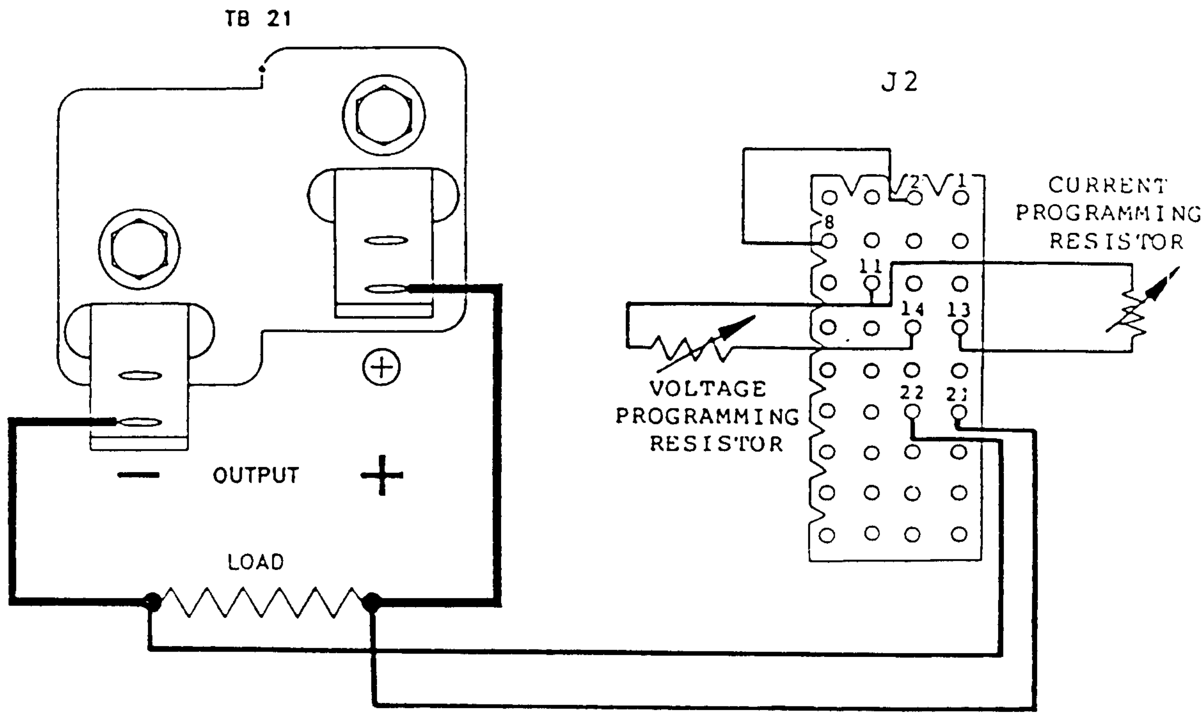


Figure 3.5 External Resistance Programming (With Remote Sense)

3.8.2 OVP Set

The unit OVP Trip Point may be externally resistance programmed. This would be desirable in those applications where one or more OVP Trip Points are required (different than the front panel OVP Trip Set adjustment).

NOTE

External OVP set programming is independent of external voltage and current mode programming. The jumper from J2 pin 2 to J2 pin 8 is not required to remote program the OVP Trip Set Point.

Example for setting the OVP Trip Set point to 8 volts on a DCR16-625T:

To determine the External Programming resistor value, proceed as follows:

A. First, determine OVP Trip Voltage needed for Section B.
Note: 0-10 volts corresponds to the 0 to full scale output of the unit to be programmed.

$$\frac{8 \text{ volts (desired OVP Point)}}{16 \text{ volts full scale}} \times 10\text{V (full scale programming voltage)} = 5 \text{ volts}$$

B. To determine the value of the program resistor, use a voltage from 0 to 10 volts, calculated above, in the following formula:

$$Rp = \frac{(\text{X volts})\ (10{,}909)}{10{,}909 - (\text{X volts})} = \frac{(5 \text{ volts})\ (10{,}909)}{10{,}909 - (5 \text{ volts})} = 9{,}231 \text{ ohms}$$

This value (9,231 ohms) would externally program the 16 volt full scale unit OVP Trip Set Point to 8 volts.

To adapt the unit to external resistance programming of the OVP Trip Point, proceed as follows:

A. Set unit ON/OFF switch to OFF and the Main Disconnect switch to OFF.

B. Set the front panel OVP set adjustment fully clockwise.

C. Connect the program resistor from J2 pin 12 (Remote OVP Set) to J2 pin 11 (Virtual Ground). See Figure 3.6 for diagram of OVP set programming connections.

NOTE

The remote programmed OVP set point may be read on the front panel voltage meter by depressing the OVP Set switch (see paragraph 3.6).

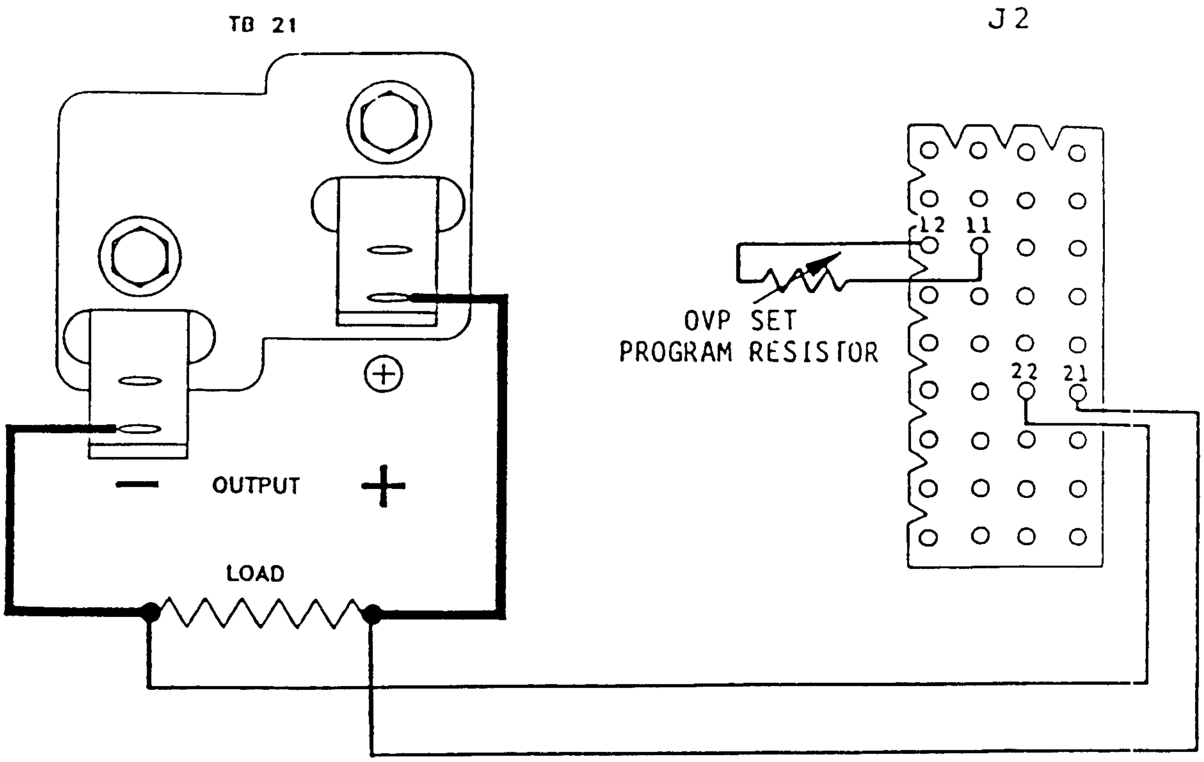


Figure 3.6 External OVP Resistance Programming
(With Remote Sense)

3.9 EXTERNAL SIGNAL PROGRAMMING

The unit output voltage, current and OVP set point, may be externally programmed to provide a variable output as a function of an input voltage signal. This is done by introducing the external signal to the current source outputs provided for programming voltage, current, and OVP set.

External Signal Programming Constants are as follows:

10 volts for 100% Output Setting.
1 volt for 10% Output Setting.
0.1 volt for 1% Output Setting.

NOTE

When unit is set for external programming, both voltage and current settings must be externally programmed. Both front panel output adjustment controls are disabled. If either programming line is open, the unit will go to zero and the front panel remote indicator lamp will flash. The OVP is unaffected.

3.9.1 Voltage and Current Mode

Remote signal programming sensitivity is 0 to 10 volts for 0 to full scale output for all models in both voltage and current mode.

In selecting a signal source, the following should be considered:

1. The source must be capable of sinking approximately 1 mA (the Programming Current).

2. A floating (ungrounded) source must be used. All signal programming voltages will, however, have a common return.

3. To obtain a full scale voltage or current output range, the source provides a 0 to 10 volt signal.

To adapt the unit to external programming, follow the procedure as outlined in paragraph 3.6.1, with one exception.

EXCEPTION: When Step C calls for connection of a resistor across the programming terminals on J2, instead connect the signal source. See Figure 3.7 for connections and observe the program signal polarity.

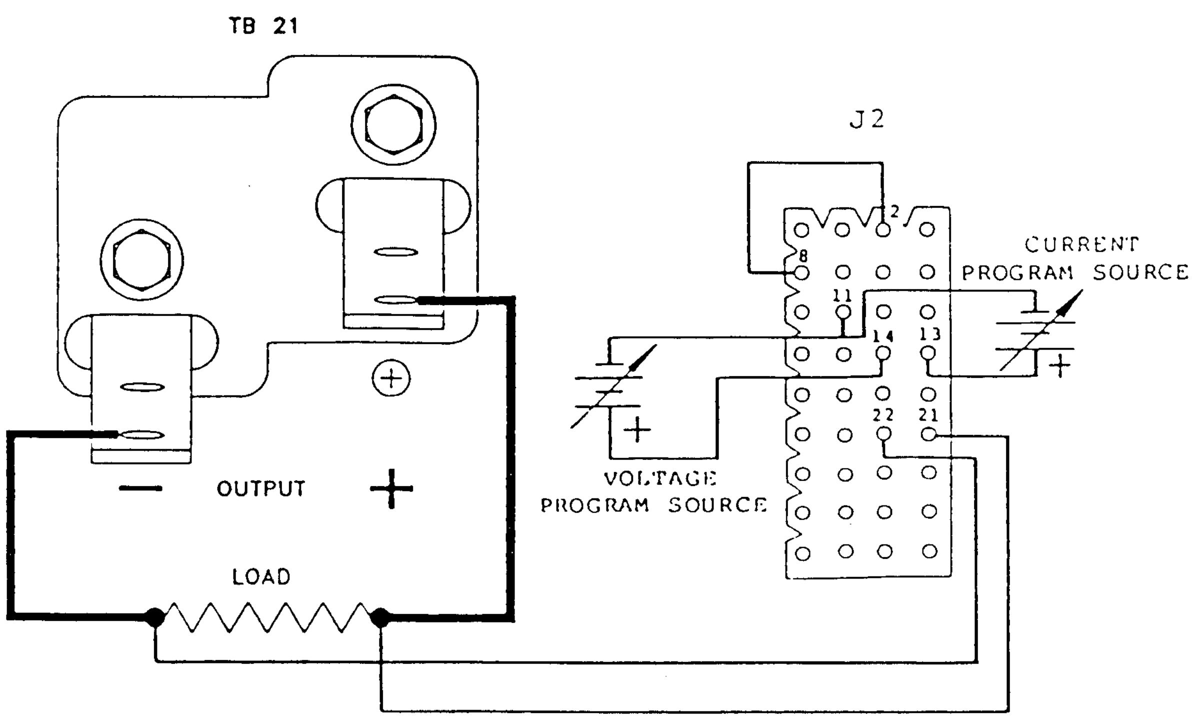


Figure 3.7 External Signal Programming (With Remote Sense)

3.9.2 OVP Set

The unit OVP Trip Point may be externally signal programmed. This would be desirable in those applications where one or more OVP Trip Points are required to be different from the OVP Trip Set Adjustment.

NOTE

External OVP Set programming is independent of external voltage and current mode programming. The jumper from J2 pin 2 to J2 pin 8 is not required to remote program the OVP Trip Set Point.

The OVP Trip Set signal programming sensitivity is 0 to full scale output for all models. The signal source requirements are the same as for the voltage and current mode signal programming source (see paragraph 3.7.1), with one exception.

EXCEPTION: The signal source value must go to 11 volts for applications where the unit is operating at Full Scale output. This allows the OVP Trip to be set to approximately 110% of the Full Scale output voltage to avoid nuisance tripping.

To adapt the unit to external signal programming of the OVP Trip point, follow the procedures outlined in paragraph 3.6.3, with one exception.

EXCEPTION: Where step C calls for connection of a resistor across the programming terminals of J2, connect the signal source instead. See Figure 3.8 for connections and observe the program signal polarity.

NOTE

The remote programming OVP set point may be read on the front panel voltage meter by depressing the OVP Set switch.

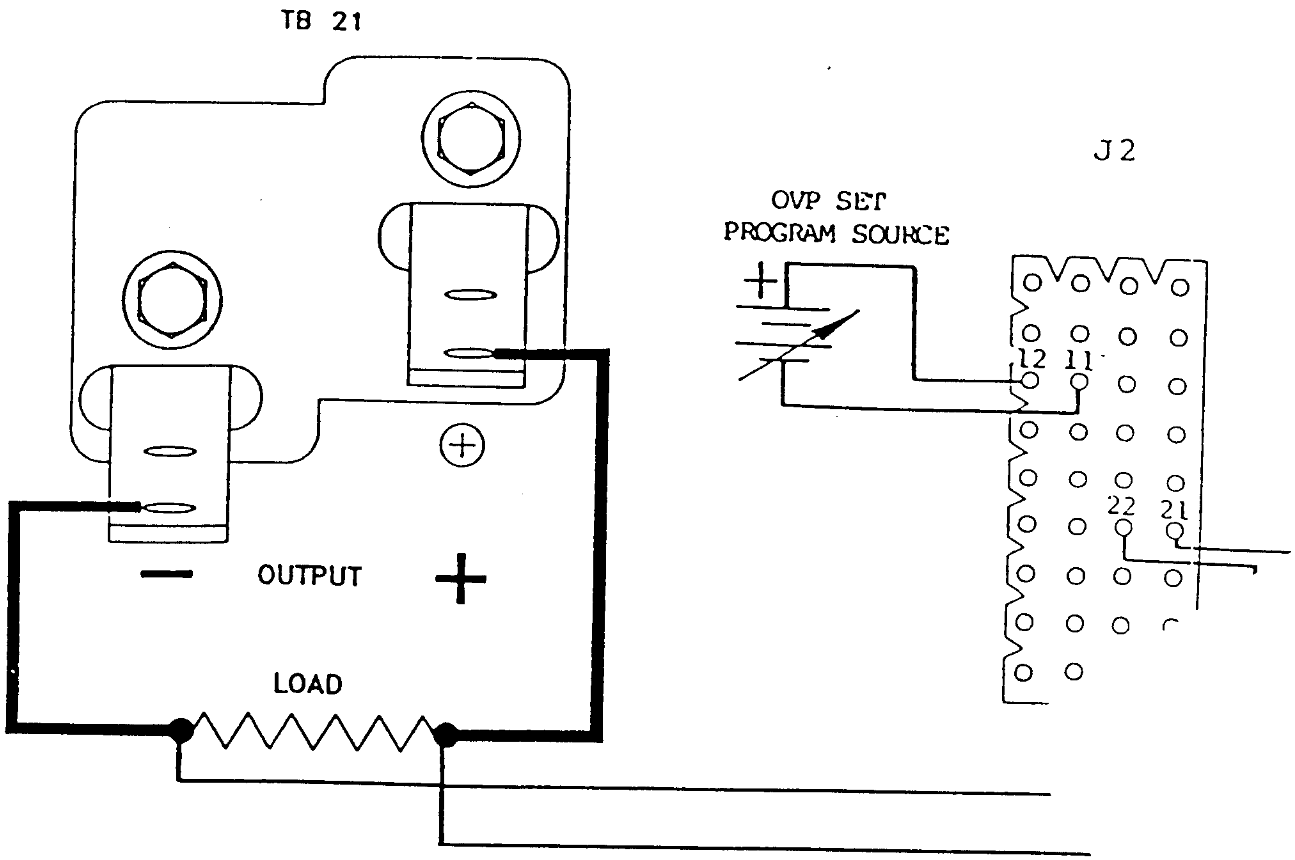


Figure 3.8 External OVP Signal Programming (With Remote Sense)

3.10 PARALLEL OPERATION

Paralleling of three-phase DCR-T units is accomplished directly by connecting the individual supplies to the load. Using this method, no current derating due to composite tolerances of wire resistance, components, etc., is required. There are no restrictions on the number of units that may be paralleled. However, paralleling units does result in lower overall regulation.

NOTE

The paralleled units may be adapted for remote sensing as illustrated in Figure 3.9. They may also be adapted for resistance programming. None of these are required for paralleled operations, however.

The following lists the procedures to be followed in directly paralleling two units. The procedure is applicable to any number of units, however. (See Figure 3.9 for connections.)

A. Set the ON/OFF switch of both units to OFF. Disconnect main power to both units by setting the Main Power Disconnect switch to OFF.

B. If applicable, disconnect output lines and sensing leads to both units.

C. Re-energize the units.

D. Rotate the VOLTAGE ADJUST control of one unit to the desired output. Repeat the procedure for the other unit. Match the two unit outputs as close as possible.

E. Set CURRENT ADJUST AMPS control on each unit to one-half of the total desired limiting current; (e.g.) if desired, to limit load current at 15A, set each control to 7.5A, etc.

F. Set the ON/OFF switch of both units to OFF. Disconnect main power to both units by setting the Main Disconnect switch to OFF.

G. Connect output cables from each unit to load. If desired, connect the remote sensing leads of each unit to load.

H. Re-energize both units. POWER ON indicators light. The unit which is supplying the highest voltage (it is possible to identically match the output voltages) will supply load. If the load requirements exceed the setting on CURRENT ADJUST AMPS control, this unit will automatically crossover to current mode operation, and its output voltage will drop. The second unit will assume that portion of the load rejected by the first. Any further increases in load will be supplied by the second unit up to its current limit setting. Regulation, therefore, will be the sum of the regulation of the two units plus the difference in the voltage settings. Set each current limit as needed to limit current to 100% of rated.

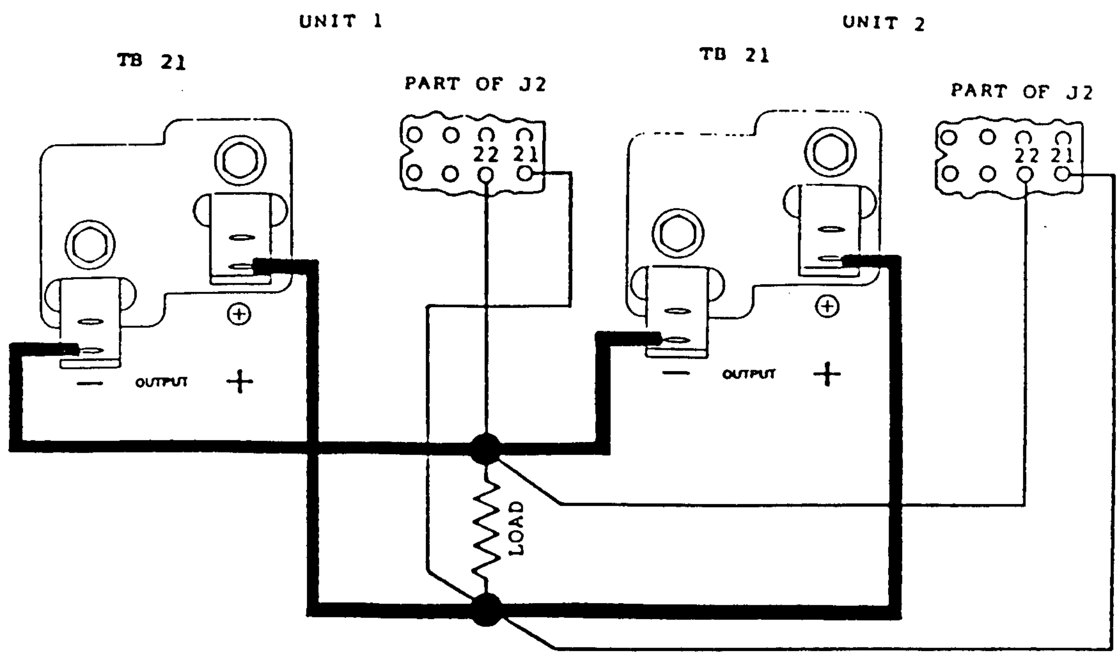


Figure 3.9 Parallel Operation (With Remote Sense)

3.11 SERIES OPERATION

Series operation allows the user to connect as many as five 10 or 32 volt DCR-T units in series. Only three of the 55, 80 and 110 volt units and only two of the 160 volt units may be connected in this manner, while the 300 and 600 volt units may not be connected in series configuration. No derating is inherent in series operation and regulation is the sum of the regulation of all units.

NOTE

Series units may be connected for remote sensing as indicated in Figure 3.10, or they may be adapted to resistance or signal programming. None of these, however, are required for series operation.

The following outlines procedures for connecting two units in series. The same procedure may be used for series connecting up to five units. (See Figure 3.10 for schematic of connections.)

A. Set desired voltage output of each unit at no load using VOLTAGE ADJUST. Select current limiting value.

B. Set the ON/OFF switch of both units to OFF. Disconnect main power to both units by setting the Main Disconnect switch to OFF.

C. Connect an output lead from the positive output terminal of one unit (for the sake of clarity, call this unit 1) to the negative output terminal of unit 2.

D. Connect an output lead from unit 1 (negative terminal) to the load; connect the other output lead from unit 2 (positive terminal) to the load.

CAUTION

In series operation, rectifiers must be connected across each set of output terminals as shown in Figure 3.10. Failure to do so may result in damage to output capacitors. See paragraph 3.11.1 for information on rectifier selection.

E. If remote sensing is desired, proceed as follows:

1. Connect a sensing lead from the (- SENSE) terminal on unit 1, remote connector J2, to the load termination of unit 1 negative output lead.

2. Connect a sensing lead from the (+ SENSE) terminal on unit 1, remote connector J2, to the negative output terminal of unit 2.

3. Connect a sensing lead from the (- SENSE) terminal on unit 2, remote connector J2, to the negative output terminal of unit 2.

4. Connect a sensing lead from the (+ SENSE) terminal on unit 2, remote connector J2, to the load termination of unit 2 positive output lead.

E. Re-energize both units. POWER ON indicator lights. Each unit operates as a separate entity, with the output of each independently adjustable. Each may be turned ON and OFF separately. (The rectifiers protect the OFF unit.)

3.11.1 Series Operation Rectifier

When operating units in series, connect rectifiers across the individual unit ouputs. Assure the diodes have current and voltage capability at least equal to its associated supply. Adequate heatsinking must be used. (See Figure 3.10.)

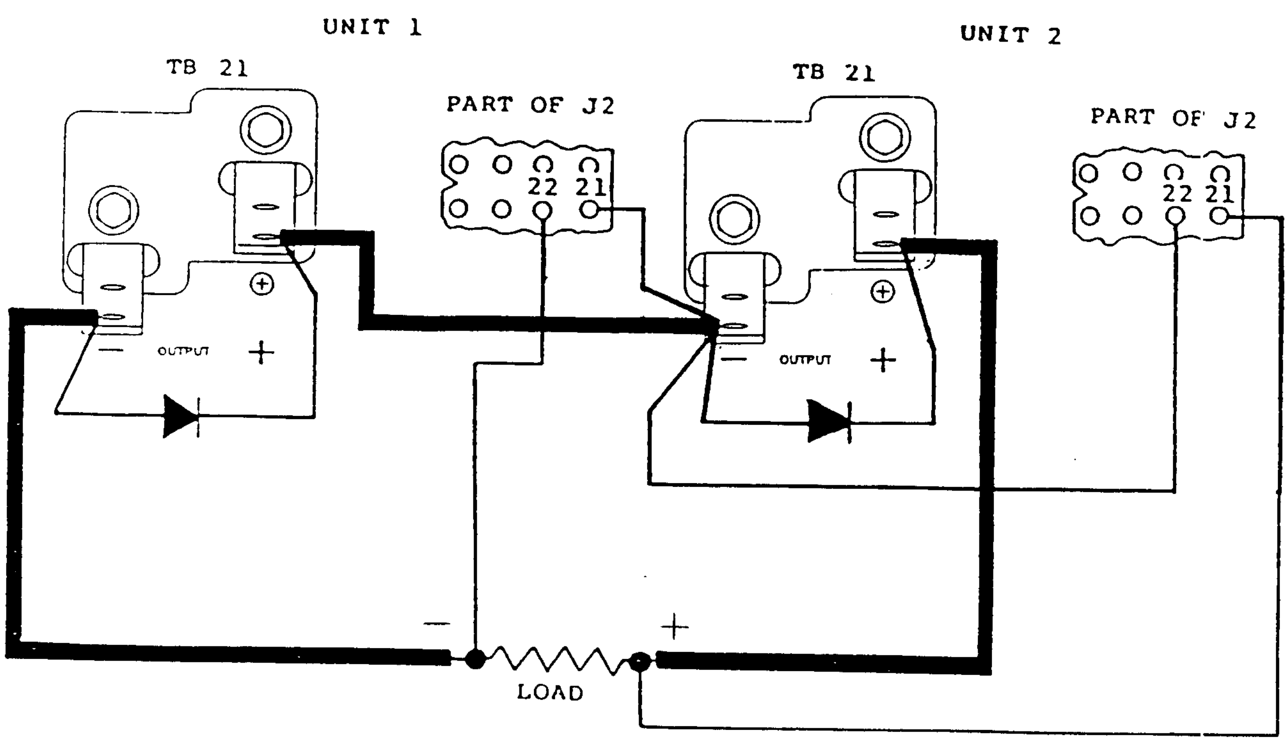


Figure 3.10 Series Operation (With Remote Sensing)

3.12 REMOTE SHUTDOWN

The unit output voltage and current may be remotely shutdown without putting the unit into the Stand-By mode. The shutdown circuit is activated by connecting J2 pin 15 (SHUTDOWN) to J2 pin 18 (MODE PLS). This connection may be made by means of a switch or relay. A transistor switch may also be used. (See Figure 3.11 for typical remote shutdown configuration.)

NOTE

The voltage magnitude on J2 pin 18 is +15 VDC referenced to J2 pin 2 (LOGIC GND).

3.13 REMOTE AC CONTROL

The front panel START and STOP functions may be remotely controlled through the J1 connector on the rear panel. This would be useful in those applications where the unit could be cycled between the Stand-By and ON modes.

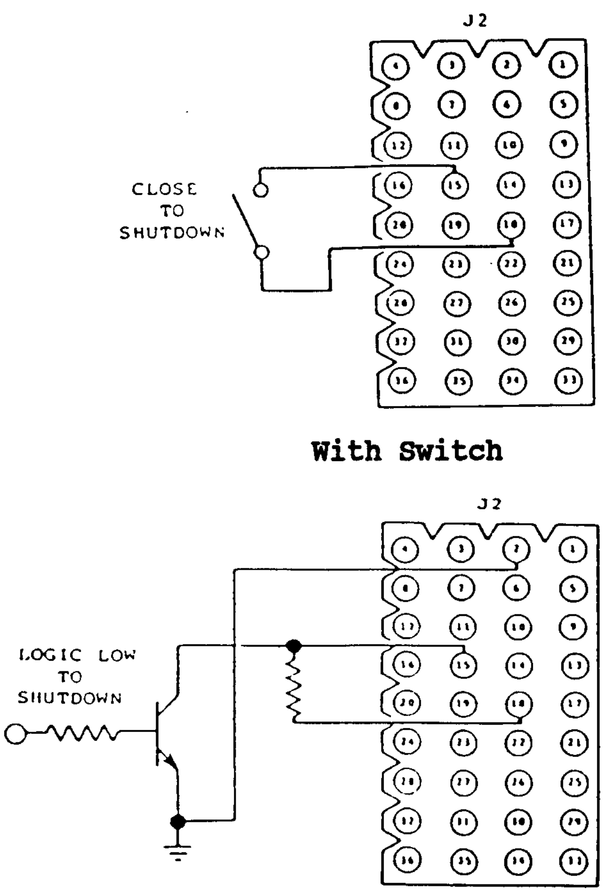


Figure 3.11 Remote Shutdown

3.14 REMOTE INDICATORS

The front panel status, voltage mode and current mode indicators, may be remotely accessed on the J2 connector. The indicator drivers may be used to turn on a remote indicator lamp or activate a remote circuit.

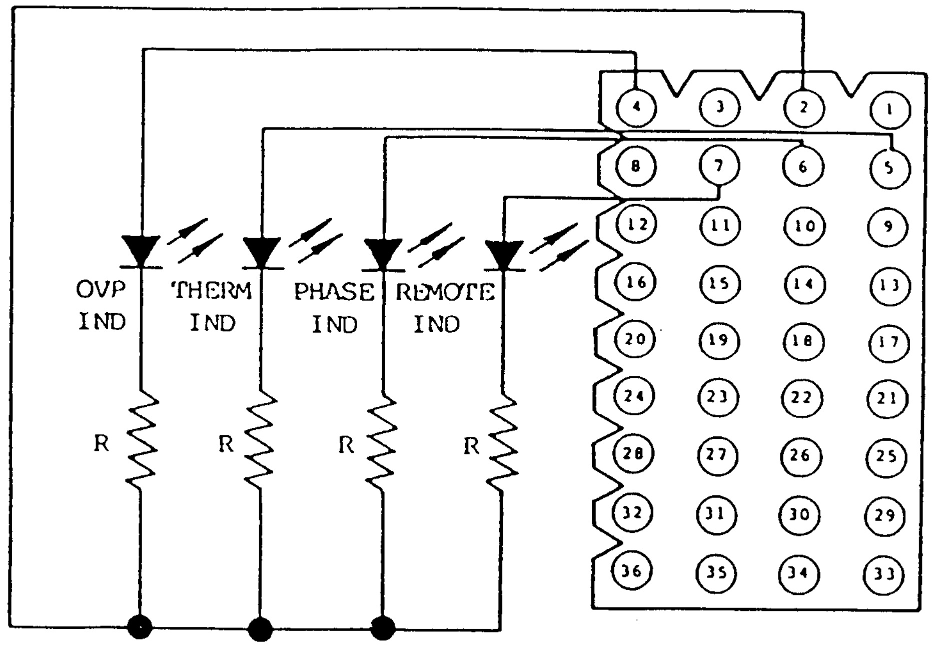
3.14.1 Status Indicator Drivers

The following indicator drivers are available on the J2 connector:

INDICATOR	J2
OVP	Pin 4 (OVP IND)
THERM	Pin 5 (THERM IND)
PHASE	Pin 6 (PHASE IND)
REMOTE	Pin 7 (OPERATE REMOTE IND)

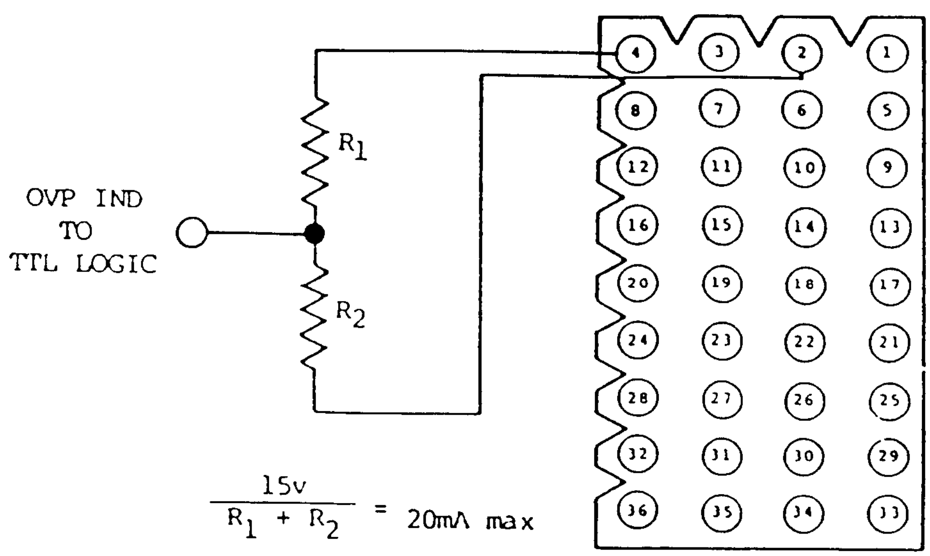
NOTE

All status indicator driver voltage levels are +15 VDC when activated. The maximum load current per driver is 20 mA, therefore, a current limiting resistor must be used. The circuit common for all status indicators is J2 pin 2 (LOGIC GND). (See Figure 3.12 for typical remote status indicator configurations).



$$\frac{(15v-V_{LED})}{R} = 20\text{ mA max.}$$

With Remote Led Indicators



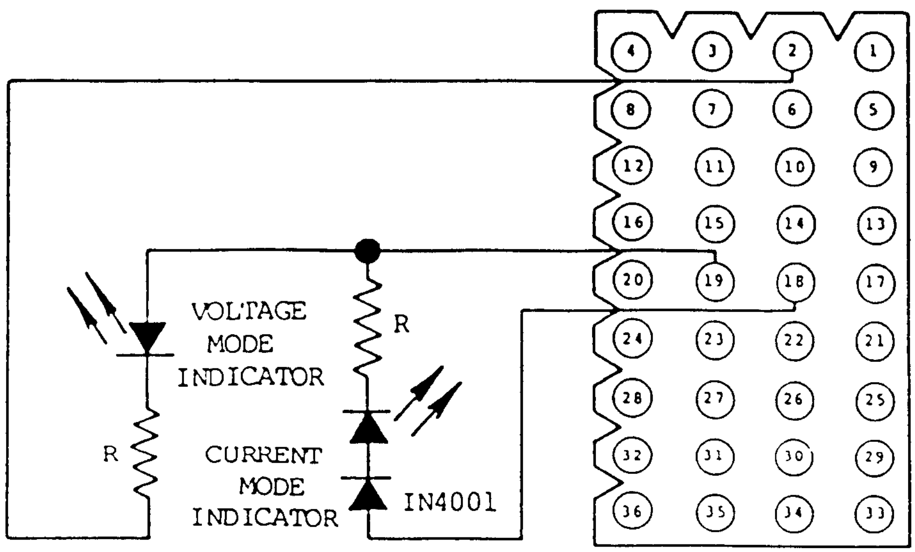
$$\frac{15v}{R_1 + R_2} = 20\text{mA max}$$

Interface to TTL

Figure 3.12 Remote Status Indicators

3.14.2 Mode Indicator Functions

Two voltage and current mode indicator functions are available on the J2 connector. The first is a mode indicator driver on J2 pin 19 (MODE DRIVE) and the second is an open collector mode flag on J2 pin 20 (MODE IND). The same precautions observed for the Status Indicator Drive (paragraph 3.14.1) also applies to the Mode Indicator Functions. (See Figure 3.13 and 3.14 for typical mode indicator configurations).



$$\frac{15v - V_{LED}}{R} = 20 \text{ mA max.}$$

Figure 3.13 Remote Led Mode Indicators

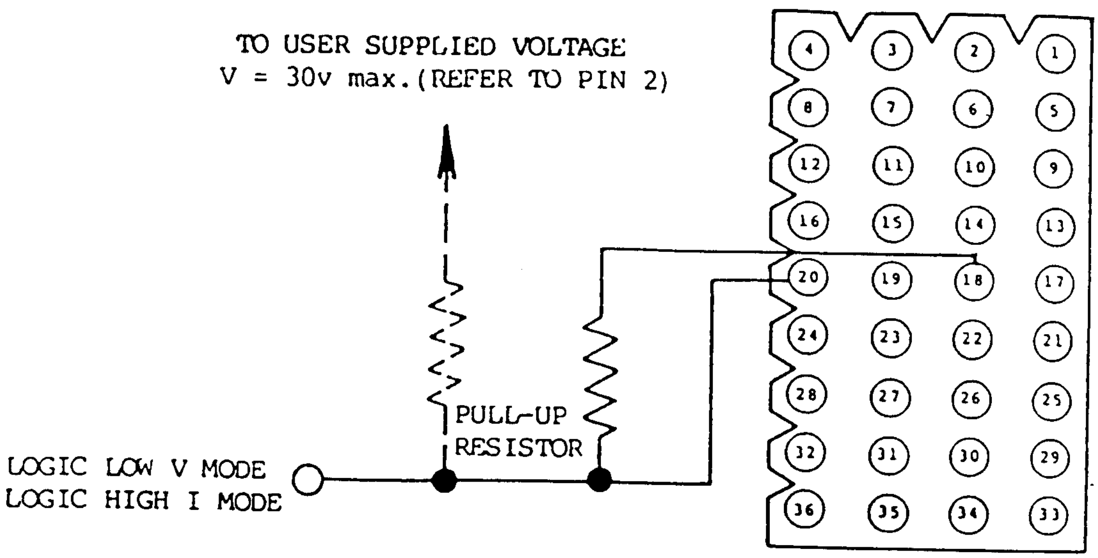


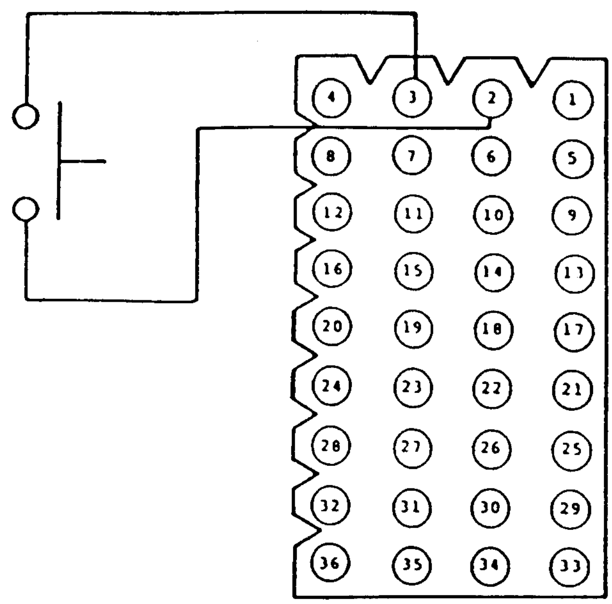
Figure 3.14 Mode Flag

3.15 REMOTE RESET

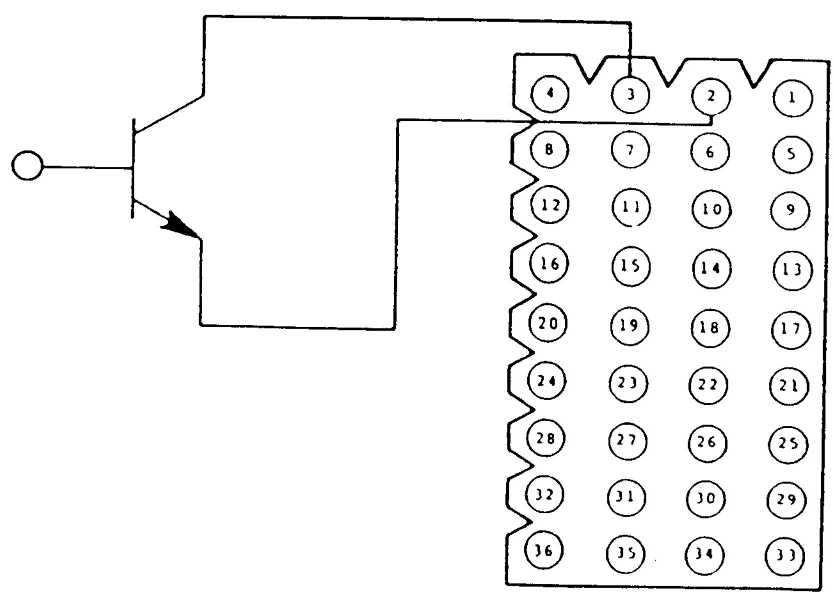
The front panel RESET function may be remotely activated. See paragraph 3.7 for details on the RESET function. The RESET function is activated by momentarily connecting J2 pin 3 (RESET) to J2 pin 2 (LOGIC GND). A momentary switch or transistor circuit may be used. (See Figure 3-15 for typical remote RESET configurations).

NOTE

The RESET current is approximately 1 mA when connected to J2 pin 2. Use a switch or transistor rated for 15 VDC minimum.



With Momentary Switch



With Transistor Switch

Figure 3.15 Remote Reset

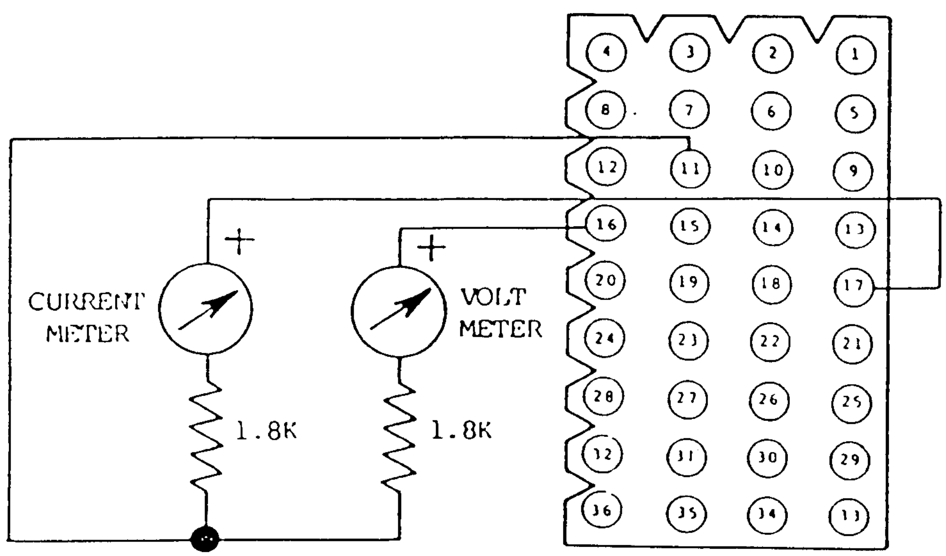
3.16 REMOTE VOLTAGE AND CURRENT MONITOR

The output voltage and current may be monitored from the J2 connector. Two 0 to 1 mA proportional current sources are provided. One each for voltage and current monitoring.

NOTE

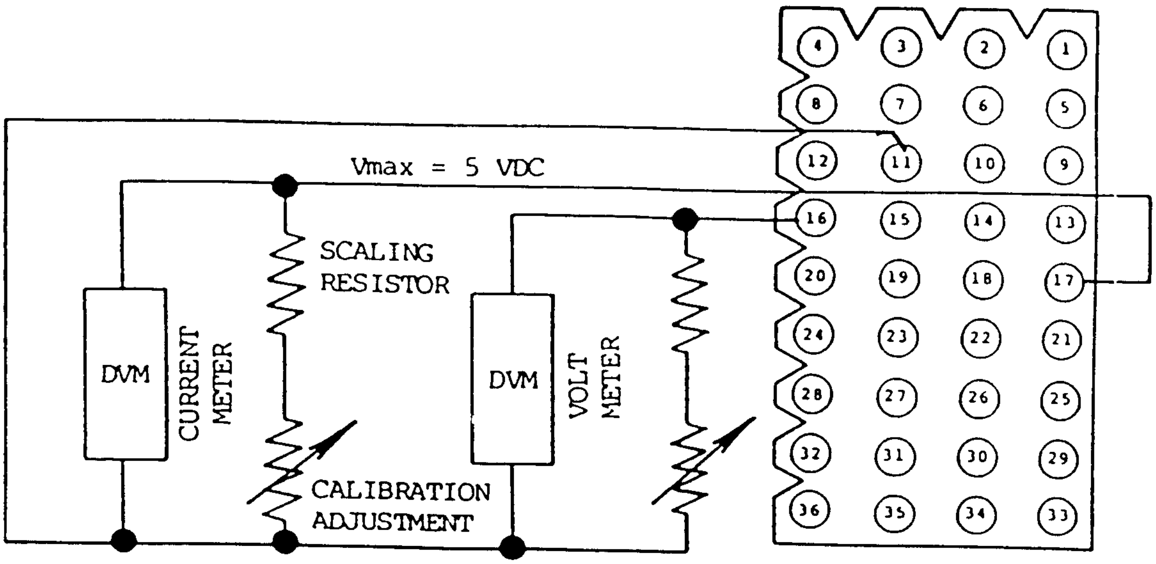
The remote monitor current source levels are identical to the internal current sources used to drive the front panel meters. These meters are 1 mA full scale meters. Since the full output ratings of the unit are approximately 80% of the front panel meter full scale, the actual remote monitor current sources are 0 to approximately 0.8 mA for 0 to full scale voltage and current output. Some method of externally calibrating the remote meters must be provided.

The remote voltage monitor current source output is on J2 pin 16 (REMOTE VOLTAGE MTR). The remote current source output is on J2 pin 17 (REMOTE AMP MTR). The remote monitor circuit return is to J2 pin 11 (VIRTUAL GND). (See Figure 3.16 for typical remote voltage and current monitoring configurations.



With Remote 1 mA Current Meters

Figure 3.16 Remote Voltage and Current Monitoring



With Remote Digital Voltmeters

Figure 3.16 Cont'd Remote Voltage and Current Monitoring

SECTION 4
THEORY OF OPERATION

4.1 GENERAL

The DCR-T units are designed like a power amplifier, see Figure 4.1. The gain of the amplifier is large so that the voltage at the minus input is held equal to the voltage at the plus input. The equation for the output is: Vo = Vi (R1 + R2) - R2

In the actual circuit, R1 in the equation is R3 + R4 on the range board. R2 in the equation is R55 on the control board.

Vin is 0 to 10 volts on all units, except the 4 and 8 volt units.

Figure 4.2 is a block diagram of the power supply. The dc output voltage is controlled by controlling the input voltage to the 3 phase power transformer. This is done as follows:

1 The output voltage or current is compared to a reference voltage. If the output voltage is too high, an error signal is developed. This error signal adjusts the firing angle of the thyristors so that the voltage to the 3 phase transformer decreases.

The voltage out of the 3 phase transformer is rectified and filtered, and is available as the output.

Details of the circuitry are presented in the following sections.

4.2 TRANSFORMER/THYRISTOR CIRCUIT

The ac power input to the power supply is a 3 wire, 3 phase configuration. The transformer is Y connected with an artificial neutral that is not connected to an external neutral power wire.

The 3 wire connection was chosen because it can be used with a 3 or 4 wire input configuration. When the 4 wire configuration is used, the neutral wire is tied to the chassis and is not used in the circuitry.

The ac power is brought into the transformer through a contactor, overload detector and an RFI filter. The thyristors are connected at the Y of the transformer.

Figure 4.3 shows how the transformer and thyristor are controlled. Also shown are 3 sine waves, drawn 120° apart. These represent the 3 power voltage phases. The SCR's that must be fired to control each one-half sine wave are shown.

This also shows how the thyristor firing must be timed. If the wrong thyristor is fired, the unit will not function properly.

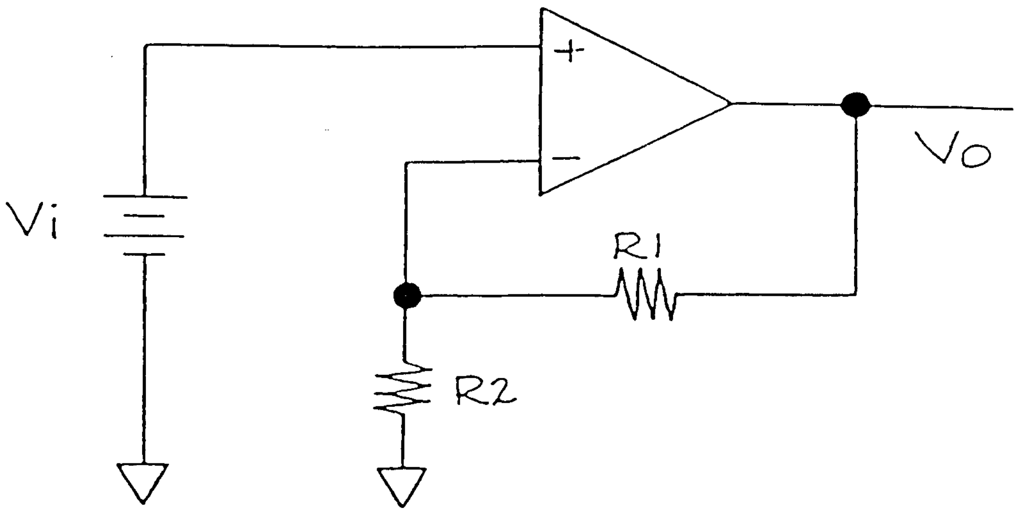


Figure 4.1 Power Amplifier Circuit

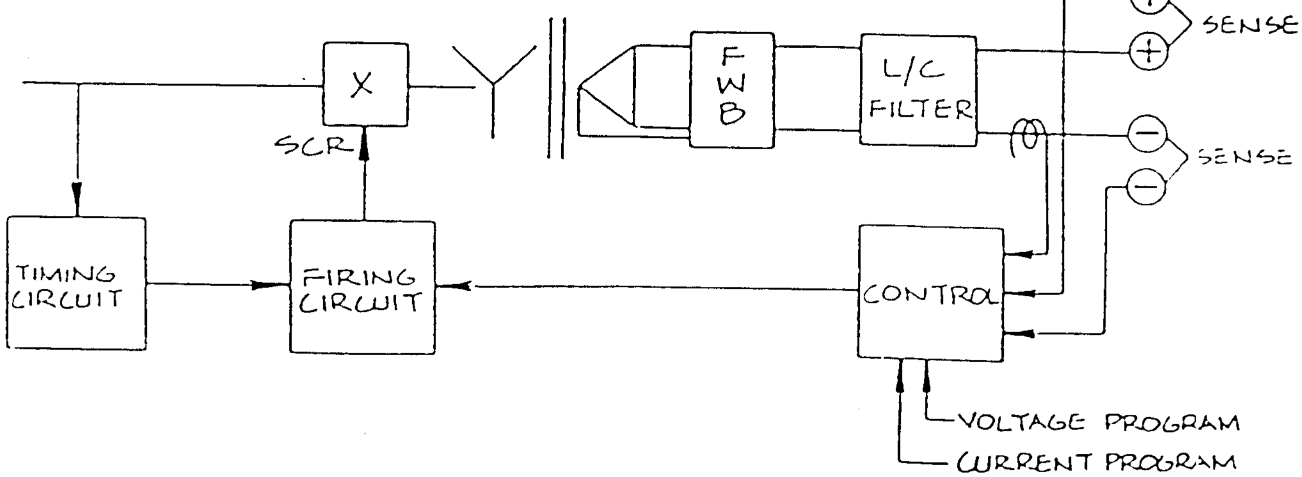


Figure 4.2 Block Diagram

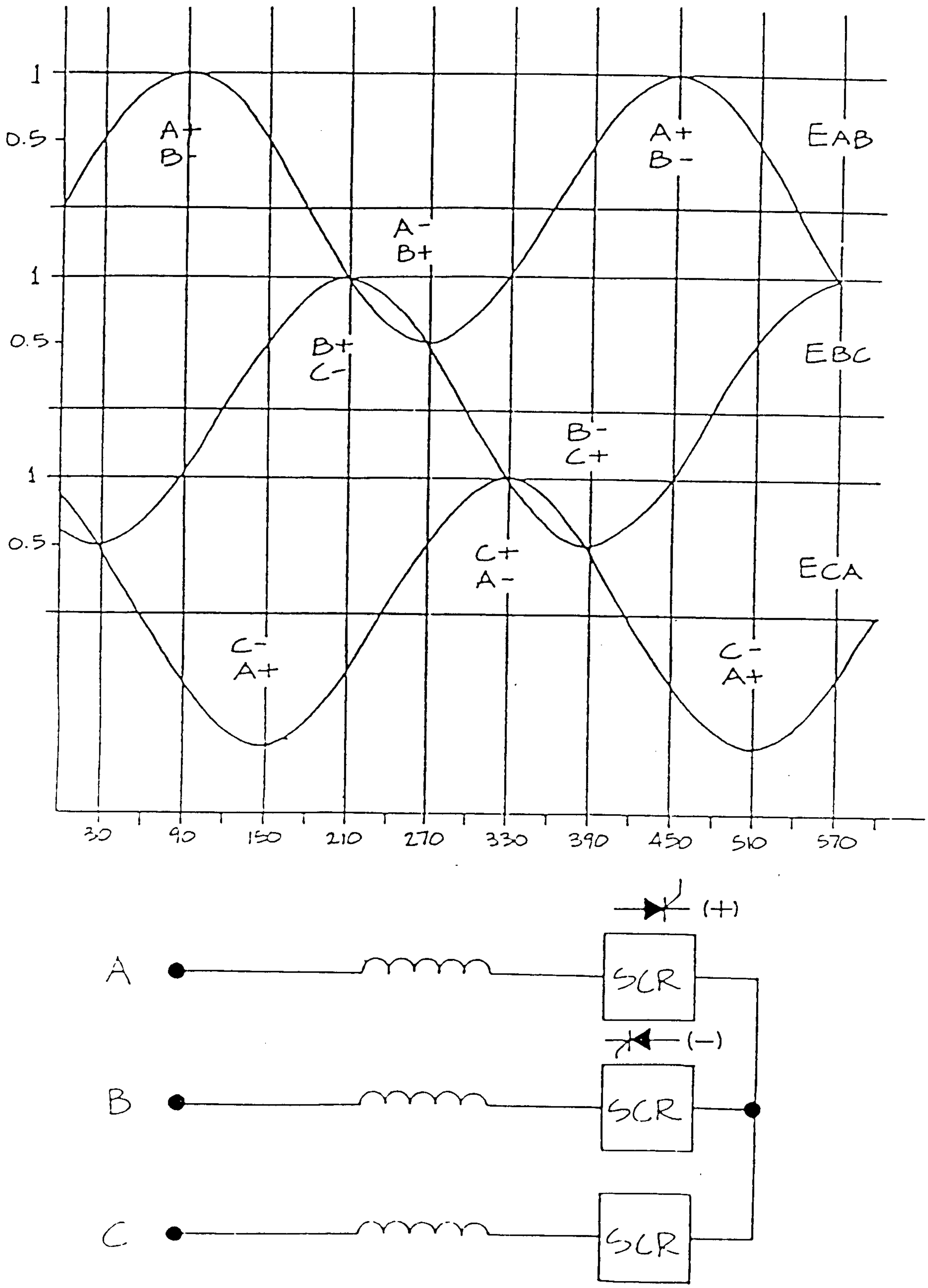


Figure 4.3 Sine Waves/Power Voltage Phases

4.3 TIMING CIRCUIT

Figure 4.4 shows the 6 ramps that are generated. Each ramp segment is used to control a unique combination of thyristors.

There are 6 thyristors designated here as: (A+), (A-), (B+), (B-), (C+) and (C-). The letter identifies the line they are in and the sign identifies the direction of current. Each ramp is one-half cycle of each phase, hence, 6 ramps.

Figure 4.5 shows how the error signal is used to compare with the ramps to develop a firing time for the thyristors. As the error voltage gets lower on the ramp the time delay angle of the firing of the thyristor becomes shorter.

Figure 4.6 is a schematic drawing of one of the 3 channels that generate two of the ramps, and detects the errors.

Q8 with R16 and op amp U2A form a constant current source to charge C2. Two additional circuits are used for the other 4 ramps.

A timing circuit (see the crossover circuit schematics) detects when the voltage associated with thyristor (A+), and another associated with thyristor (A-), crosses zero voltage. A pulse is developed and is fed to amplifier U1-D through CR1. This shorts out C2, discharging it and initiating the next ramp.

When the voltage associated with (A-) crosses zero, a second pulse is generated, repeating the action. The action alternates, causing 2 ramps to be successfully generated and is used as one input to the error comparator circuit, U2-D.

The trigger board schematic drawing shows the other 2 ramp generators and error comparators.

NOTE

Because the AC power lines can have unbalanced voltages, and the unbalances can vary from area to area, 2 ramp adjustments have been included. The ramp rate adjustments are R12 and R13. These allow the user to compensate for varying ac phase voltage unbalances (see also the zero cross board).

The outputs of U2-D, U3-B and C are shown in Figure 4.5.

The outputs of U2-B, C and D are fed to 6 (AND) gates, see trigger circuit diagram.

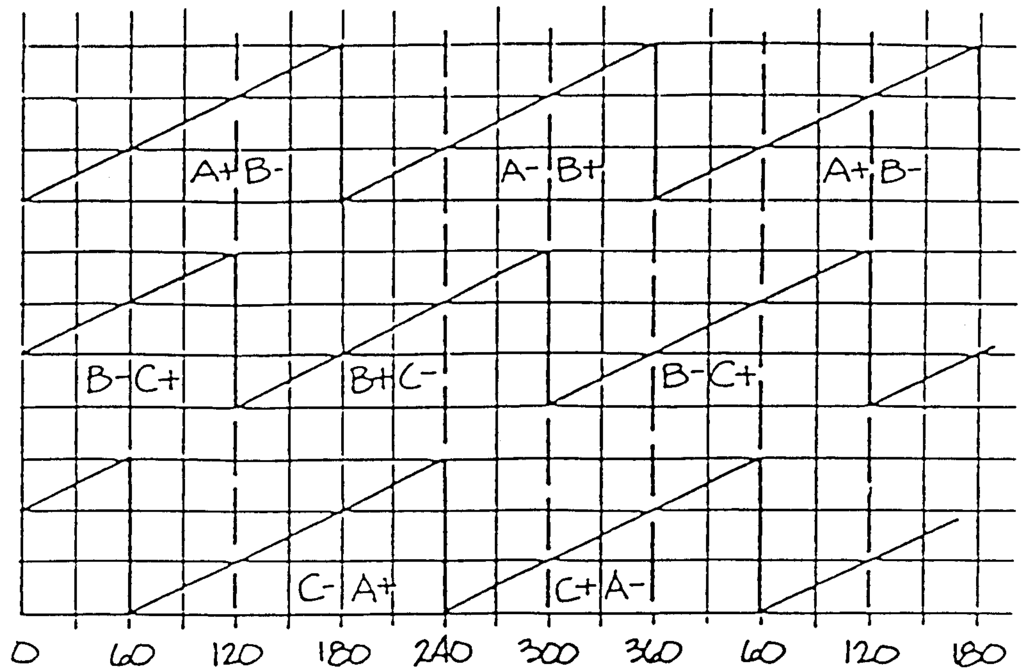


Figure 4.4 Timing Ramp

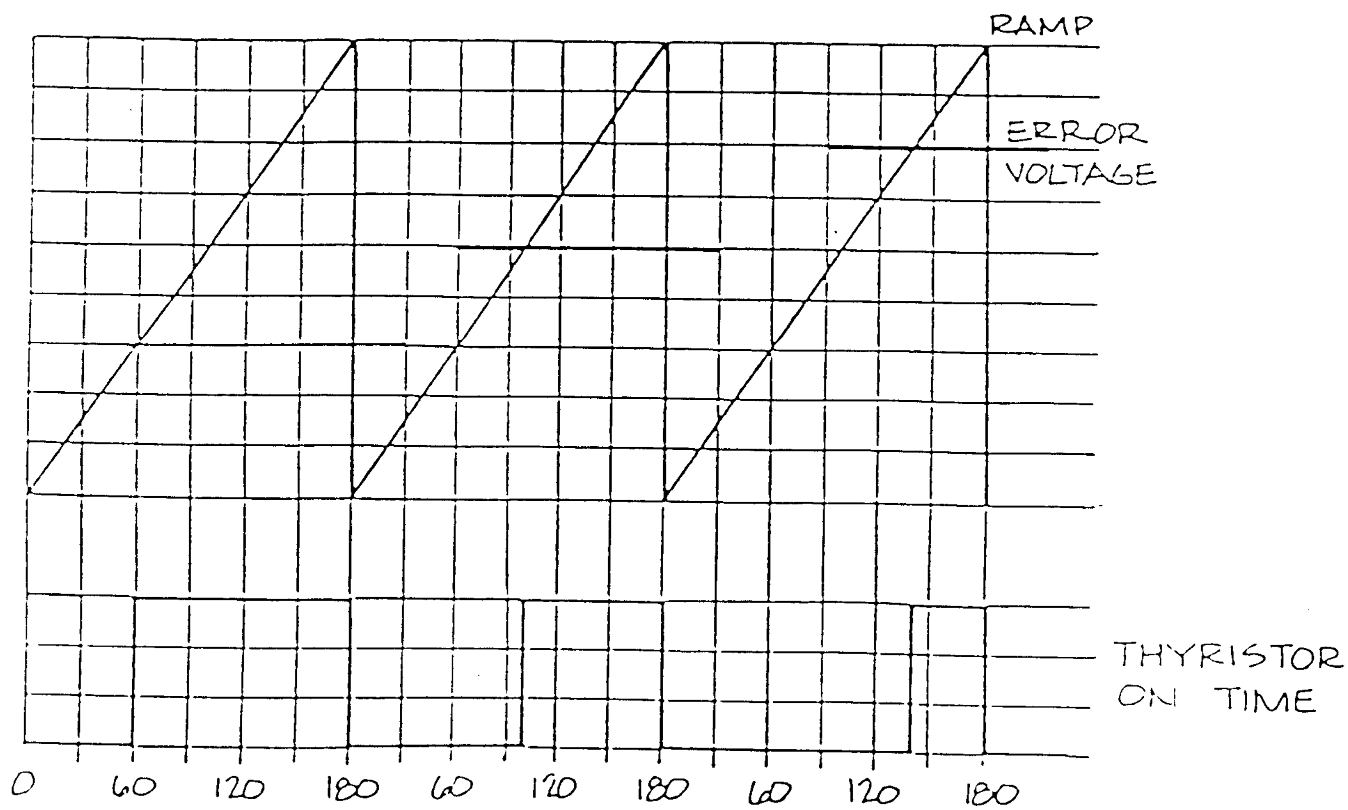


Figure 4.5 Control Signal

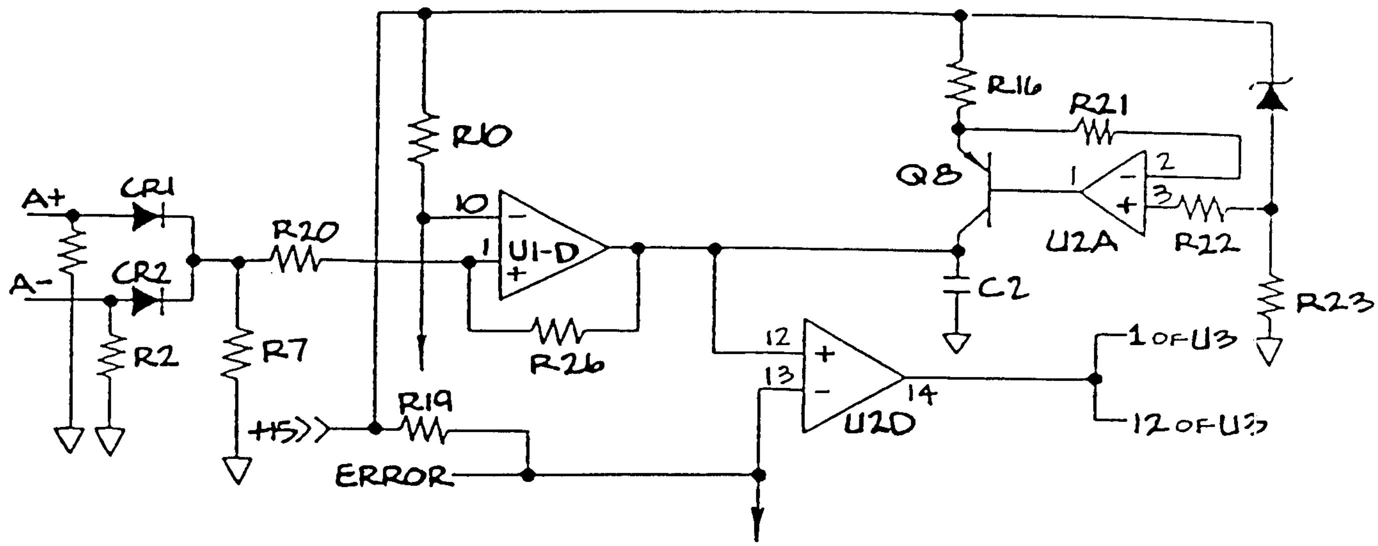


Figure 4.6 Error Detection Circuit Schematic

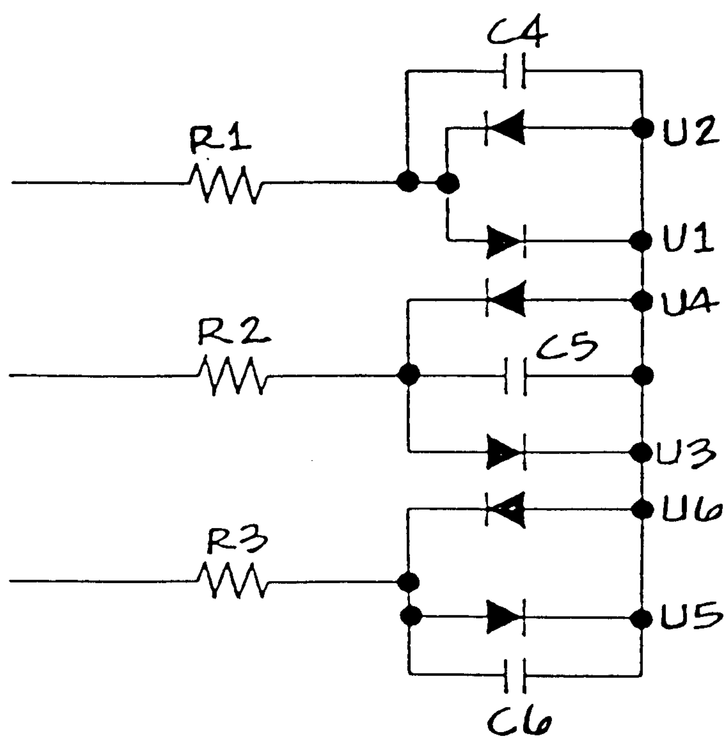


Figure 4.7 Crossover Circuit Schematic

The outputs of the error comparators are for driving both the (+) and (-) thyristors, and these are divided into the proper (+) and (-) signals from the zero cross circuit and allow only the correct signal through.

Thus, the outputs from the (AND) gates are unique to each of the 6 thyristors. The on-time voltage signals, out of buffer U5, are the requirement for each of the (+) and (-) thyristors in each power line.

In Figure 4.3, it was seen that to control the positive one-half cycle of phase voltage (AB), thyristor (A+) and (B-) must be controlled. The output of (A+), 2 of U5, goes to CR7 and CR14. These 2 diodes are inputs to U6 and U9.

U6 and U11 are opto couplers that trigger internal thyristors that in turn trigger a pilot thyristor, that in turn triggers one of the power thyristors.

When the requirement exists for (A+) to be ON, (B-) is also turned on completing the circuit. Using the waveforms of Figure 4.3 and schematic drawing for the trigger circuit, all of the other 5 firing combinations can be seen.

Obviously, if two or more of these circuits gets miswired the unit will not function properly.

4.4 CROSSOVER CIRCUIT (ZERO CROSS CIRCUIT)

This circuit develops 6 thyristor "on time" signals per 1 full, 3 phase cycle. Each "on time" has a duration of one-half cycle or approximately 8.3 milliseconds.

Figure 4.7 is part of the schematic drawing of the crossover board.

Each of the diodes is part of an opto coupler that turns ON a transistor during the one-half cycle that is associated with a specific thyristor.

Comparing Figure 4.7 with Figure 4.2, it is seen that each diode has a counterpart thyristor and the 2 voltages are in phase. Thus, a specific thyristor should only be ON when its counterpart diode is ON.

The outputs of the opto couplers are fed to the trigger board where they time the ramps and select the thyristor that is to be fired.

The start of each of the 6 ramps can be varied over a few parts of a millisecond by the 6 pots. Thus, with the 2 ramp-rate adjustments on the trigger board and the 6 ramp-start adjustments, the output ripple can be adjusted by compensating for unbalanced phase voltage. For a given operating point, the ripple can be adjusted much lower than the optimum value.

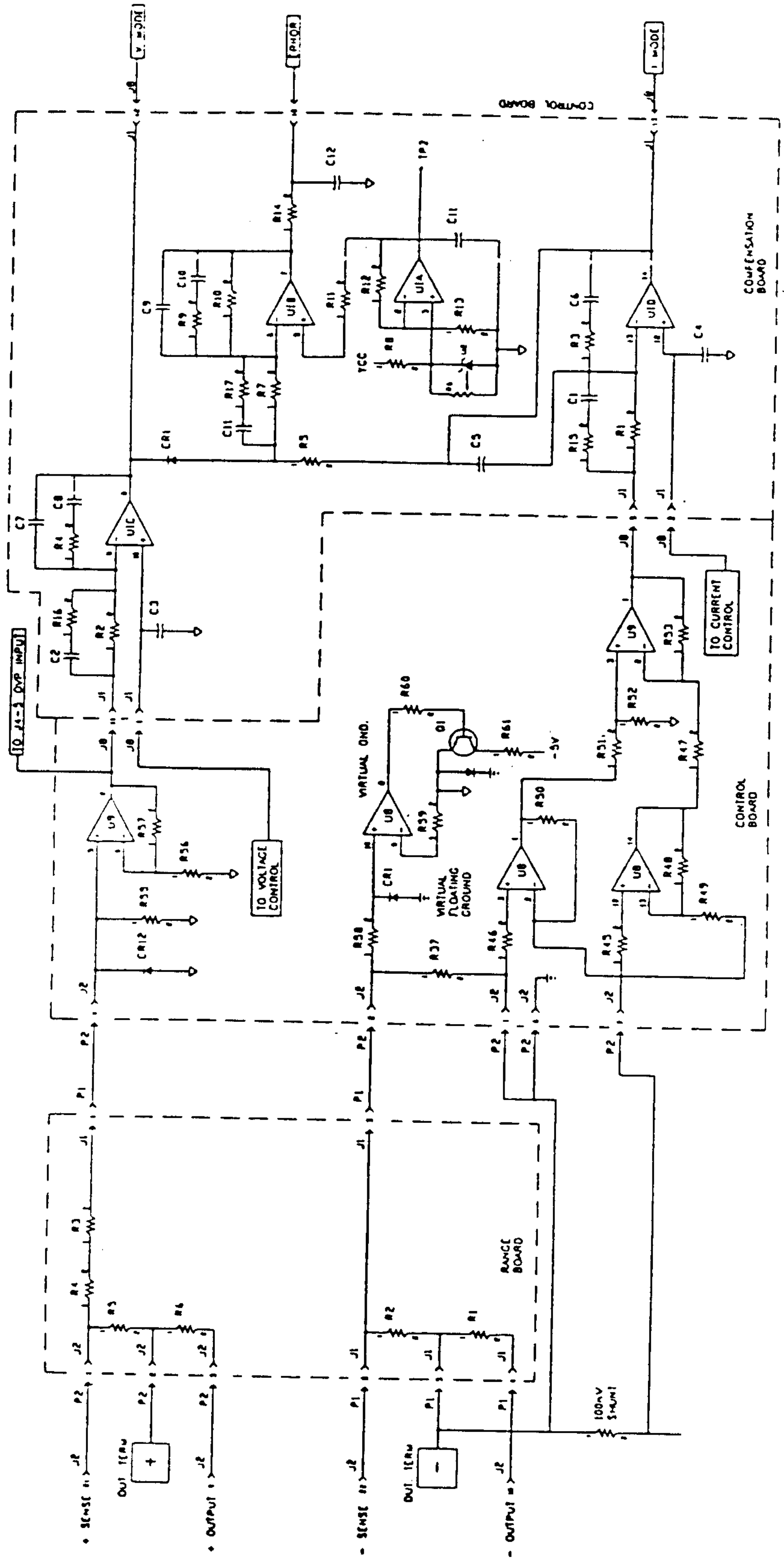


Figure 4.8 Control Loop Schematic

N O T E

Because the phase voltage balance varies from area to area, an adjustment to control the start of each of the 6 ramps is included. Thus, to optimize the output ripple, these 6 adjustments can be used to compensate for the phase voltage unbalance.

4.5 CONTROL LOOP

Figure 4.8 is the control loop. There are 2 channels: a voltage channel and a current channel. The channels are "OR'd" at the negative input of amplifier C-U1-B. As indicated previously, low error voltage means a high dc output. If the unit is in current control and the load resistance increases, (until the voltage channel takes effect) the output of amplifier C-U1-C decreases to a voltage lower than the output of the current channel, and the voltage channel takes control through diode C-CR1.

The voltage is sensed through J2-21. Resistor A-R6 is a safety resistor should the sense leads open. The unit will not function properly (within specs.) if the sense leads are not in place.

The output voltage is divided down to 10 volts and applied to amplifier B-U9. This is set to unity gain and is a buffer for the difference amplifier C-U1-C.

This voltage is compared to the control voltage which is 0 to 10 volts. The loop adjusts the output voltage so that the voltages at the input pins 9 & 10 of C-U1-C are equal.

The current loop operates in a similar manner. The voltage drops across a 100 mV shunt and then is amplified through amplifiers B-U8 and B-U9. The voltage output of pin 1 of B-U9 goes from 0 to 10 volts as the output current goes from 0 to rated current.

This voltage is fed to the current comparator C-U1-A where it is compared to a control voltage of 0 to 10 volts.

4.6 VIRTUAL GROUND

Because it is necessary to measure the voltage directly across the shunt and yet be able to sense at the negative of the load, a virtual ground has been generated that remains at the negative sense potential. All of the amplifiers are common to the virtual ground.

The negative sense lead is fed to pin 10 of B-U8. This is a current-buffered amplifier, B-Q1, with a unity gain. Thus, the virtual ground is at negative sense potential while the voltage drop across the shunt is measured true.

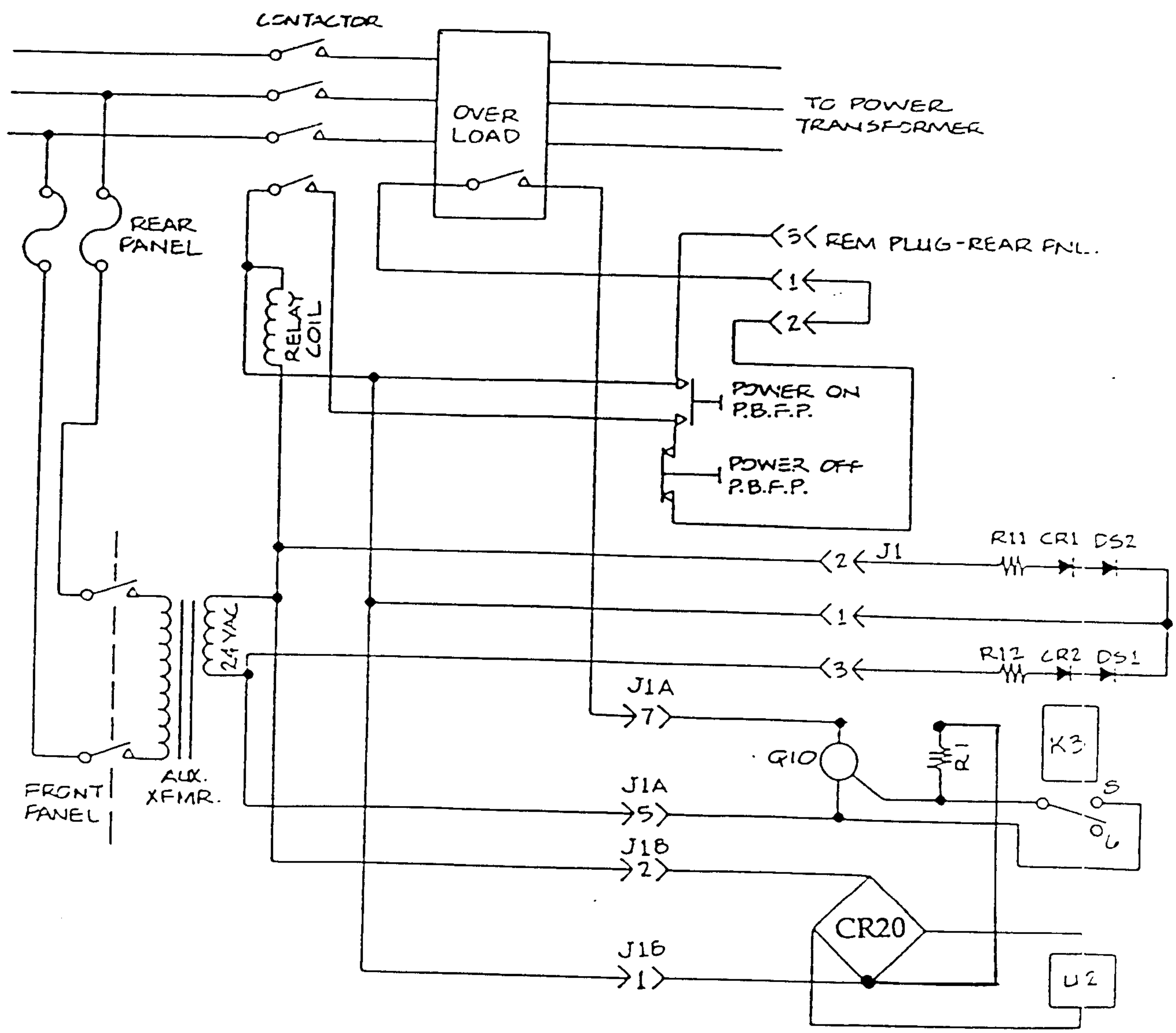


Figure 4.9 AC Power Control Schematic

4.7 AC TURN ON

The AC power is applied through the use of a modified 3 wire contactor control system. The advantage is that if offers the user a remote ac control and it keeps the heavy ac wiring from the front panel (see Figure 4.9).

NOTE

One side of the contactor coil is connected to one side of the 24 volt ac out of the auxiliary transformer.

When the Stand-By switch is turned ON, the auxiliary transformer is energized and ac power is applied to the control board. Thus, all of the amplifiers are turned ON.

In addition, the Stand-By lamp is lit (DS-1). It is in series with the coil of the contactor. Triac Q3, on the control board, is turned ON, connecting the available voltage for the contactor coil.

When the power ON button is pushed, the contactor coil is energized from the other side of the 24 volt secondary through the following paths:

- A. J1-A-5
- B. Triac Q10
- C. J1-A-7
- D. The auxiliary contacts of the OL.
- E. Pin 1 of the remote connector.
- F. A jumper to pin 2 of the remote connector.
- G. Pin 2 of the remote connector.
- H. The power OFF push button.
- I The power ON push button.

The sealing contacts of the contactor are in parallel with the power ON push button. When the contactor closes, the power ON push button can be released and the contactor stays closed.

The contactor will open by any one or more of the following happenings:

- A. The OL auxiliary contacts open.
- B. The remote plug is pulled.
- C. The power OFF switch is pushed.
- D. K3 is de-energized, turning Q10 OFF.

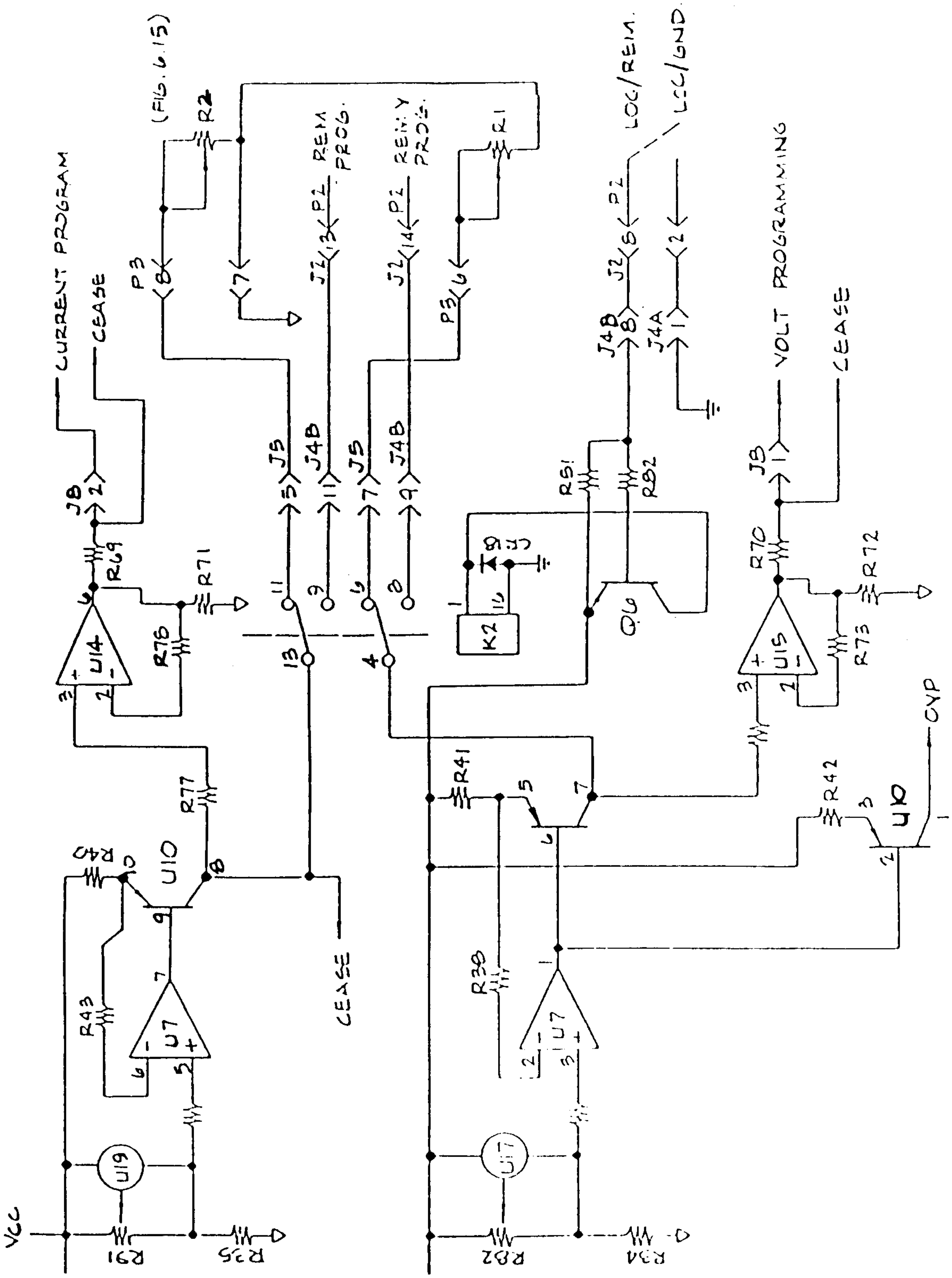


Figure 4.10 Variable Reference Schematic

K3 is the OVP control. Thus, when the OVP actuates all power is removed from the output. See OVP explanation.

CR6 and U2 are signals to the cease line to allow the unit to come ON. See cease operation explanation.

Remote push buttons, to control the ac, can be plugged into the remote plug.

4.8 REFERENCE VOLTAGES TO CONTROL THE OUTPUTS

The outputs can be controlled by the following:

- A. The front controls.
- B. Remote resistors.
- C. Remote voltages (0 to 10 volts).

Figure 4.10 shows the circuitry that provides these options.

As described earlier, the loop is controlled by a voltage that goes from 0 to 10 volts. Both the current and voltage channels are controlled by these voltages.

To develop the 10 volts, a current source has been used. An adjustable zener, U19 and U17, provide a reference voltage for amplifiers U7-5 and U7-3. The output of the amplifier adjusts the drive on two transistors in U10 to keep the voltage across a resistor, R40 and R41, constant. Thus, the current delivered out of U10-8 and U10-1 is constant.

Resistors R1 and R2 are adjustable from 0 to 10K ohms. Thus, with 1 ma of current, the voltage at U14-3 and U15-3 is adjusted from 0 to 10 volts.

The voltage is buffered through U14 and U15 and presented to the current and voltage channels for comparison with the voltage or current outputs (see loop explanation).

For remote programming, a jumper is placed between pins 2 and 8 of P2, the external connector. This turns Q6 ON, energizing K2. The current sources and the buffer amplifiers are now available to be controlled by an external 0 to 10K ohm resistor.

For voltage programming, the voltage source (which must be capable of sinking at least 1 ma of current) is connected in place of the external resistor.

4.9 OVERVOLTAGE PROTECTION

U4 is an SG3542 overvoltage sensing and activating integrated circuit.

The output voltage is picked up from U9-7 amplifier. This is a 0 to 10 volt signal (see loop explanation) and is compared to a voltage that is set up by R13 on the front panel or remote (see Figure 4.11).

The OVP can be set without turning the main power ON and without actuating the OVP circuit. This is done by pushing S5 on the front panel. Relay K1 transfers the voltmeter from reading the output to reading the OVP input.

When the OVP is actuated, relay K3 closes. This turns Q10 OFF and opens the main contactor, removing power from the output. It also pulls up the cease line turning the thyristors OFF immediately.

As an option, a crowbar can be included. When activated, the crowbar will short out the output. However, because the power is removed there is a reduced need for a crowbar. This feature is offered only as an option.

4.10 SLOW START

The nature of the phase-controlled power supplies is such that the control loop must be "rolled-off" at a very low frequency. Thus, it is very slow to respond.

Without a slow start circuit, the amplifier would be calling for maximum voltage out when the main power is OFF. When main power is turned ON, the SCR's would be fired at high voltage before the amplifier could respond to prevent it.

The slow start circuit is shown in Figure 4.12 . Prior to ac turn ON, the cease line is high causing Q3 to be turned ON. C20 is charged in a negative direction. The voltage and current programming voltages are pulled negative through the two amplifiers, causing the loop amplifier to call for minimum (zero) output voltage.

When the power is turned ON, the cease line falls, turning Q3 OFF. This allows C20 to charge in a positive direction through Ra. This also allows the voltage out, on the two amplifiers, to rise at a slow rate, set by Ra and C20.

Eventually, the output of one of the amplifiers exceeds the programming voltage, and the unit is in control.

The rate of rise on the voltage across C20 can be altered. However, it must always be slower than the loop amplifier speed. If not, an over start will occur.

4.11 CEASE/INHIBIT

As indicated in Section 4.10, when the cease line is high, the unit is programmed to zero volts. In addition, it prevents any turning sign from getting to the SCR's. (See Figure 4.13 and the Trigger Board schematic diagram.)

The cease line is pulled high by the main power being OFF or the OVP operating.

The unit can be inhibited by putting a voltage on the REM shutdown. This turns ON the transistors in U16. This also pulls the voltage drop across C20 to zero causing the output voltage to be programmed to zero.

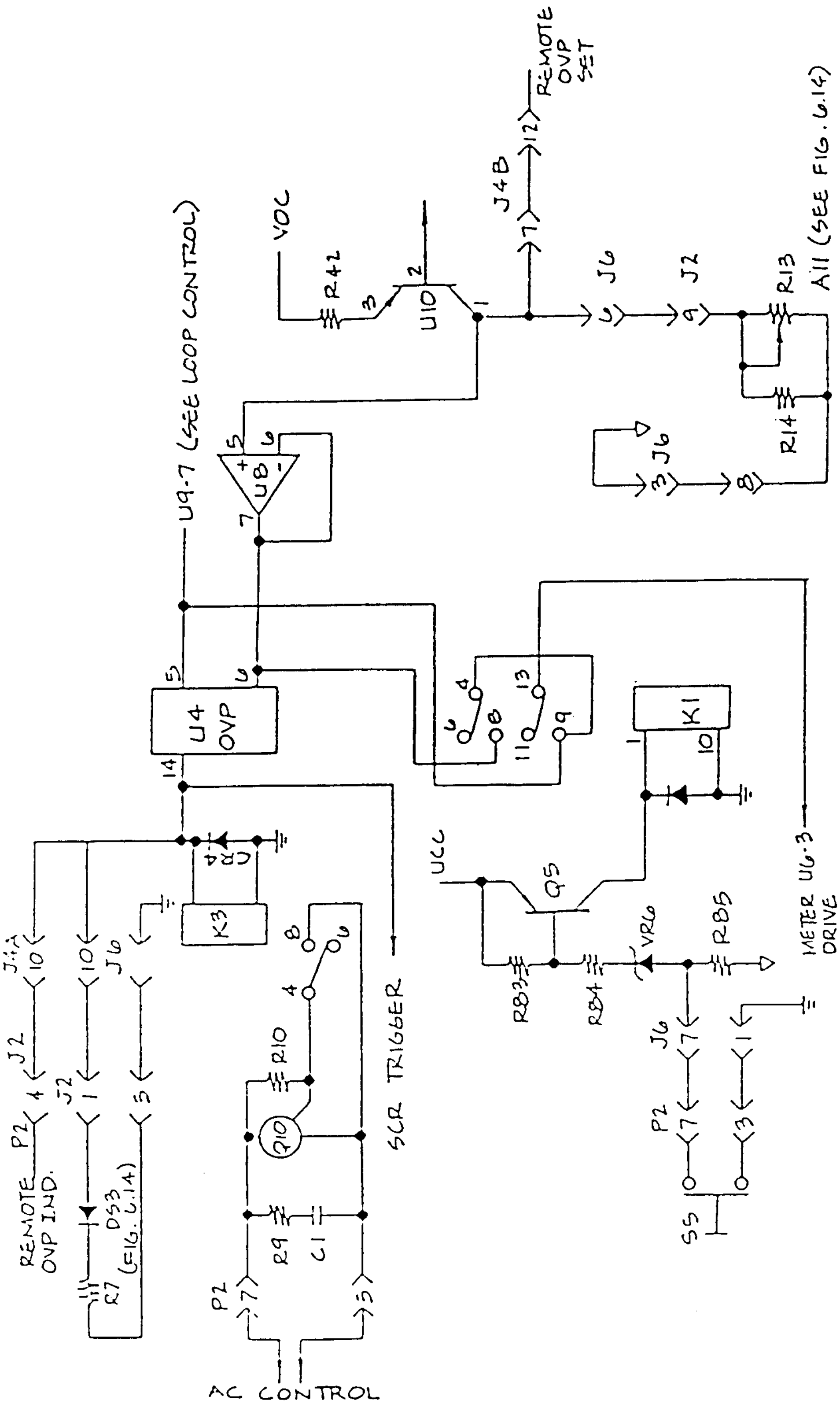


Figure 4.11 OVP Control Schematic

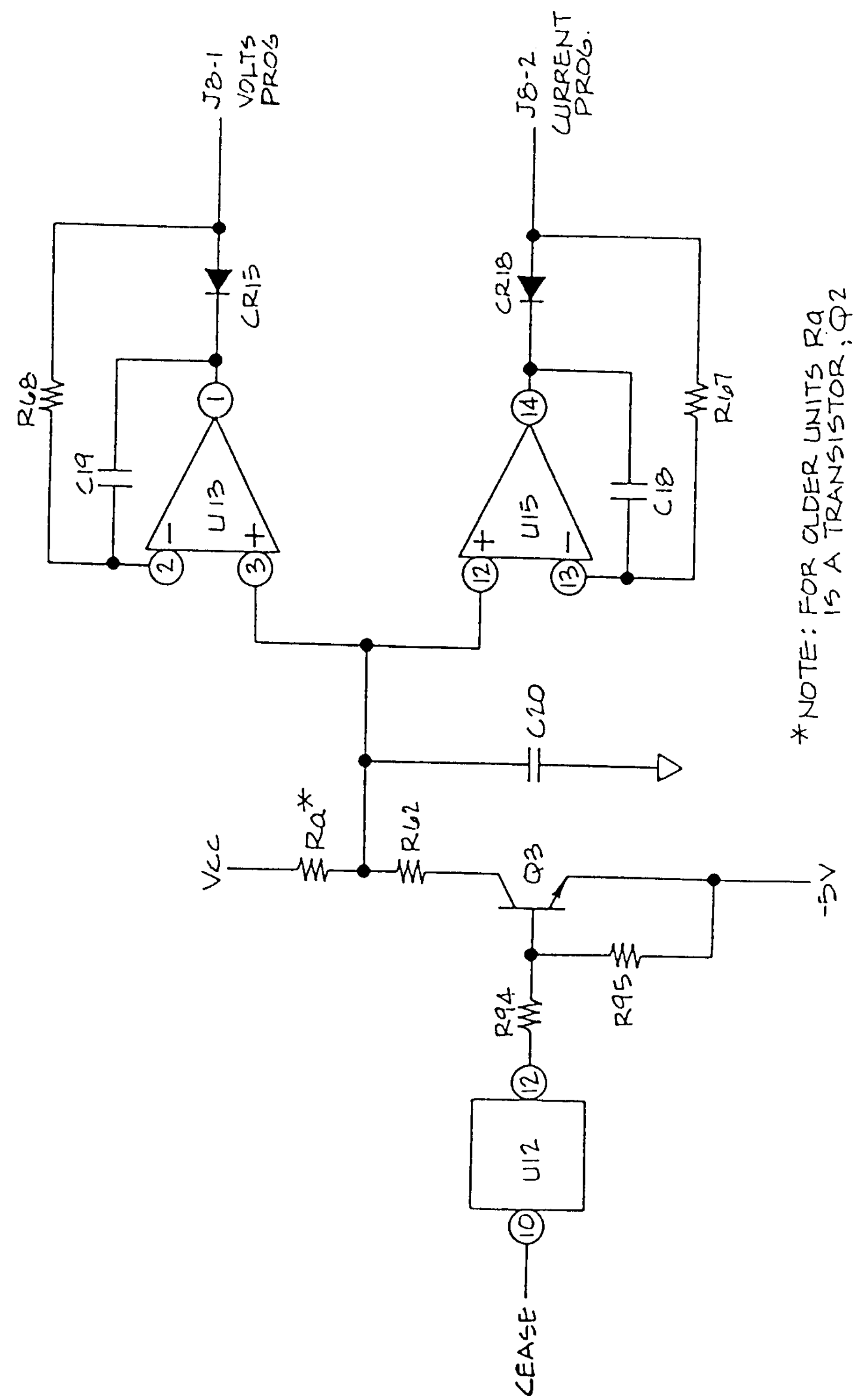


Figure 4.12 Slow Start Circuit Schematic

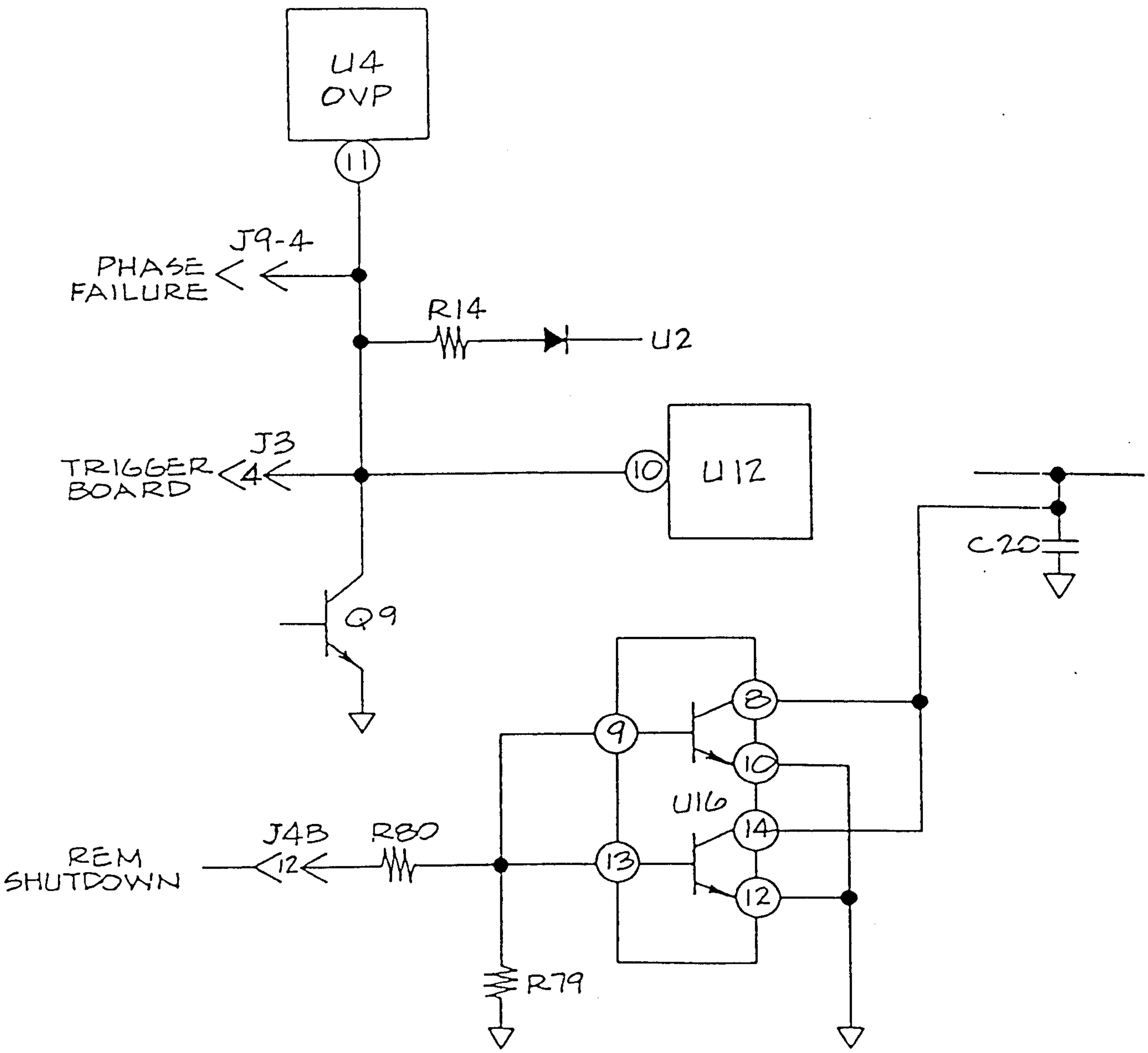


Figure 4.13 Cease and Inhibit Schematic

4.12 METER DRIVE CIRCUITS

Figure 4.14 shows the drive circuits for the internal and external meters.

In general, the circuits take a 0-10 volt input and converts it into a 0 to approximately 1 ma output. The 0 to 10 volt represents the conversion of 0 to rated output for either the current or voltage.

Calibration adjustments for R93 (Current) and R92 (Voltage) are used to match the internal or external meters to the actual measured currents

U6-14/U5-12 and U6-7/U5-5 are two current sources. The meters becomes the emitter-follower loads for the transistors. The current through R31 or R30 is thus proportional to the input voltage to U6-3 (10).

Thus, meter lead lengths are immaterial, as the current drive compensates for lead losses.

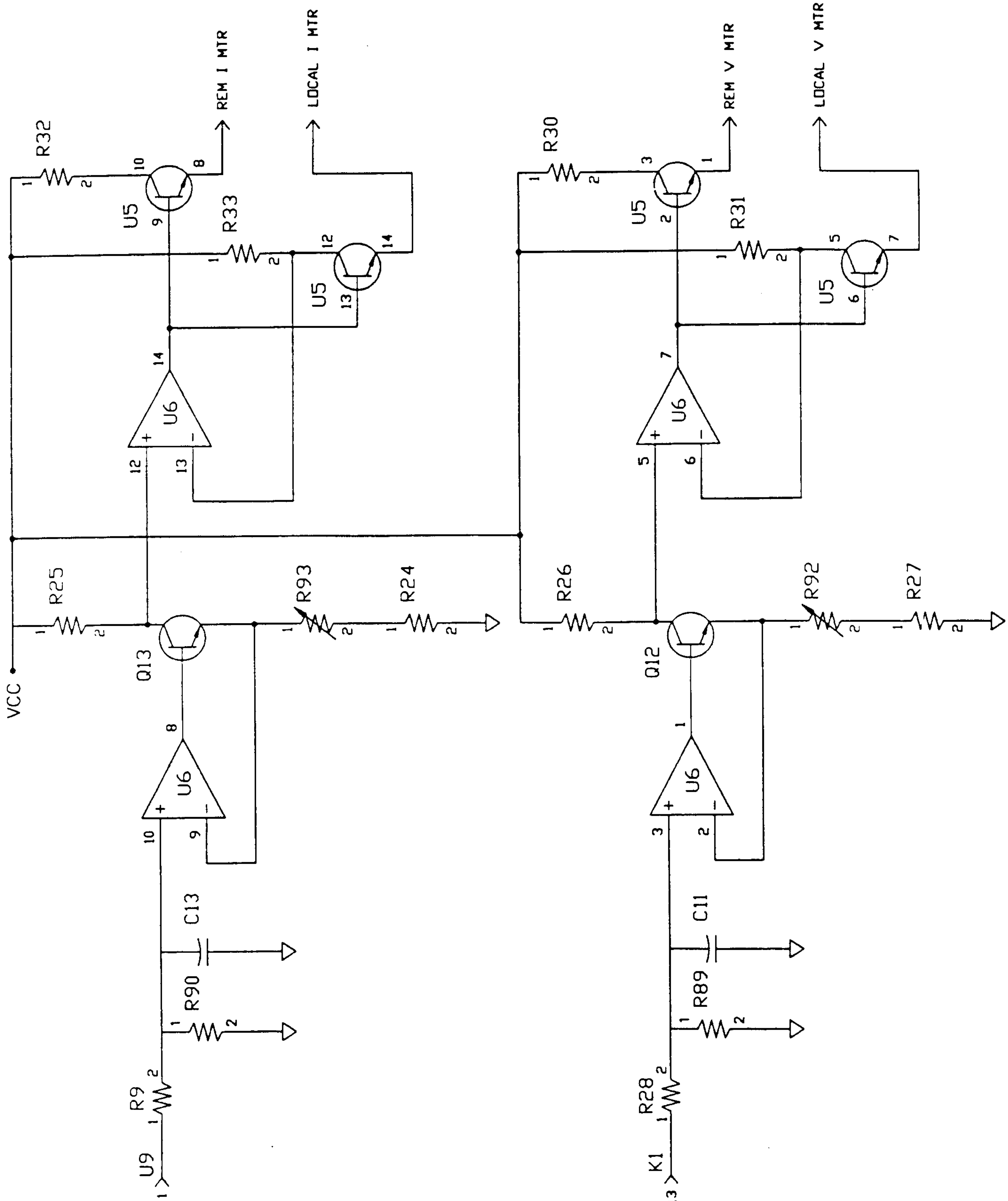


Figure 4.14 DCRT Meter Drive Circuit

SECTION 5
MAINTENANCE

5.1 GENERAL

This section provides troubleshooting data, periodic servicing, calibration and performance testing procedures. The troubleshooting data should be used in conjunction with the schematic diagrams and Section 4, which outlines the principles of operation. Any questions pertaining to repair should be directed to the nearest Sorensen representative or to the factory. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, prior authorization from Sorensen Company must be obtained.

5.2 PERIODIC SERVICING

Whenever a unit is removed from service, it should be cleaned using naphtha or an equivalent solvent on painted surfaces, and a weak solution of soap and warm water for the front panel. Compressed air may be used to blow dust from in and around components.

5.3 TROUBLESHOOTING

Table 5-1 provides a list of malfunction symptoms along with a tabulation of the possible cause(s) for each symptom. Note that the failure of a single component may result in a chain reaction effect.

5.4 CALIBRATION

5.4.1 Voltage Mode

Following repair, the unit should be recalibrated to insure that replacement components have not altered performance. The following is the calibration procedure to ensure that full rated voltage output is available:

1 Rotate the CURRENT control fully clockwise.

2 Check that the remote plugs are properly terminated and installed.

3 Place a precision DC voltmeter across the output sense leads.

4 Set unit POWER switch to ON, and adjust R82 on the control printed circuit board until the voltmeter indicates 105% of the full output voltage rating of the supply.

5 Set POWER switch OFF. Disconnect the voltmeter.

5.4.2 Current Mode

1 Set unit POWER switch to OFF. Short output terminals, and set CURRENT control to 100% and VOLTAGE control to about 50%.

2 Set potentiometer R91 on the PCB to about 20% rotation. Set POWER switch to ON and adjust R91 to about 115% of rated current.

3 Turn unit POWER switch to OFF. Remove short. (Test completed.)

Table 5-1
DCRT Troubleshooting

Symptom	Probable Cause/Corrective Action
1 No output (voltage mode).	a) Wrong input voltage. - Check voltage. b) Open fuses. - Check fuses. c) Reference voltages. - Check levels.
2 Fuse opens or over load trips.	a) SCR A, B or C shorted. b) CR4, CR5, CR6, CR7, A, B or C shorted or open.
3 Meters jump.	a) Noise in the power supply. - Reverse two of the AC power wires.
4 Regulation out of specification, low frequency oscillation.	a) Sensing leads from the remote plug to power leads were not connected for shipment. There are internal resistors that prevent disaster should sensing leads come loose. - Sensing leads must be connected.
5 Front Panel controls don't work.	a) Unit out of control. - Check manual for remote/local operation and remote plug.
6 Ripple too high.	a) Large 60 Hz. components. - Check manual for ripple adjustments.
7 Output voltage for maximum.	a) SCR A, B or C shorted.
8 Power won't come on when ON button is pushed.	a) Check to make sure the AC remote plug is properly terminated and in place.

5.5 PERFORMANCE TESTING

Sensitive instruments like the DCR-T require rigorous testing methods if a true performance evaluation is to be made. Whenever possible, twisted leads should be used with test equipment to reduce stray pickup. At the power supply terminal board, these leads must be firmly held by the terminal screws. Alligator clips and similar types of connectors are not suitable. Grounding techniques, in which more than one device in the setup is grounded, may introduce extraneous ripple that, although unrelated to the power output ripple, is displayed on the test oscilloscope.

5.5.1 Voltage Mode Regulation and Ripple

To check voltage mode regulation and ripple, proceed as follows:

1 Connect a sensitive digital voltmeter and an RMS AC voltmeter across unit output terminals. Select a current shunt for current rating and a DVM for current output readings.

2 Apply high ac line input per specifications, and set load switch to OFF. Set the POWER switch to ON.

3 Rotate COARSE CURRENT control fully clockwise.

4 Use VOLTAGE controls to obtain rated output voltage. Note DVM reading after a few minutes of warm-up time.

5 The DC output voltage should be measured and recorded at four points.
- a) Max. AC Line - Max Load Current.
- b) Max. AC Line - 50% Load Current.
- c) Min. AC Line - 50% Load Current.
- d) Min. AC Line - Max. Load Current.

5.5.2 Current Mode Regulation

To check current mode regulation, proceed as follows:

1 At no load, adjust output to maximum rated voltage, and set COARSE CURRENT control fully clockwise.

2 Connect a sense resistor or a precision meter with shunt meter in series with a variable load across the output terminals.

3 Connect input power at low line per unit specifications. Apply load until rated current of supply is reached. (Unit has voltage mode indicated.) Adjust CURRENT control until CURRENT mode indicator is lit and output volts DVM drops at least 5% of full scale value.

4 The DC output current should be measured and recored at four points.

a) Max. AC Line - Max DC Voltage.
b) Max. AC Line - 1 Volt.
c) Min. AC Line - 0 Volts
d) Min. AC Line - Max. DC watt.

NOTE

All combinations of regulation can be calculated from these measurements.

5.6 HI-POT TEST PROCEDURES

High potential test procedures have been carefully carried out at the factory. These units are 100% tested and should not require further testing in the field.

CAUTION

High potential tests can overstress or destroy the power semiconductors in this power supply if improperly applied.

Isolation measurements may be made using a standard VOM (Simpson 260 or equivalent) on the highest resistance scale available.

If it is essential to use the high potential test method, please contact the factory for information on special precautions that should be taken.

CAUTION

Sorensen Company cannot be held liable for any malfunctions resulting from the application of a high potential test (greater than 100V). See standard Sorensen Company warranty.

5.7 RIPPLE ADJUSTMENTS

The DCR-T units have a unique feature that provides the user the capabilities of compensating for unbalanced ac phase voltages or minimizing ripple for a specific operation region.

The units have been adjusted to accomodate the factory ac line and to meet specifications over total voltage range. If the unit is to be used over a narrow voltage range, ripple can be reduced by 50% for some settings.

5.7.1 Steps to Adjust Ripple

With unit OFF, make the following set up:

A. Remove the six connections from the trigger board: J3, J4, J5, J6, J7 and J8. Carefully lay them next to connector as they must go back exactly as they were taken off.

B. Place an oscilloscope between virtual ground and TP3. Turn unit ON, both Stand-By and POWER.

NOTE

Care must be exercised as the ac line voltage is present on the crossover board and the wires taken off in Step A.

C. Note the wave form on the oscilloscope. It should be a 60 Hz sawtooth with a peak of about 8 volts. Note and record peak voltages.

D. Turn unit power OFF, and move oscilloscope to TP2.

E. Turn unit power ON, and note wave form. Adjust R13 until peak is identical to Step C.

F. Turn unit power OFF, and move oscilloscope to TP1.

G. Turn unit power ON, and note wave form. Adjust R12 until peak is identical to Step C.

NOTE

All wave forms should be the same. If a multi-traced scope is used, this adjustment can be accomplished by looking at all three wave forms at the same time. They will be 120 degrees or about 5.4 MS apart.

H. Turn power and stand-by switches OFF.

I Reconnect wires to J3 through J8.

J Connect oscilloscope across output.

K. Connect load for desired operating lead.

L. Turn voltage control to zero.

M. Turn unit ON.

N. Bring voltage up to desired level.

O. With a screwdriver having a plastic blade, move pots R8, R10, R12, R16, R17 and R18 very slightly, and note effect of ripple on oscilloscope.

NOTE

Study the crossover circuit. AC line voltage is present and is dangerous.

P. Adjust the one that makes the greatest impact on the ripple.

Q. Repeat Step P until the best ripple is achieved for the desired operating conditions.

R. Touching-up R12 and R13 from Steps E and G may be necessary.

SECTION 6
DRAWINGS AND PARTS LISTS

6.1 GENERAL

This section provides schematic diagrams, PCB parts location drawings, and replaceable parts lists. The parts lists are keyed to the applicable schematic diagrams.

Replacement Parts List

Circuit Symbol	DCRT 10KW T1 MODEL								Description	Sorensen Part No.
	16-625T5	32-310	55-180	80-125	110-90	160-62	300-33	600-16		
									Capacitors Cont'd (mF unless noted)	
C7	X	X		X	X	X	X	X	Not Used	
			X						10, 75V	586386-8
C8 thru C19	X	X							Not Used	
			X	X	X	X	X	X	Cap. Assembly	1063925-1
C1A	X	X	X	X	X	X			Not Used	
							X	X	4.2K, 350V	1060201-2
C2A	X	X	X	X	X	X	X		Not Used	
								X	4.2K, 350V	1060201-2
C1B, C2B	X	X	X	X	X	X			Not Used	
							X		1.7K, 450V	1060201-5
								X	2.6K, 350V	1060201-3
RC1 thru RC3	X	X	X	X	X	X	X	X	Snubber Assembly	5361158-01
									Diodes	
CR1 thru CR3	X	X	X	X	X	X	X	X	Thyristor, 90A, 600V, (CD430690)	1060513-1
CR4A thru CR4C	X	X							300A, 200V, R6110230XXZA	1060270-02
			X	X	X	X	X	X	100A, 600V, R5110615XXZT	1059426-4
CR5A thru CR5C	X	X							300A, 200V, R6100230XXZA	1060270-01
			X	X	X	X	X	X	100A, 600V, R5100615XXZT	1059426-3
CR6A thru CR6C	X	X							300A, 200V, R6110230XXZA	1060270-02
			X	X	X	X	X	X	100A, 600V, R5110615XXZT	1059426-4
CR7A thru CR7C	X	X							300A, 200V, R6100230XXZA	1060270-01
			X	X	X	X	X	X	100A, 600V, R5100615XXZT	1059426-3
									Fuses	
F1, F2	X	X	X	X	X	X	X	X	Midget, 600V, 2A	1058990-3
XF1, XF2	X	X	X	X	X	X	X	X	Fuse Holder	1060226-1
K1	X	X	X	X	X	X	X	X	**Contactor**	861-034-90
									Filter Chokes	
L1 thru L3	X	X	X	X	X	X	X	X	RFI Filter Choke	1060603-1
L4	X								Inductor	1059686-1
		X							Inductor	1059686-2

Replacement Parts List

Circuit Symbol	DCRT 10KW T1 MODEL 16-625T5	32-310	55-180	80-125	110-90	160-62	300-33	600-16	Description	Sorensen Part No.
SW4 thru SW7	X	X	X	X	X	X	X	X	**Thermostat**	1058402-3
									Transformers	
T1	X	X							Power Transformer	1060650-4
			X		X				Power Transformer	1060650-1
				X		X			Power Transformer	1060650-2
							X	X	Power Transformer	1060650-16
T2	X	X	X	X	X	X	X	X	Control Transformer	1060221-1
TB1	X	X	X	X	X	X	X	X	**Terminal Block**, 4P, 70A	1059428-3
									Miscellaneous	
J1	X	X	X	X	X	X	X	X	Remote Jack (.093)	1060157-20
	X	X	X	X	X	X	X	X	Female Pin (.093)	1059564-3
P1	X	X	X	X	X	X	X	X	Remote Conn. Assy. (.093)	1059309-1
	X	X	X	X	X	X	X	X	Male Pin (.093)	1059564-4
J2	X	X	X	X	X	X	X	X	Control Jack (.062)	856-136-36
	X	X	X	X	X	X	X	X	Female Pin (.062)	589657-15
P2	X	X	X	X	X	X	X	X	Control Plug (.062)	1063091-1
	X	X	X	X	X	X	X	X	Male Pin (.062)	1061355-1
Feet	X	X	X	X	X	X	X	X	**Feet**	30-473
									Panels	
	X	X	X	X	X	X	X	X	**Top Front Panel**	1059738-40
	X	X	X	X	X	X	X	X	**Bottom Front Panel**	1059739-40
	X	X	X	X	X	X			**Base**	1059077-60
							X	X		1059077-62
	X	X	X	X	X	X	X	X	**Side Right Panel**	1059078-60
	X	X	X	X	X	X	X	X	**Side Left Panel**	1059078-61
	X	X	X	X	X	X	X	X	**Rear Panel**	1060460-1
	X	X	X	X	X	X	X	X	**Cover**	1059086-60
	X	X	X	X	X	X	X	X	**Upper Deck**	1059246-60

Replacement Parts List

Circuit Symbol	DCRT 10KW T3 MODEL 16-625T5	32-310	55-180	80-125	110-90	160-62	300-33	600-16	Description	Sorensen Part No.
									Note: Same as DCR-T1 with the following exceptions:	
									Printed Circuit Board	
A1	X	X	X	X	X	X	X	X	Trigger PCB	1059074-3
A3	X	X	X	X	X	X	X	X	Crossover PCB	1059062-3
									Diodes	
CR1 thru CR3	X	X	X	X	X	X	X	X	Thyristor, 55A,1200V,CD431260	1060512-1
									Fuses	
F1, F2	X	X	X	X	X	X	X	X	Non-Delay, 1.5A, 600V	1058990-2
K1	X	X	X	X	X	X	X	X	Contactor, 24V, 1 Phase	861-034-24
OL1	X	X	X	X	X	X	X	X	**Relay Overload,**	861-034-02
									Transformers	
T1	X	X							Power Transformer	1060650-6
			X		X				Power Transformer	1060650-10
				X		X			Power Transformer	1060650-13
							X	X	Power Transformer	1060650-80
T2	X	X	X	X	X	X	X	X	Control Transformer	1060221-4

Replacement Parts List

Circuit Symbol	DCRT 10KW T5 MODEL 16-625	32-310	55-180	80-125	110-90	160-62	300-33	600-16	Description	Sorensen Part No.
									Note: Same as DCR-T1 with the following exceptions:	
									Printed Circuit Board	
A1	X	X	X	X	X	X	X	X	Trigger PCB	1059074-1
A3	X	X	X	X	X	X	X	X	Crossover PCB	1059062-1
									Capacitors	
RC4		X							Cap. Assy.	1061351-1
	X		X	X	X	X	X	X	Not Used	
									Diodes	
CR1 thru CR3	X	X	X	X	X	X	X	X	Thyristor, 75A,1200V,CD431240	1059431-1
									Fuses	
F1, F2	X	X	X	X	X	X	X	X	Non-Delay, 1A, 600V	1058990-1
K1	X	X	X	X	X	X	X	X	Contactor, 24V, 3 Phase	861-034-24
OL1	X	X	X	X	X	X	X	X	**Relay Overload,**	861-034-02
									Transformers	
T1	X	X							Power Transformer	1060650-8
			X		X				Power Transformer	1060650-12
				X		X			Power Transformer	1060650-15
							X	X	Power Transformer	1060650-20
T2	X	X	X	X	X	X	X	X	Control Transformer	1060221-3