USER'S GUIDE AND TECHNICAL REFERENCE

AC SOURCE

BEHLMAN MODEL BL1350

FOR SERVICE ASSISTANCE

CONTACT BEHLMAN
CUSTOMER SERVICE DEPARTMENT

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DATE: 3/00 REV. D

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PACKAGING INSTRUCTIONS

RACK MOUNTED UNITS

1. Box(es) must be double wall with minimum 350 lbs. bursting test.

2. Box(es) must provide for a minimum of 2 to 3 inches of clearance around sides, top and bottom of unit.

3. When packing unit, utilize either a foam-in-place system or high density foam. Clearance provided for above must be completely filled with foam.

   FAILURE TO COMPLETELY SECURE UNIT IN BOX WILL ALLOW MOVEMENT DURING SHIPPING, RESULTING IN DAMAGE.

DO NOT USE PEANUTS OR BUBBLE WRAP

4. Secure box(es) to pallet(s). This is necessary to insure proper handling and protection during shipping.

5. Place the following warning label on box(es)

   DO NOT STACK

6. Ship unit(s) using a freight cargo carrier; air or ground.

DO NOT USE UPS

CABINET MOUNTED UNITS

Cabinet mounted units require that a special crate be used. The crate should be manufactured of plywood (3/8" or thicker) and reinforced (using 1 x 3 or larger pine) on all edges. The unit must be firmly secured to the crates base. The crate must be shock mounted to avoid damage during shipping.

Detail drawings for Behlman's crates are available upon request.

CLAIM FOR DAMAGE IN SHIPMENT

Under the FOB factory terms of sale, ownership and responsibility are transferred to the customer when the equipment leaves the factory. Each Behlman equipment is shipped from the factory in proper operating condition.

Immediately upon receiving equipment, unpack and inspect it for evidence of damage incurred in shipment. File a claim with the freight carrier if the equipment has been damaged in any way or it fails to operate properly. Forward a copy of the damage claim report to Behlman. Include the model number, serial number and date the shipment was received. Behlman will advise the disposition of the equipment and will arrange for necessary repair or replacement.

RETURNING EQUIPMENT TO FACTORY

Do not return equipment to the factory without prior authorization from Behlman.

This equipment, like all precision electronic equipment, is susceptible to shipping damage. It contains heavy magnetic components as well as delicate electronic components.

If equipment is returned without prior authorization, the shipment will be refused, the customer being liable for all shipping, handling and repair costs.

When packing for reshipment, use the original shock absorbent material and shipping container to preclude damage to the equipment.

Ensure that the return authorization number (RMA) is available on the container.

LIMITED WARRANTY

Behlman Electronics, Inc. warrants, to the original purchaser, for a period of one (1) year from the date of shipment from Behlman, each item to be free from defects in material and workmanship. Behlman's obligation and the Purchaser's sole remedy for any breach or violation of this agreement is limited to adjustments, repair or replacement for parts which have been promptly reported by the Purchaser as having been, in its opinion, defective and so found by Behlman upon inspection. All replacement parts will become the property of Behlman on an exchange basis. This warranty will not apply if such adjustments, repair or parts replacement is required because of accident, neglect, misuse, failure of environmental controls, transportation damage or causes other than normal use.

If during the warranty period a defect should impair the performance of the unit, Behlman agrees, at its option, to repair or replace the unit or its defective components F.O.B. Behlman at 80 Cabot Court, Hauppauge New York 11788 or at another Behlman service facility at Behlman's option. To obtain service under this warranty, the original Purchaser shall notify Behlman at the above address or by Telephone at 631-435-0410 and provide information about the defect or impairment of performance. Behlman will then supply the Purchaser a Return Material Authorization (RMA) number. This number must be attached to the equipment sent back for warranty repair. Equipment must be shipped back to Behlman prepaid. No collect shipments will be accepted.

Behlman shall be excused from supplying warranty service if the units case shall have been opened or if the unit had been subject to unauthorized repair. All service outside the scope of this Warranty shall be paid for by the Purchaser at Behlman's rates in effect at the time of repair. Behlman will not perform any repairs outside of the Warranty without written authorization by the Purchaser. If the repair is a warranty repair, Behlman will ship the unit back to the Purchaser, by a method determined solely by Behlman, prepaid. If the Purchaser requests any other means of transportation it shall be at the Purchaser's expense.

The use of the equipment shall be under the Purchaser's exclusive management and control. The Purchaser will be responsible for assuring the proper installation, use, management and supervision of the equipment. Behlman will not be liable for personal injury or property damage.

The foregoing warranties are in lieu of all other warranties, expressed or implied including without limitation warranties of merchantability and fitness for purpose.

In no event shall Behlman be liable for loss of profits, loss of use, or an other indirect, consequential or incidental damages. Purchaser agrees that Behlman will not be liable for any damages caused by the Purchaser's failure to fulfill any of the Purchaser's responsibilities set forth herein.

SECTION 1

INTRODUCTION

1.1 GENERAL DESCRIPTION

The Behlman AC Source models (table 1) are sophisticated ac power supplies. Each of the six models provide independent verification of operating voltage, current, and frequency values thereby lessening the need for external measuring devices. Two models provide a single voltage range output while the other four provide dual voltage range outputs.

Any of the six models can include all or any combination of the four available options if desired (see OPTIONS listed below table 1).

TABLE 1. BEHLMAN MODELS

MODEL	INPUT VOLTAGE (ac)	OUTPUT VOLTAGE (ac)	DUAL RANGE	ISOLATED OUTPUT
BL1350A-1	115V	0 - 135V		
BL1350B-1	115V	0 - 135V 0 - 270V	√	
BL1350B-2	115V	0 - 34V 0 - 135V	√	
BL1350C-1	115V/230V	0 - 135V		√
BL1350C-2	115V/230V	0 - 135V 0 - 270V	√	√
BL1350PF	115V/230V	85-270V	√	√

OPTIONS:
Add A to dash number for front panel safety sockets.
Add B to dash number for rubber feet.
Add E to dash number for extended frequency range.
Add G to dash number for circuit breaker guard.
Add I to dash number for IEEE Interface.
Add IR to dash number for RS232 Interface.
Add J to dash number for 100/200 Vac input (C-1, C-2, C-3).
Add L to dash number for front panel locking controls (VOLTS, FREQ) on voltage and frequency.
Add P to dash number for parallel wiring of 2 or 3 units.
Add S to dash number for chassis slides.
Add T to dash number for 0-150/0-300 Vac output (B-1, C-2).
Add CE to dash number for CE mark.
Add H to dash number for cabinet enclosure for 3 units.
Add W to dash number for wiring for 3 phase connection.
Add MT to dash number for motor test.

1.2 SPECIFICATIONS

INPUT POWER

Voltage:	See Table 1*
Frequency:	47-440 Hz., 47-63Hz. for PF

OUTPUT POWER

Voltage:	See Table 1*
Frequency:	45-500 Hz (option E, 45-1,000 Hz).
Maximum Power:	1,350 VA; units can be stacked for increased power or for three phase output. Not available on PF units.
Maximum Current:	10 amperes 0-135 Vac range. 5 amperes 0-270 Vac range where available.
Current Crest Factor:	3:1.
Power Factor:	100% of rated output into any power factor load.
Distortion:	0.5% THD (measured at full load, 100 Vac, 50 Hz).
Load Regulation:	±0.7% from no load to full load.
Line Regulation:	±0.1% for ±10% of line change.
Efficiency:	BL1350A-1 is 80%, all other models are greater than 70%.

MECHANICAL

Dimensions:	19 in. wide, 3.5 in. high, 22 in. deep .
Weight:	BL1350A-1, B-1, and B-2 models are under 40 lbs. BL1350C-1, C-2, and PF models are under 70 lbs.
Operating Temperature:	0°C to 55°C (32°F to 131°F).

* For units with special options (-J, -T), refer to nameplate located at rear of unit.

SECTION 2

UNPACKING AND INSTALLATION

2.1 UNPACKING

After unpacking the AC Source (unit), carefully conduct a thorough inspection of controls, indicators, and chassis. If the unit shows signs of damage, do not attempt to operate. File a damage claim with the carrier responsible. Notify Behlman immediately.

2.2 INSTALLATION

1) This unit is rack mounted.

NOTE

The unit must have bottom support when mounting in a rack or cabinet. Do not attempt to mount by front panels only. These units, when stacked as in multi phase use, require proper cooling air circulation and a six inch clearance at the rear of unit(s).

2) Ensure that the line circuit breaker and all other unit controls are in the OFF position before connecting input power.

3) Connect input/output power lines as follows:

CAUTION

Ensure that input neutral is connected to unit neutral. If grounding is desired, connect input power ground to ground stud located on the unit's rear panel.

a) INPUT POWER- Connect 115 Vac or 230 Vac (for C models), 47-440 Hz, power lines to the designated terminals on the INPUT terminal block located at the unit's rear panel. (See figures 1 through 3).

b) OUTPUT POWER- Output power lines can be connected to either the front panel HOT, NEUT, and GND binding posts or to the HOT and NEUT terminals on the OUTPUT terminal block located at the unit's rear panel (see figure 1, Section 3).

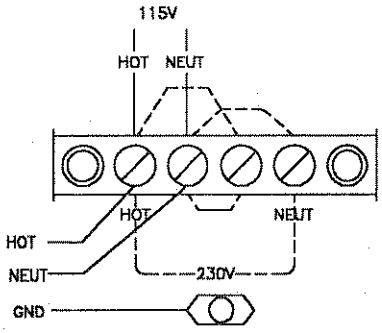


Figure 1. Input connections for BL1350A-1, BL1350B, BL1350B-2

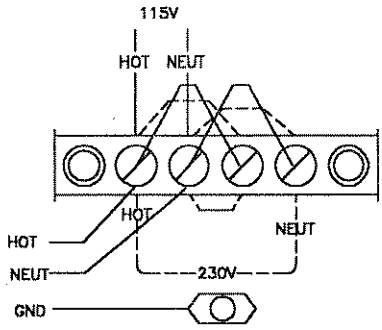


Figure 2. Input connections for BL1350C-1, 2 for 115V input

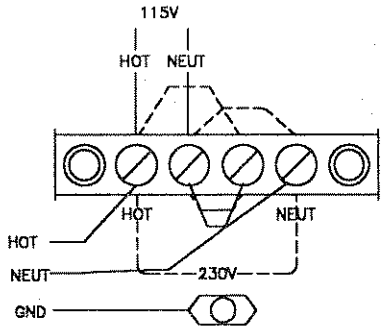


Figure 3. Input connections for BL1350C-1, 2, for 230V input

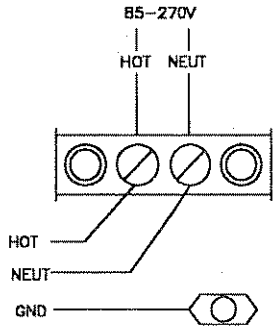


Figure 4. Input connections for BL1350pf

MANUAL ADDENDUM
MODEL BL1350

OPERATIONAL CONSIDERATIONS FOR PARALLEL OPERATION OF 2 OR MORE UNITS

The BL 1350 Series of AC power supplies may be connected in a "master/slave" configuration to provide high output power. The inter-connection of units is illustrated elsewhere in this manual. Up to three units may be used in this configuration to provide a total output power exceeding 3000 watts.

When using the parallel connection, the following "rules" must be applied to provide proper operation and prevent damage to the units.

1.) All three supplies must be fed from the same AC line branch circuit. Failure to do this will cause an imbalance in current sharing and may create circulating currents between units.

2.) The line and neutral of the input connections ***MUST BE !*** in phase. If it is not known, the circuit should be checked by a competent electrician.

3.) The master unit ***MUST ALWAYS*** be turned on before the slave units. During turn off, the output voltage of the master must be set to zero. At this point the slave units can be switched off followed by the master. **Failure to follow this sequence will cause damage to one or both power supplies.**

If the power sources are to be left in this configuration and it is only desired to use the master, the 9 pin remote inter-connect cable must be removed. This is required for proper operation of the master as a "stand-alone" unit.

NOTE ABOUT THREE PHASE CONFIGURATION

The model BL1350's may also be connected in a three phase configuration. Although this is not as restrictive as the parallel configuration, the following must be considered.

1.) Because phase B and C receive their sync signals from A phase, A should be switched on and adjusted to the proper amplitude and frequency prior to switching on B and C units.

2.) The sync signal is taken directly from the output of the A unit. If the output amplitude of any Unit is reduced below some value (below 50 Vrms) the units will become unstable. This may cause trouble for or damage to frequency and phase sensitive loads. If operation at low output voltage is desired, reduce the value of the 5K resistor shown in the 3 phase hook-up diagram to a lower value (reduce it by the same percentage as the output voltage).

SECTION 3

OPERATION

WARNING

This equipment involves the use of voltages and currents that can be hazardous. Only qualified personnel should be allowed to operate or service it. The top cover(s) must always be in place during operation.

3.1 CONTROLS AND INDICATORS

Table 1 lists the controls and indicators used on the different models of the AC Source. The table also includes their function. Figure 1 locates these front panel controls and indicators. Also shown are the rear panel REMOTE PRGM connector, four terminal blocks, and two cooling fans.

3.2 TO OPERATE THE EQUIPMENT

1) Ensure that line circuit breaker and OUTPUT switch are set to OFF.

WARNING

Front panel binding posts are rated at 10 amperes maximum.

2) Connect suitable load across output terminals. (Do not exceed rating of unit).

3) Set output RANGE switch to desired HI or LO voltage position (dual range models only).

4) Set line circuit breaker to ON (cooling fan noise should become evident).

5) Rotate VOLTS control to desired voltage (selector switch set to VOLTS).

6) Rotate FREQ control to desired frequency (selector switch set to FREQ).

7) Set OUTPUT switch to ON to energize load.

NOTE

It is permissible to energize a load gradually by setting the OUTPUT switch ON and rotating the VOLTS control from zero to low voltage position up to the voltage desired.

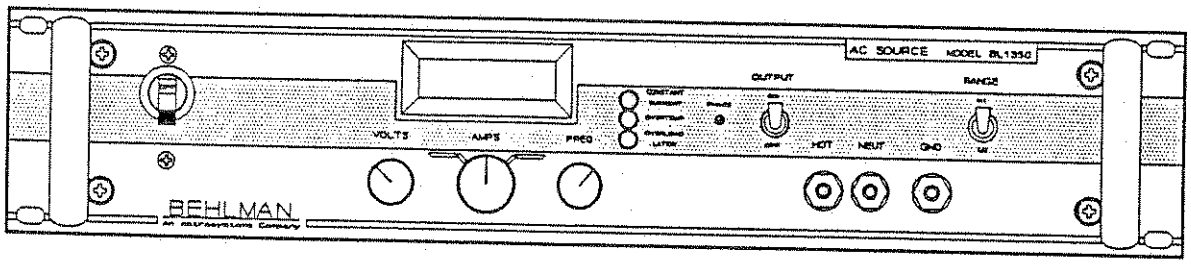
3.3 SHUTDOWN PROCEDURE

1) Set OUTPUT switch to OFF.

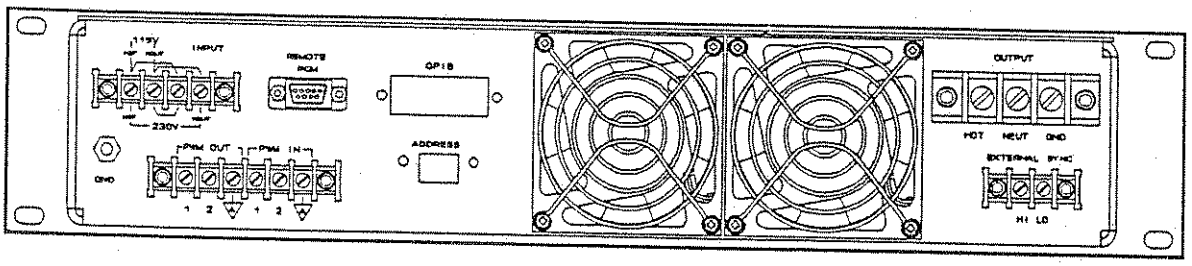
2) Set line circuit breaker to OFF.

TABLE 1. CONTROLS AND INDICATORS

CONTROL/INDICATOR	FUNCTION
Circuit breaker	ON: Connects input power to unit. OFF: Disconnects input power from unit.
CONSTANT CURRENT indicator	Lights to indicate protective circuits are automatically operating to provide rated current and distortionless output during an overload condition.
Digital readout meter	Provides digital (three numerical, one decimal) readout associated with setting of selector switch: true RMS voltage, RMS current, or frequency.
FREQ control	Used with selector switch (set to FREQ) to establish output frequency.
OUTPUT switch	ON: Connects output power to unit front panel HOT, NEUT, and GND binding posts and rear panel HOT and NEUT terminals on OUTPUT terminal board. OFF: Disconnects output power at front and rear panels.
OVERLOAD LATCH indicator	Lights to indicate short circuit protection for overload conditions that disables the output. Overload latch is reset by removing load and recycling power.
OVERTEMP indicator	Lights to indicate over temperature condition and removal of output power. Output power is automatically restored on termination of overtemperature condition.
PHASE control	Used to precisely trim two or more units for a desired phase shift (from 50° to 140°). Refer to Section 4 for detailed phase adjustment procedures.
RANGE switch (Dual range models only, see table 1 in Section 1.)	HI: 0-135 Vac, 0-270 Vac LO: 0-34 Vac, 0-135 Vac
Selector switch	VOLTS: Provides output voltage (RMS) display. AMPS: Provides output current (RMS) display. FREQ: Provides output frequency display.
VOLTS control	Used with selector switch (set to VOLTS) and RANGE switch (set to HI or LO) to establish desired output voltage

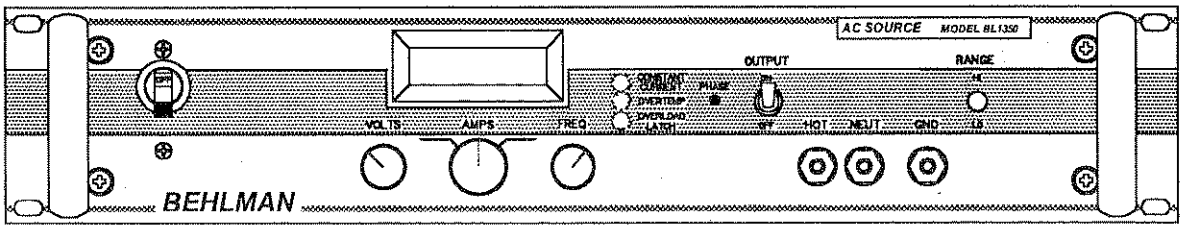


FRONT PANEL

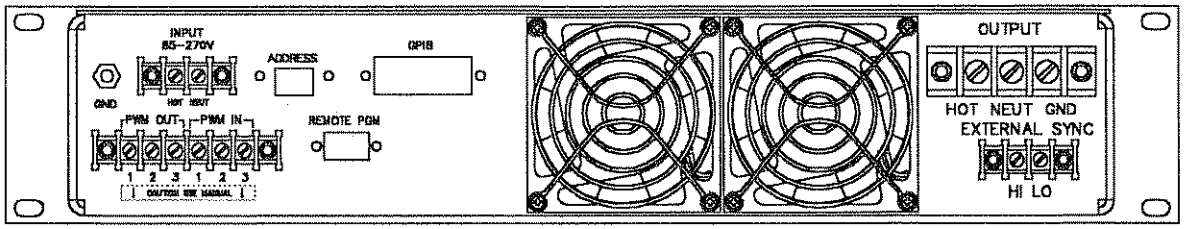


REAR PANEL

Figure 1. Ac Source, Front and Rear Panel Views



FRONT PANEL



REAR PANEL

Figure 1. AC Source, Front and Rear Panel Views
Shown for BL1350pf

3.4 SINGLE UNIT CONNECTION

For single unit operation ensure jumpers are in place at the unit's rear panel as shown in figure 2.

- USE AWG 20 JUMPER WIRES.
- CONNECT NO. 6 (0.31" WD MAX.) SPADE LUG TO END OF JUMPER WIRES.

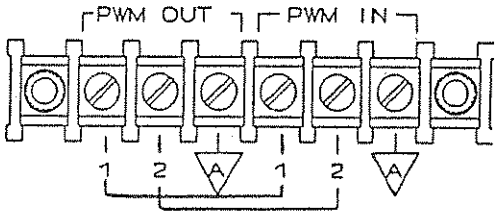


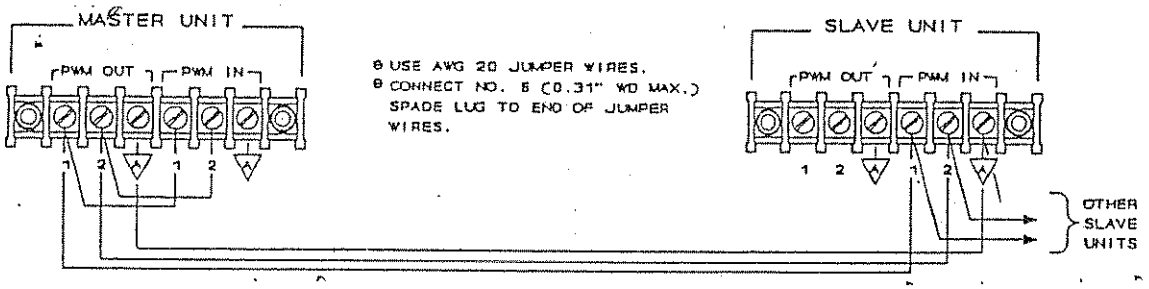
Figure 2. Single Unit Connection

3.5 MULTIPLE UNIT CONNECTION

For connecting a master (controller) unit to one or more slave units, connect units as shown in figure 3. In this configuration, the master unit is used to control the voltage and frequency of both units. The voltage displayed on the slave unit(s) front panel meter is the same as that on the master front panel meter. The frequency displayed on the slave unit(s) may be different than that on the master unit, however, every slave unit in the configuration has the same output frequency as is displayed on the master unit.

CAUTION !!!

All output switches must be in the ON position before power is applied. Set Voltage Pot of Master to zero Volt (CCW), before power is applied. The master must have power before any of the slave units. Range and Output Relay switches must be set in the Low position on the Slave Unit. If these steps are not followed, damage may result which may not be covered by the warranty.



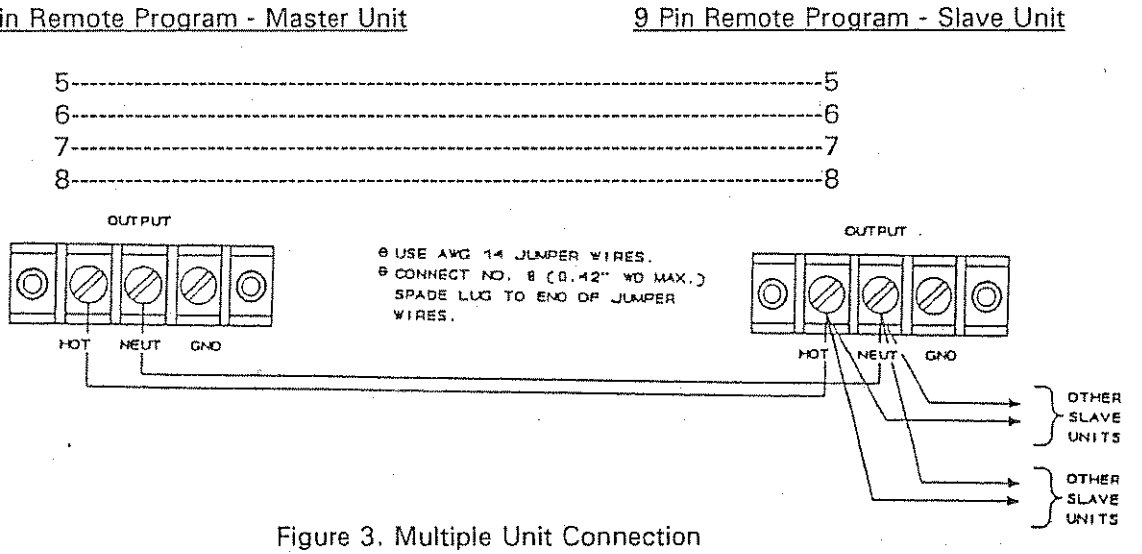


Figure 3. Multiple Unit Connection

TABLE 2. REMOTE PRGM CONNECTOR PIN DESCRIPTIONS

PIN	DESCRIPTION
1	Amplitude control (hi).
2	Amplitude control (rtn).
3	Frequency control (hi).
4	Frequency control (rtn).
5	Range select. (Dual range models only).
6	Range select. (Dual range models only).
7	Output relay control.
8	Output relay control.
9	Not used.

3.7 EXTERNAL SYNC

CAUTION

The external sync signal applied to the unit must not be lower than 45 Hz to avoid possible damage to the unit.

The unit provides for external syncing via its rear panel EXTERNAL SYNC terminal block. When an external sync signal is applied to the unit, it reacts to produce an output frequency that is equal to the sync signal regardless of the FREQ control setting. The external sync signal can be either TTL compatible or an AC signal from 5 to 30 VRMS.

SECTION 4

MAINTENANCE AND ADJUSTMENTS

WARNING

This equipment involves the use of voltages and currents that can be hazardous. Only qualified personnel should be allowed to operate or service it. The top cover(s) must always be in place during operation.

Before performing any adjustments where access to the inside of the equipment is required, be sure to turn off the unit and allow five minutes for the DC power supply capacitors to discharge.

4.1 MAINTENANCE

WARNING:

FAILURE TO MAINTAIN OR OPERATE THE UNIT PROPERLY WILL VOID THE WARRANTY. AMONG THE ABUSES THAT ARE INCLUDED (BUT NOT LIMITED TO) ARE:

NOT MAINTAINING THE CLEANLINESS OF THE FILTERS (VACUUMING), OPERATING OUTSIDE THE ALLOWABLE ENVIRONMENT, AND PHYSICALLY DAMAGING THE UNIT.

The decision on whether a units warranty has been voided will be exclusively reserved for Behlman.

4.2 ADJUSTMENTS

NOTE

All the potentiometers used in the procedures that follow are located on the controller card A1. See the printed wiring assembly 106-685-000 in Section 6 for parts location.

CAUTION

Always use a non-metallic screwdriver when adjusting potentiometers.

4.2.1 TEST EQUIPMENT REQUIRED

TEST EQUIPMENT	MANUFACTURER/MODEL
Current Clamp	Fluke 80I-600 (or equivalent current transformer)
Digital Voltmeter (DVM)	Fluke 8062A (or equivalent)
Frequency Counter	HP 5314A (or equivalent)
Oscilloscope	Iwatsu SS-5571 (or equivalent)

4.2.2 CONTROLLER CARD POTENTIOMETER ADJUSTMENTS

Since certain potentiometer adjustments affect other associated potentiometer settings, a sequence of adjustments must be followed to ensure the proper setting of each potentiometer within the three groups comprising the unit. The three groups: frequency, voltage, and current, are listed below in the sequence to be performed within each group.

FREQUENCY		VOLTAGE		CURRENT	
POT.	PARA	POT.	PARA	POT.	PARA
R52	4.2.3	R135	4.2.6	R137	4.2.9
R53	4.2.4	R93	4.2.7	R25	4.2.10
R57	4.2.5	R65	4.2.8		

4.2.3 LOW FREQUENCY TRIM (45 Hz R52)

1) Connect frequency counter to front panel HOT and NEUT binding posts.

2) Turn FREQ control fully CCW.

3) Set circuit breaker to ON.

4) Set OUTPUT switch to ON.

5) Set selector switch to VOLTS.

6) Adjust VOLTS control until panel meter indicates 10 Vrms minimum.

7) Adjust 45 Hz potentiometer R52 until frequency counter indicates 45 Hz.

4.2.4 HIGH END FREQUENCY TRIM (500 Hz R53)

1) Turn FREQ control fully CW.

2) Adjust 500 Hz potentiometer R53 until frequency counter indicates 500 Hz.

4.2.5 FREQUENCY METER ADJUST (Hz-METER R57)

1) Turn FREQ control fully cw.

2) Adjust Hz-METER potentiometer R57 until front panel meter indicates 500 Hz.

4.2.6 OFFSET VOLTAGE (V-OFF R135)

1) Using DVM set to ac volts, connect it to front panel HOT and NEUT binding posts.

2) Turn VOLTS control fully CCW.

3) Set unit circuit breaker to ON.

4) Set OUTPUT switch to ON.

5) Adjust V-OFF potentiometer R135 until DVM indicates 0 VRMS.

4.2.7 LOW VOLTAGE RANGE METER ADJUST (135V F.S. R93)

1) Set RANGE switch to LO (dual range models only).

2) Turn VOLTS control fully CW.

3) Set selector switch to VOLTS.

4) Adjust 135V F.S. potentiometer R93 until front panel meter indicates same as DVM.

4.2.8 HIGH VOLTAGE RANGE METER ADJUST (270V F.S. R65)

1) Set RANGE switch to HI (dual range models only).

2) Adjust 270 V F.S. potentiometer R65 until front panel meter reads same as DVM.

4.2.9 OFFSET CURRENT (I-OFF R137)

1) Ensure no load is connected to unit outputs (front or rear panel).

2) Set circuit breaker to ON.

3) Set selector switch to AMPS.

4) Adjust I-OFF potentiometer R137 until front panel meter indicates 0.

4.2.10 CURRENT METER ADJUST (I-METER R25)

1) Set circuit breaker to OFF.

2) Set OUTPUT switch to OFF.

3) Turn VOLTS control fully CCW.

4) Connect load to front panel HOT and NEUT binding posts or rear panel OUTPUT terminals.

5) Connect current clamp or other current measuring device across load.

6) Set circuit breaker to ON.

4.2.10 CURRENT METER ADJUST (I-METER R25) (cont)

7) Set OUTPUT switch to ON.

8) Set selector switch to AMPS.

9) Adjust VOLTS control, making certain not to approach current limit of about 12 amperes. Any value less than 10 amperes is sufficient. Note current indication.

10) Adjust I-METER potentiometer R25 until front panel meter indication is same as load current noted in step 9.

4.2.11 20KHZ TRIANGLE WAVE TRIM (DIST. TRM R129)

1) Turn VOLTS control fully CCW.

2) Connect oscilloscope across front panel HOT and NEUT binding posts.

3) Set oscilloscope gain to 500 mV/div.

4) Adjust DIST. TRM potentiometer R129 for smallest waveform peak-to-peak value.

4.2.12 LINE DROP COMPENSATION TRIM (I.R. COMP R31)

1) Connect selected load to front panel HOT and NEUT binding posts or rear panel OUTPUT terminals

2) Connect DVM at load input so as to compensate for IR losses in the connecting lines.

3) Set circuit breaker to ON.

4) Set OUTPUT switch to OFF.

5) Adjust VOLTS control to desired setting on DVM. Note voltage setting. (Should be the same as the panel meter indication).

6) Set OUTPUT switch to ON.

7) Adjust I.R. COMP potentiometer R31 to pre-load voltage setting noted in step 5.

4.3 PHASE ADJUSTMENT (TWO UNITS)

4.3.1 To create a phase shift between two units (same model), proceed as follows:

1) First select one unit as a reference ϕA unit and designate the other unit as ϕB unit.

2) Ensure circuit breaker and OUTPUT switch on both units are set to OFF.

3) Depending on the model used and output voltage range selected, connect the two units (same model) as shown in figure 1.

4) On ϕA unit, set controls as follows:

   a) Set selector switch to VOLTS.
   b) Set circuit breaker to ON.
   c) Adjust VOLTS control until panel meter indicates 100 Vac.

5) On ϕB unit, set controls as in step 4.

6) Connect DVM between HOT binding posts on ϕA and ϕB units.

7) To produce a phase shift between two units, adjust front panel PHASE control on ϕB unit until DVM indicates the Vrms value required to produce the desired phase angle. Use the table below as a guide. It shows five predetermined values. For in-between phase angles, use the formulas shown.

DVM (Vrms)	Phase Angle(°)
81.3	48
100.0	60
141.4	90
173.2	120
190.2	144

$V = [(1-\cos \phi)\ 20{,}000]^{1/2}$

$\phi = \cos^{-1} [1-V^2/20{,}000]$

where V = Vrms setting on DVM
and ϕ = phase angle desired

4.4 PHASE ADJUSTMENT (THREE UNITS)

4.4.1 To connect three units (same model) into a three-phase configuration, proceed as follows:

1) First select one unit as reference ϕA unit and other two units as ϕB and ϕC.

2) Ensure circuit breaker and OUTPUT switch on three units are set to OFF.

3) Depending on the model used and output voltage range selected, connect the three units (same model) as shown in figure 2.

4) On ϕA unit, set controls as follows:

   a) Set selector switch to VOLTS.
   b) Set circuit breaker to ON.
   c) Adjust VOLTS control until panel meter indicates 100 Vac.

4.4 PHASE ADJUSTMENT (THREE UNITS) (cont)

5) On ϕB unit, set controls as in step 4.

6) Connect DVM between HOT binding posts on ϕA and ϕB units.

7) On ϕB unit, adjust PHASE control until DVM indicates 173.2 Vrms. (ϕA unit now leads ϕB unit by 120°).

8) Set circuit breaker on ϕA and ϕB units to OFF.

9) On ϕA unit, set circuit breaker to ON and adjust VOLTS control until panel meter indicates 100 Vrms.

10) On ϕC unit, set circuit breaker to ON and adjust VOLTS control until panel meter indicates 100 Vrms.

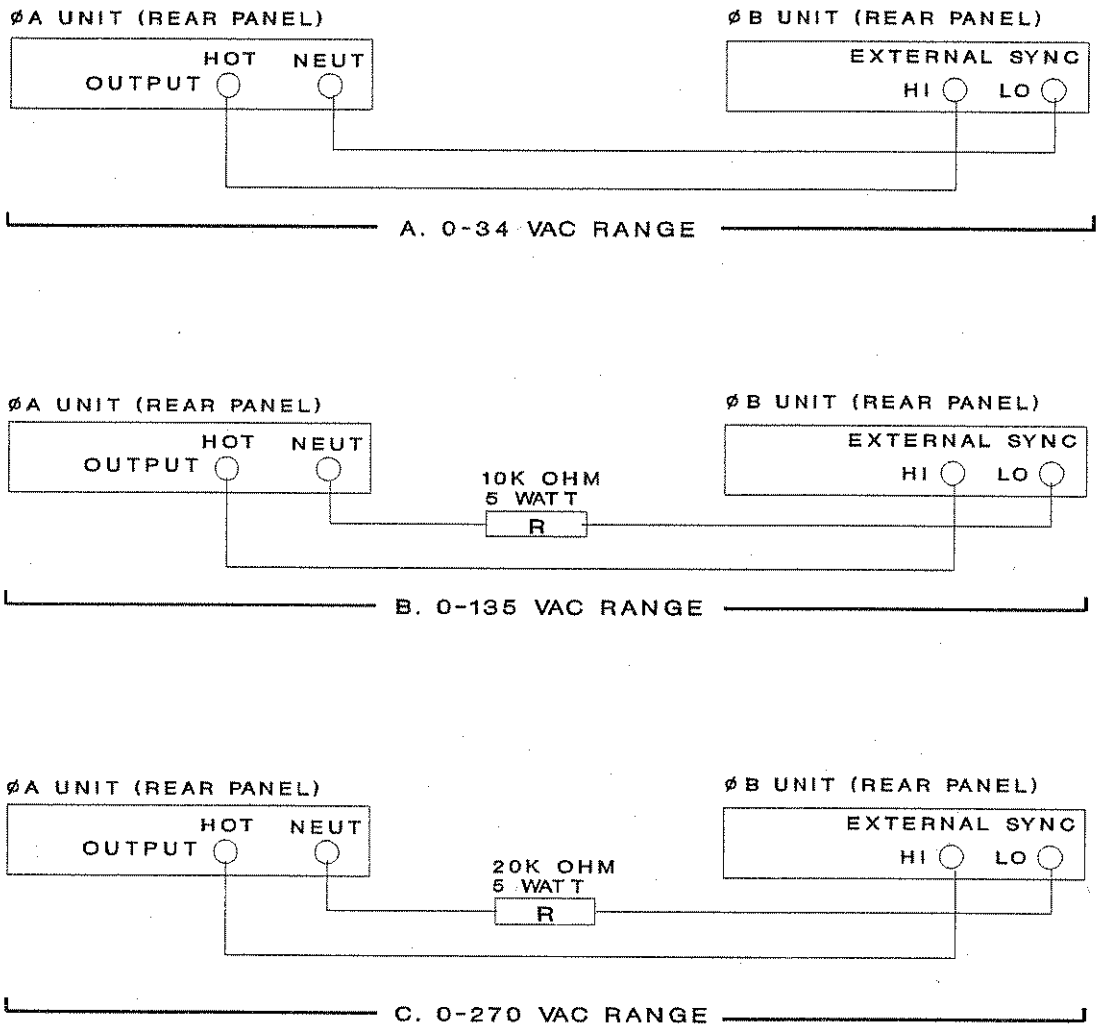
11) Connect DVM between HOT binding posts on ϕA and ϕC units.

12) On ϕC unit, adjust PHASE control until DVM indicates 173.2 Vrms. (ϕA unit now lags ϕC unit by 120°).

NOTE

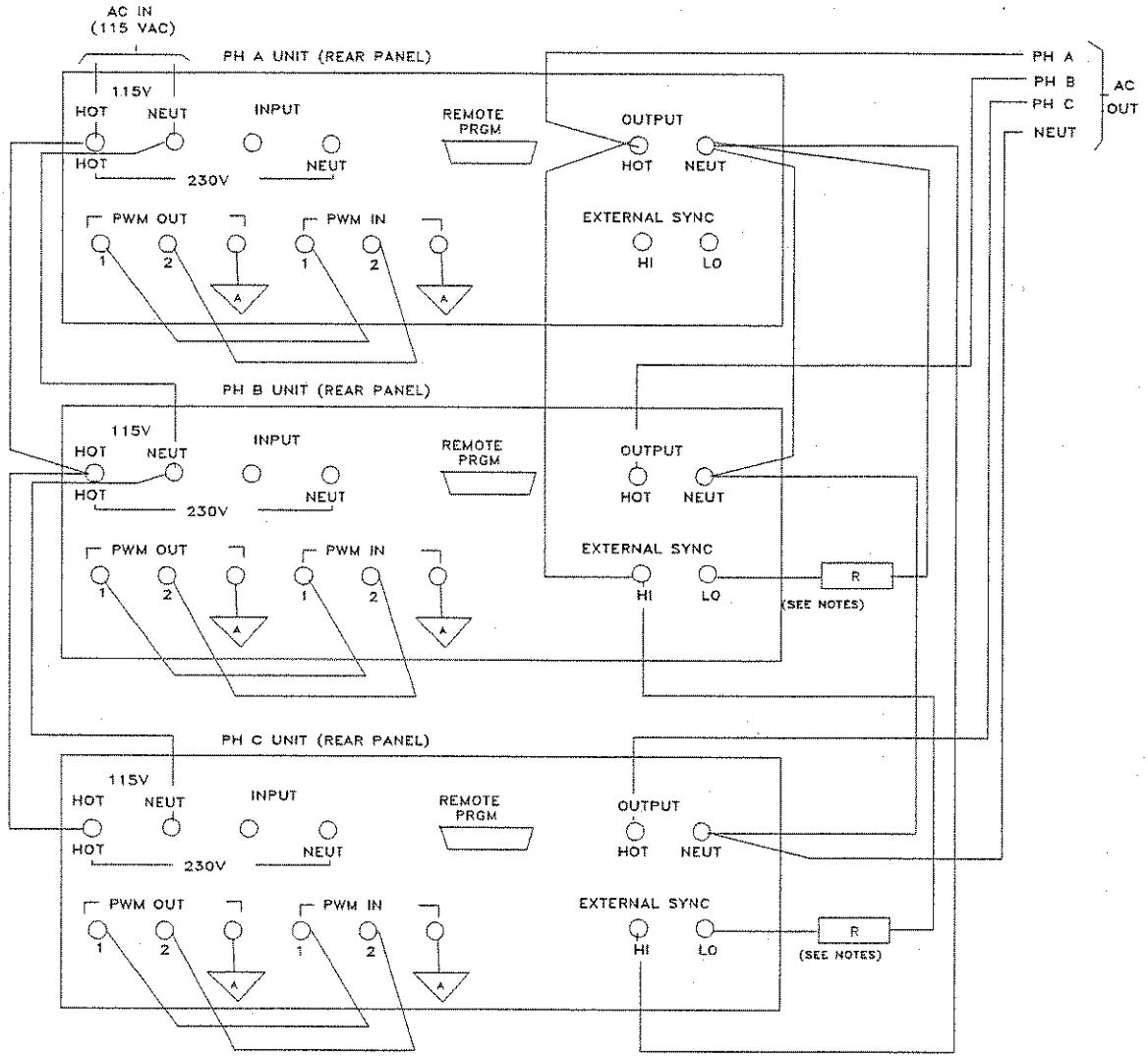
When units are wired in a three-phase configuration, it is good practice to turn on the reference unit (phase A) and its OUTPUT switch before turning on phases B and C. Failure to do this, may cause an overload latch condition. Although this condition does not damage the unit, it should be avoided.

It is also good practice to connect the output neutrals together in a three-phase configuration. This practice provides a cleaner and lower current carrying grounding scheme for the output.



NOTES:
1. USE AWG 20 JUMPER WIRES WITH NO. 6 AND NO. 14 SPADE LUGS.
2. WHEN USING HOOKUP B ABOVE, EXTERNAL SYNC IS RELIABLE DOWN TO 20 VAC OUTPUT.
3. WHEN USING HOOKUP C ABOVE, EXTERNAL SYNC IS RELIABLE DOWN TO 40 VAC OUTPUT.

Figure 1. Phase Adjustment, Two Unit Hookup



NOTES:

R = NOT REQUIRED FOR 0 – 34 VAC (BL1350B–2, C–3 MODELS).
R = 5K OHMS 5W FOR 0 – 135 VAC (ALL MODELS)
R = 10K OHMS 5W FOR 0 – 270 VAC (BL1350B–1, C–2 MODELS)
USE AWG 20 JUMPER WIRES WITH NO. 6 AND NO. 14 SPADE LUGS.
COOLING FANS NOT SHOWN.

7B

Figure 2. Phase Adjustment, Three Unit Hookup

SECTION 5

THEORY OF OPERATION

5.1 GENERAL

5.1.1 The BL1350 series (unit) represent a low-cost, high performance AC to AC converter. The unit operates from a 115 Vac or a 230 Vac input. Its output voltage and frequency can be adjusted from 0-270 Vac and from 45-500 Hz.

5.1.2 If desired, a DC option can be used to provide the same AC voltage and frequency ranges. In this mode of operation, a battery chassis must be supplied.

5.2 DETAILED THEORY

5.2.1 The input voltage is rectified by employing a voltage doubler circuit consisting of a half wave rectifier and two banks of input capacitors. Voltages approximating the positive and negative peaks of the input (+/-150 Vdc) are stored on the capacitor banks that are centered around the input neutral. (On non-isolated units, the input neutral is carried through to the output for safety.) The two rectified voltages provide the necessary DC buses. A differential input choke is also used to increase ripple reduction and power factor. The EMI filter in non-isolated units at the input, limits the conduction of electromagnetic interference back on to the line.

5.2.2 When power is applied to the unit, the low impedance seen by the AC input line due to the unit's large input capacitors would cause most line circuit breakers rated under 20 amperes to trip. To prevent this, in-rush resistors are used to limit the initial current surge at power turn-on. These resistors are placed in series with the large capacitors to keep the start-up current low and effectively provide a soft start. Once the DC buses are up to approximately 120 Vdc, a relay is energized to bypass the in-rush resistors thus providing uninterrupted power application to the unit.

5.2.3 The pulse width modulation (PWM) design of this switching unit generates a high frequency square wave of variable duty cycle. By varying the duty cycle from 8% to 92% and allowing for dead time, a net DC component is created that ranges between the positive and negative DC buses. A two stage LC low-pass filter averages the PWM to produce the DC component.

5.3 REFERENCE OSCILLATOR

5.3.1 The reference oscillator and associated circuitry are shown in figure 1. The reference oscillator produces a digitally derived sine wave in which the amplitude and frequency are controlled by DC levels selected by the unit's FREQ and VOLTS front panel control settings or from external inputs. The DC voltage from the FREQ control is applied to the voltage controlled oscillator (VCO). The resulting pulse train frequency is proportional to its input DC voltage.

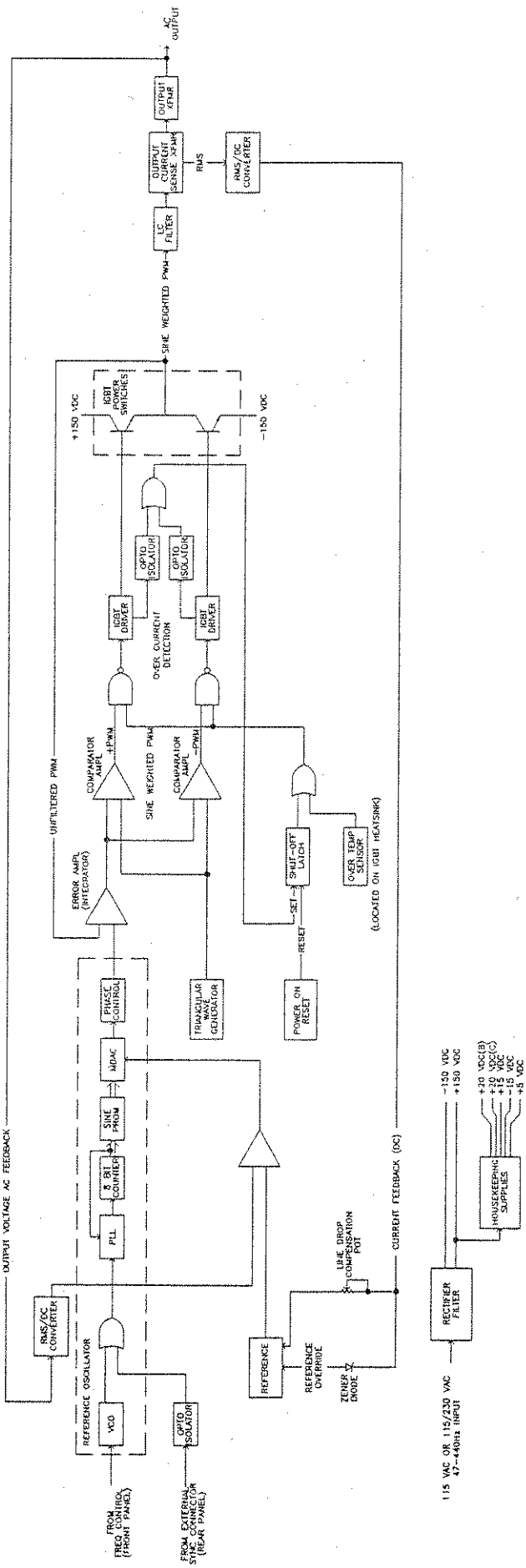


Figure 1. SYSTEM BLOCK DIAGRAM FOR SINGLE PHASE

5.3 REFERENCE OSCILLATOR (cont)

5.3.2 A phase locked loop (PLL), 8-bit counter, PROM (programmed with a sine function), and the multiplying digital-to-analog converter (MDAC) are configured to transform the pulse train into a sine wave of the same frequency. The PLL multiples the input square wave from the VCO (or EXTERNAL SYNC, see next paragraph) by 256 in the 8-bit counter. The output of the counter acts like an address to a PROM programmed as a sine function [e.g. address 0 = 0 (sine 0°), 64 = 1 (sine 90°)]. The output of the PROM is the data input to the MDAC. The output of the MDAC is a sine wave at the frequency of the input square wave. Rather than being a perfect analog voltage, the oscillator output is actually comprised of 256 digital steps approximating a sine wave.

5.3.3 The unit also provides for external syncing via its rear panel EXTERNAL SYNC connector. When an external sync signal is applied to the reference oscillator, it reacts to produce an output frequency that is equal to the sync signal regardless of the FREQ control setting. The external sync signal can be either TTL compatible or an AC signal from 5 to 30 VRMS.

5.3.4 The reference oscillator also contains a unique phase control circuit that is used to compensate for unequal phase shifts in the output LC filter. It can also be used to adjust the phase shift for units being used in combination for three phase operation, where the application causes unwanted phase errors or where a phase error is desired. The phase shift is accomplished by the phase control circuit shown in figure 2. The output signal from the reference oscillator MDAC is applied to an all-pass network that has a phase shift equal to 2 arctan ωRC. The all-pass network produces a phase shift that is constant in amplitude as a function of frequency. Consequently, feedback is used to keep the phase constant independent of frequency.

5.4 ERROR AMPLIFIER

The error amplifier is configured as an integrator that algebraically sums the reference sine wave with the unfiltered PWM output to produce the instantaneously required signal to the PWM to reproduce the desired sine wave.

5.5 SINE WEIGHTED PWM

The output of the error amplifier is summed with a high frequency (20 kHz) triangular wave to produce a PWM sine weighted function. This signal is applied to the insulated gate bipolar transistor (IGBT) drivers that drive the IGBT power switches. (Refer to Appendix A for additional data on the IGBT driver).

5.6 OUTPUT SECTION

The sine weighted PWM power output of the IGBT is filtered by a double LC filter network to remove high frequency switching transients. An output current sense transformer is used to monitor the output current. The maximum output voltage is 90 VRMS and is scaled to the required maximum output (135, 270, or 34 VRMS) by the appropriate output transformer, depending on the model.

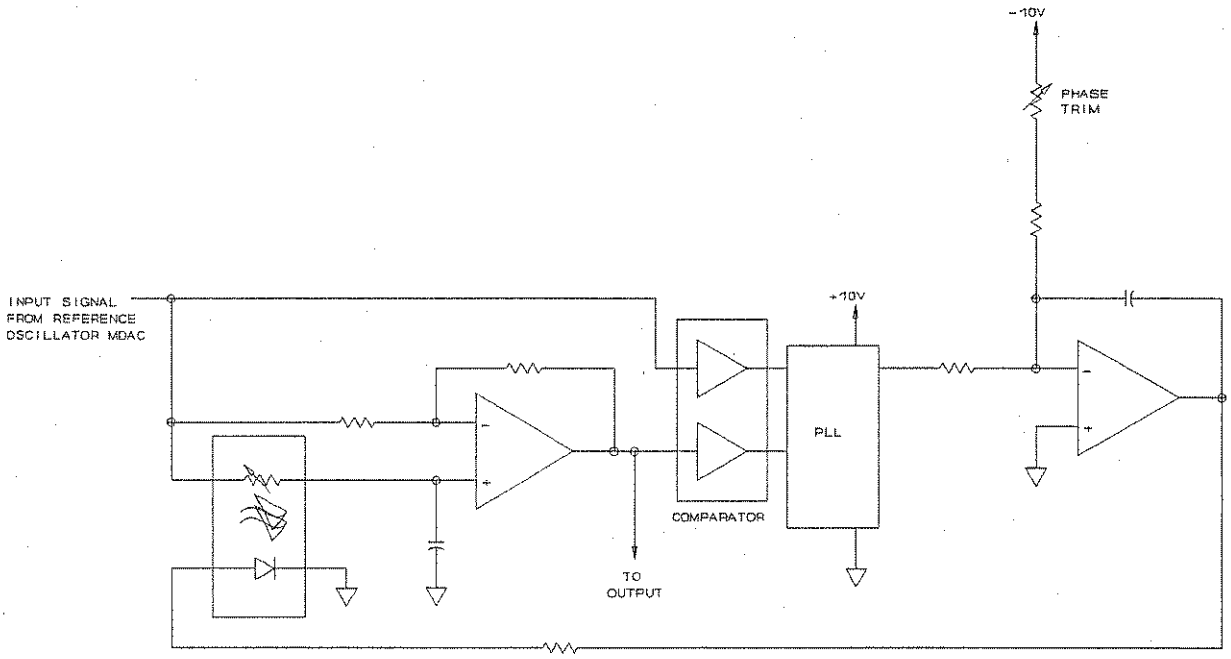


Figure 2. Phase Control Circuit

5.7 CLOSING THE LOOP

In order to provide a clean output with very good regulation, two feedback loops are used. One feedback loop is a fast loop that takes the IGBT output and closes the loop to the error amplifier. This loop, on a pulse-by-pulse basis, corrects for switching effects. The second feedback loop corrects for regulation. It is a slow loop that takes the output at the output transformer and converts it from RMS to DC to modify the MDAC reference. Current feedback from the current sense transformer is used in another loop to effectively limit the output current. The output of this transformer is converted from RMS to DC and is used to modify the MDAC reference. Line drop compensation is achieved by boosting the output voltage with a portion of the DC as a function of load.

5.8 CURRENT LIMIT

There are two distinct current limits:

Slow Limit- The slow current limit uses the RMS/DC converter output of the output current sense transformer. When the DC exceeds a zener diode breakdown voltage (approximately 120% of nominal), the reference to the MDAC gets overridden and the output goes into constant current mode. The voltage decreases to force the unit to hold the current at 120% of nominal. When this happens, the CONSTANT CURRENT front panel LED indicator lights. The RMS/DC converter has a filter with an equivalent 200 millisecond delay. This means that as long as the RMS output current does not exceed 120% of nominal for more than 200 milliseconds, the output will not be affected. This allows the unit to drive capacitor input dc power supplies with continuous peak currents exceeding 300% of nominal, indefinitely.

Fast Limit- The fast current limit circuitry protects the unit and load from short circuits of greater than 500% of nominal current. The IGBT drivers have internal circuitry to sense desaturation of the IGBT. Desaturation is caused by excessive output current. The driver overcurrent commands are used to set a latch. This latch gets reset with the recycling of input power. The latch is used to inhibit the PWM to the IGBT drivers which immediately shuts off the output and lights the OVERLOAD LATCH front panel LED.

5.9 OVERTEMPERATURE

The unit contains an over temperature sensor that is located on the IGBT heatsink. If an excessive temperature is sensed, the sensor output which is ORed with the overcurrent latch signal, turns off the output until the temperature has decreased to an acceptable limit and lights the OVERTEMP front panel LED.

5.10 HOUSEKEEPING SUPPLIES

A 100 kHz switching power supply that runs off the +150 Vdc rail generates all the DC voltages needed to run the internal circuits.

APPENDIX A

IGBT DRIVER

The insulated gate bipolar transistor (IGBT) driver is a hybrid IC that is used in the overcurrent detector circuit of each BL1350 unit. Two of these drivers are used in each unit to provide signal isolation, overcurrent detection, and low-speed overcurrent cutoff features. Figure 1 shows the internal parts of an IGBT driver and its pin descriptions.

SIGNAL ISOLATION - A photocoupler with a high isolation voltage is used for signal isolation.

OVERCURRENT DETECTION - The IGBT driver can withstand an overcurrent of 10 μsec duration when short circuited. An extremely fast protection circuit is used here for this reason.

LOW-SPEED OVERCURRENT CUTOFF - A low-speed cutoff circuit slowly turns off the IGBT driver in response to an overcurrent sensing. This feature protects the driver against damage from high voltage spikes generated during normal drive speed cutoffs.

PIN	DESCRIPTION
1	Connected to smoothing capacitor for reverse bias power supply.
2	Power supply (+20 Vdc).
3	Drive output.
4	Not connected.
5	Overcurrent detection output.
6	Collector voltage monitoring.
7,8	Not connected.
9	Power supply (0 Vdc).
10-13	Not connected.
14	Drive signal input (-).
15	Drive signal input (+).

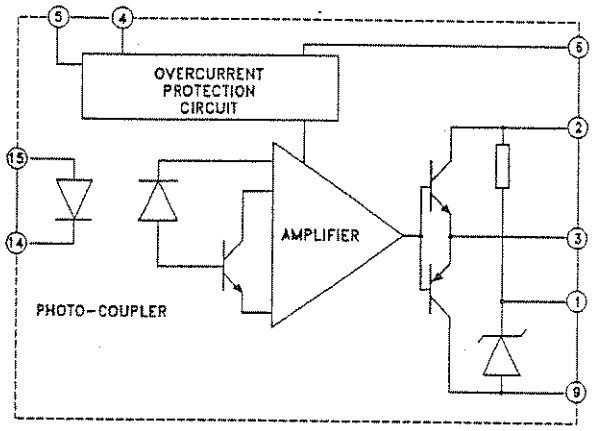


Figure 1. IGBT Driver, Pin Description and Schematic

APPENDIX B

BL SERIES AC POWER SUPPLY
IEEE-488 INTERFACE SPECIFICATIONS

1.1 IEEE-488 BUS UTILIZATION

The BL Series Power Supplies incorporates an embedded TMA that is compatible with the electrical and mechanical standards outlined in IEEE-STD-488. The IEEE-488 interface uses a TI LSI device to implement all necessary talker/listener functions. This device is configured under software control to support the following subsets:

SH1 - Source Handshake
AH1 - Acceptor Handshake
T8 - Basic Talker
L4 - Basic Listener
DC1 - Device Clear
RL0 - No Remote / Local Function
SR0 - No Service Request
PP0 - No Parallel poll response
DT0 - No Device Trigger
C0 - Not a controller

1.2 IEEE-488 BUS COMMANDS

1. Single-Line Commands

IFC - Clears GPIB interface

2. Multi-Line Command

DCL - Resets AC Power Supply to the quiescent state if a catastrophic failure is not present. The only way to clear a catastrophic failure is to read the Power Supply's response by using the Status command.

1.3 GPIB COMMUNICATION

The embedded TMA receives ASCII encoded command strings via a GPIB IEEE-488 according to MATE System Control Interface Standard No. 2806763 (IEEE-716 CIIL). Programmed I/O is utilized to transmit and receive command strings after a talker/listener relationship is established. The AC Power Supply supports all OPCODES, NOUNS, and MODIFIERS required by the stimulus module. They are as follows:

OPCODES
FNC, FTH, INX, :CH0, SET, SRX, SRN, CLS, OPN, RST, CNF, IST,
STA
MODIFIERS
FREQ, VOLT, CURR, VLT0, VLT1

NOUN
ACS

1.4 AC POWER SUPPLY SYNTAX

Setup Command:

FNC ACS :CHØ SET VOLT <value>

[SET FREQ <value>]
[SRX VOLT <value>]
[SRN VOLT <value>]
[SRX FREQ <value>]
[SRN FREQ <value>]
[SET VLT(Ø,1)] <cr><lf>

Table 1-1

CIIL SOFTWARE COMMANDS

CIIL COMMANDS	EXPLANATION
- All SET, SRX, SRN commands are part of the setup command above.	
SET VOLT <value>	Sets output voltage to given value,in volts rms. The following values are permitted: Ø ≤ value ≤ 135, or 27Ø, dependent on range selected and type of unit. If set volt (value) not received, then use SRN VOLT (value), or SRX VOLT (value). If none of these 3 are sent then generate error message.
SET FREQ <value>	Optional. Sets frequency of output voltage to given value, in Hz. The following values are permitted: 45 ≤ value ≤ 5ØØ. Default is 6Ø Hz only if SET FREQ, SRN FREQ, or SRX FREQ are not received. Otherwise the values shall be used in the order stated.
SRX VOLT <value>	Optional. Sets maximum limit for SET VOLT command. If SET VOLT value is greater than SRX VOLT value in a command string, an error message is generated and the setup command ignored. The following values are permitted: Ø < value ≤ 135, or 27Ø, dependent on range selected and type of unit. If a value for SRX VOLT is not specified, the required maximum value for SET VOLT default to 135, or 27Ø, dependant on range selected and type of unit.

Table 1-1
CIIL SOFTWARE COMMANDS (cont)

CIIL COMMANDS	EXPLANATION
SRN VOLT <value>	Optional. Sets minimum value limit for SET VOLT command. If SET VOLT value is less than SRN VOLT value in a command string, an error message is generated and a setup command ignored. The following values are permitted: 0 ≤ value < 135, or 270, dependent on range selected and type of unit. The SET VOLT default is 0 for the minimum value if a value is not specified for SRN VOLT.
SRX FREQ <value>	Optional. Sets maximum limit for SET FREQ command. If the SET FREQ value in a command string is grater than the maximum limit, an error message is generated and the setup command ignored. Legal values are: 45 < value ≤ 500. If a value for SRX FREQ is not specified, SRX FREQ defaults to 500.
SRN FREQ <value>	Optional. Assigns minimum value to SET FREQ command. If the SET FREQ value in a command string is less than the minimum limit, an error message is generated and the setup command ignored. Legal values are: 45 ≤ value < 500. If a value for SRN FREQ is not specified, SRN FREQ defaults to 45.
SET VLT0	Set LO voltage range.
SET VLT1	Set HI voltage range.

Delay is necessary after issuing setup command, due to output voltage slew rate of 100v per 250 ms.

On dual range Power Supplies, this command selects the LO or HI voltage range. Dual Ranges are 0-135 volts and 0-135/0-270 volt. If this command is omitted from the setup string the unit will default to the lowest available range. On single range units this command will be ignored.

NOTE

1. The setup command specifies the voltage and frequency of the AC power Supply output. The AC Power Supply responds only to the last setup command entry. Its memory does not retain previously entered setup commands.

2. During IEEE operation, the unit's front panel VOLTS and FREQ controls must be fully CCW. If the controls are not set fully CCW, then the output voltage and frequency will be a sum of the programmed value and the value set with the front controls.
Front Panel OUTPUT switch must be set to OFF position.
Front Panel RANGE switch (on dual range units) must be set to LO.

Table 1-1
CILL SOFTWARE COMMANDS (cont)

CILL COMMANDS	EXPLANATION
FTH VOLT <cr><lf>	The AC supply responds to this command by transmitting the RMS voltage (in volts resolute to 0.1V) measured at its output, in decimal format as follows: <sp><digit><digit><digit><dp><digit><cr><lf>
FTH CURR <cr><lf>	The AC Supply responds by transmitting the current (in amps resolute to 0.1A) measured at its output, in decimal format, as follows: <sp><digit><digit><dp><digit><cr><lf>
FTH FREQ <cr><lf>	The AC Supply response by transmitting the frequency (in hertz) measured at its output, in decimal format, as follows: <sp><digit><digit><digit><cr><lf>
CLS :CHØ <cr><lf>	Closes output relay contacts. Connects AC Power Supply outputs to output terminal block. The setup command specifies the voltage and frequency. The setup command must be entered before the CLS :CHØ command.
OPN :CHØ <cr><lf>	Opens output relay contacts. Disconnects output of AC Power Supply from output connector. AC Power Supply retains voltage and frequency assigned by setup command.
RST ACS :CHØ	Resets AC Power Supply to quiescent. The output relay opens and error messages are erased. Catastrophic error messages are cleared by reading the Power Supply's response, by use of the Status command.
CNF <cr><lf>	Instructs AC Power Supply to perform internal confidence test. STA command transmits the message. The AC Power Supply responds with one of the following: Pass <sp><cr><lf> Fail FØ7ACSØ(DEV): CONFIDENCE TEST FAILURE <cr><lf>

Table 1-1
CILL SOFTWARE COMMANDS (cont)

CILL COMMANDS	EXPLANATION
IST <cr><lf>	Instructs AC Power Supply to perform internal self test. The STA command transmits the message. The AC Power Supply responds with one of the following: Pass <sp><cr><lf> Fail F07ACS0(DEV): BIT TEST FAILURE -PROM CHECKSUM FAULT -RAM FAULT -AC SUPPLY HARD FAULT <cr><lf>
STA <cr><lf>	Status. Prepares AC Power Supply for a response transmission. Clears error condition if one exists. The following response messages and conditions exclude confidence and internal self <sp><cr><lf> Device error messages F07ACS0(DEV):BIT TEST FAILURE <description consisting of up to 60 characters>< cr><lf> TMA error messages All begin with: F07ACS0 (MOD): This message is followed by one explanatory message from the following text: ILLEGAL NOUN AC Power Supply does not recognize illegal noun. ILLEGAL NOUN MODIFIER AC Power Supply does not recognize illegal noun modifier. ILLEGAL OPCODE AC Power Supply does not recognize illegal opcode. ILLEGAL VALUE Entered value lies outside upper and lower limits. NO SETUP Close command received but setup not programmed.

Example: F07ACS00(MOD): NO SETUP <cr><lf>

1.5 CATASTROPHIC ERRORS

A catastrophic failure is generated each time the AC Power Supply experiences a hardware failure. Errors are cleared whenever the AC Power Supply transmits a response, except in the case of a short circuit fault which may only be cleared by cycling power to the AC Supply.

Catastrophic Error Messages
All begin with:

F00ACS0(DEV):

This message is followed by one explanatory message from the following text:

OVERTEMP FAULT <cr><lf>

The heatsink temperature has exceeded its upper limit. The OVERTEMP LED on the front panel will light.

CURRENT LIMIT FAULT <cr><lf>

SHORT CIRCUIT FAULT: AC SUPPLY<cr><lf>

An output loading fault has occured causing the supply to exceed 500% rated current output. The supply automatically shuts down and opens its output relay. The OVERLOAD LATCH LED on the front panel will light.

1.6 ADDRESS SELECTION

The GPIB Address for the BL Series Power Supplies is configured via the dipswitch located on the rear panel. The dipswitch represents the address in binary format. Valid GPIB Address settings are from 0 to 30. Switch 1 is the LSB, switch 5 is the MSB. Each individual switch bit is set ('1') when in the 'OFF' position and reset ('0') when in the 'ON' position.

Example - Address 1

ON
OFF

1 2 3 4 5

Dipswitch Element	Equivalent Binary Value
1	1
2	2
3	4
4	8
5	16

THEORY OF OPERATION FOR GPIB \ RS232 INTERFACE

(refer to dwg # 106-945-000)

All BL series power supplies including the "I" option contain an additional circuit card providing a computer interface. This interface may be one of two standards, IEEE 488 or RS232. This card controls the supply output voltage, frequency , and range as well as providing data back to the controlling computer. Operation of the interface card is described in the following section.

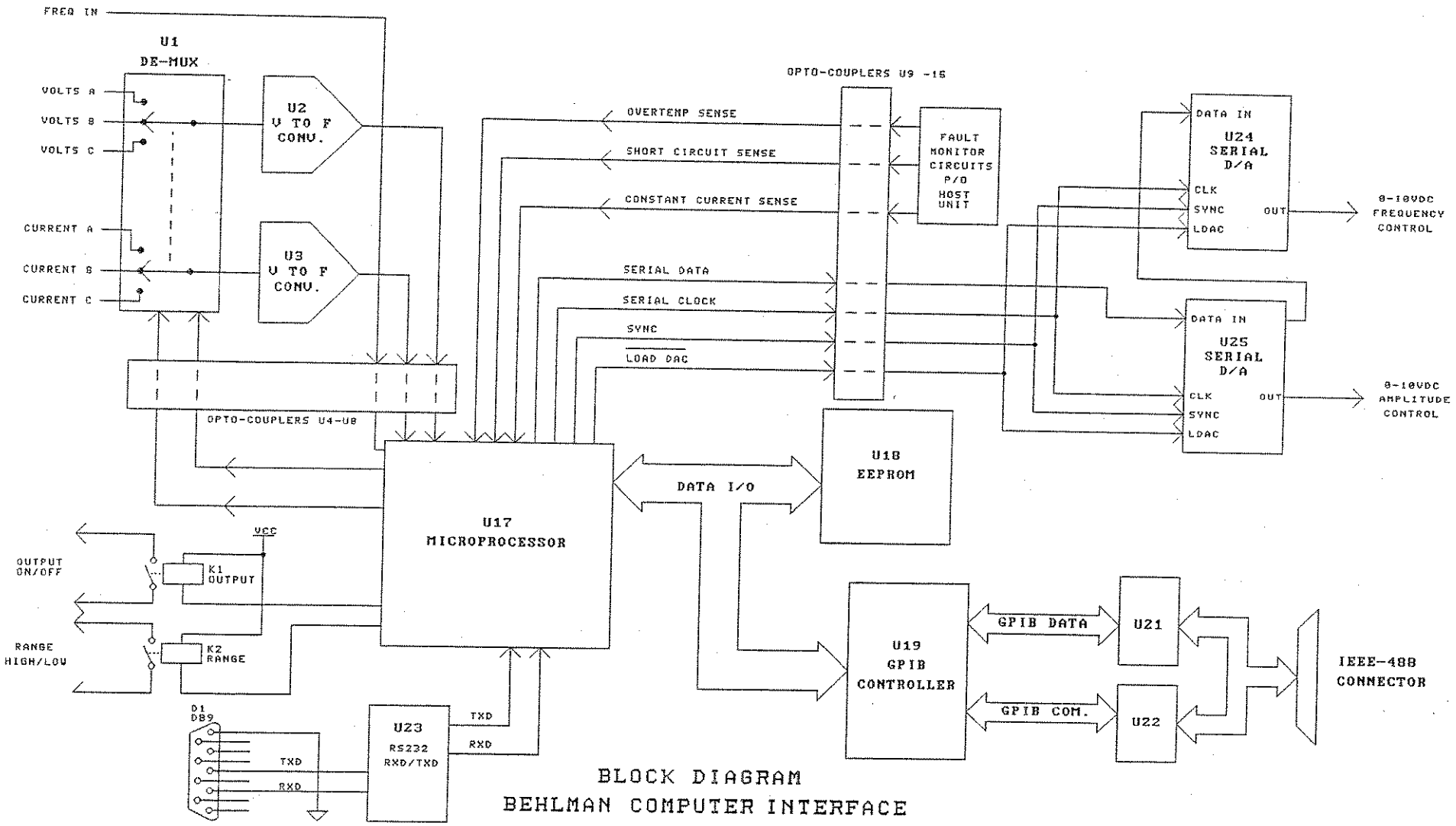
The heart of the interface card is the 80C196 micro processor U17. This device used in conjunction with a programmable memory/logic device U18, provides all the required communication functions. RS232 communications are handled directly by U17 while IEEE 488 proto call is handled by buss controller U19. U19 is an industry standard TMS 9914. Data stored in the U18 EEPROM determines which communication proto call is selected. EEPROM data also determines scale factor and other set up parameters which are determined by the actual model and size of the unit being controlled.

Programmed output voltage and frequency data is applied to serial D/A convertors. These convertors provide a 0 to 10Vdc output that is applied to the analog remote inputs of the host unit. Control of these parameters is as described in the theory of operation for the power source.

Read back of output current and voltage is obtained by monitoring the internal circuits of the power source. These dc signals are selected via U1 a two channel "one of four" demultiplexor. Note that the actual number of channels and inputs used depends on the model of the power source. Again , this is determined by the EEPROM data . The outputs of U1 are applied to a set of voltage to frequency convertors. The output of these convertors range from 100 hertz to 200 hertz . These frequencies are measured by the microprocessor and scaled to provide the proper current and voltage data to the controlling computer. The output frequency of the power supply is measured by monitoring its internal clock signal via U4. This input is labeled "Hz-FDBK".

Control of the output on/off relay and range relay is provided via the interface board via dry contacts from K1 and K2. These small PCB mounted relays are controlled by U18. All signals coming to and exiting from the interface board and the power source are optically isolated. This adds a measure of safety and prevents ground loops between the controlling computer and power source circuitry.

All firmware for the interface card is written in INTEL's PL/M format. A list of supported commands and syntax is provide in appendix B of this manual.



BLOCK DIAGRAM
BEHLMAN COMPUTER INTERFACE
IEEE-488/RS232