CENTRILIFT
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SECTION 1

GENERAL

1.1 INTRODUCTION

This manual contains installation, operation, and troubleshooting procedures for the Electrospeed Variable Speed Controller Integrated Control System.

It describes the assembly and installation procedures for the basic controller, plus installed options. Product specifications, safety procedures, spare parts list, theory of operation, and user set up and operational procedures.

Note: The entire manual should be read and understood before performing an installation or start up.

1.2 GENERAL

The Electrospeed Integrated Control System is available in two types of enclosures; weatherproof (NEMA 3, IP54) and general purpose (NEMA 1, IP20). Each of the two types are offered in two enclosure sizes referred to as "2000" and "4000" series. The weatherproof units use a patented cooling system that eliminates the inefficiencies and reliability problems associated with heat pumps.

The Electrospeed ICS is classified as a variable voltage inverter (VVI). It uses a six pulse silicon controlled rectifier converting AC power into variable DC power. A series inductor, and capacitors across the DC bus are used to filter the AC ripple. The inverter uses six power electronic switches to synthesize a 3-phase quasi-sinusoidal output voltage (six-step).

A unique feature of the Electrospeed ICS is that it uses Darlington bipolar transistors for the inverter. Transistors provide increased reliability over SCR's in this type of application. The inverter transistors switch at zero current in the VVI design, providing higher efficiencies and better reliability than can be achieved with PWM inverters.

This modern AC variable voltage inverter is designed to meet all the requirements of installation requiring a variable frequency source. It operates directly from 460/380 volt, 3-phase, 50/60 Hertz power. Use of the latest micro-processor technology allows for ease of set up, operation and diagnostics, reducing the need of multitude of circuit boards of other similar machines, high reliability and versatility. Operator interface provides ease of programming negating the required pre-programmed E-Proms for special applications. The ICS is programmable for many types of loads, such as variable torque, constant torque, and constant voltage with extended speed range.

1.3 COMPONENT DESCRIPTION

The converter and inverter each have a separate control board which in turn is controlled by the Digital Control Board (DCB). Interconnections of the converter and inverter sections to the DCB are via mass terminated cable assemblies.

1.3.1 Digital Control Board

The Digital Control Board (DCB) uses a state-of-the-art high speed 16 bit microcontroller to provide digital outputs for the control of the input SCR's and the output transistors. DC bus voltage and the three phase output currents are fed back into the DCB for system regulation. The DCB is mounted to the back of the enclosure door.

1.3.2 Converter Control Board

The Converter Control Board (CCB) is located over the converter. The CCB receives six digital signals from the Digital Control Board, which are conditioned and transformer coupled to the SCR gates. Snubbers are installed on the CCB to prevent misfiring of the SCR's from transients. An auxiliary Converter Control Board is used on the 4000 series to provide a second set of gate signal outputs to drive parallel SCR's.

1.3.3 Inverter Control Board

The Inverter Control Board (ICB) is located over the inverter. The ICB receives six digital signals from the Digital Control Board. The signals are optically coupled for isolation, and then conditioned to provide base current to the inverter transistors. The ICB contains circuitry to protect the transistors in the event of an over-current condition. The three phase output currents are detected with current transformers then routed to the Digital Control Board.

1.3.4 Operator Interface

The Operator Interface is mounted on the front of the controller behind a lockable door, and is connected directly to the Digital Control Board. The Operator Interface consists of the Operator Interface Board (OIB) with a membrane type key pad and a 16 character alpha-numeric display. The OIB uses an eight bit microcontroller to service the key pad and display. All setup parameters are all entered from the key pad.

1.3.5 Door Interface Board

The Door Interface Board (DIB) mounts inside on the door just above the Digital Control Board, and connects to the Operator Interface Board. The DIB provides inputs and outputs for all optional door mounted controls (i.e. run light, start push-button, speed pot, etc.). The digital outputs on the DIB are suitable for driving relays to provide contact closure outputs for external indicators.

1.3.6 System Power Supply

Power to operate the Integrated Controls is supplied from the Power Supply. This consists of two transformers and the Power Supply Board (PSB). Both transformers are ferro-resonant to provide stable regulated voltages over a wide input voltage range. The VSC supply voltage is connected to the PSB through a two winding inductor which attenuates common mode inputs, i.e. transients from lightning or switching. Two metal oxide varistors, connected phase-to-ground, are used to further protect the control system and cooling fan motors from transients. The control circuit input fuses, along with output fuses for each supply is located on the PSB.

1.3.7 Customer Interface Board - Optional

The Customer Interface Board (CIB) is an option. The CIB mounts on the Option Panel located inside the VSC on the left wall of the enclosure. The CIB provides terminals for all optional remote inputs and outputs and connects to the Door Interface Board via a mass terminated cable assembly.

1.3.8 PHD Interface Board - Optional

The PHD interface board is optional. The PHD interface board is used in conjunction with the PHD Inductor Package to obtain down hole pressure measurements from Centrilift Submersible Pumps equipped with the PHD option. The PHD board mounts to the Door Interface Board, and connects between the Operator Interface Board and the Door Interface Board.

1.3.9 Analog Input Board - Optional

The Analog Input Board is optional. The Analog Input Board is provided as a low cost alternative to the Customer Interface Board when only analog inputs are required. The Analog Input Board mounts to the Door Interface Board, and connects between the Operator Interface Board and the Door Interface Board.

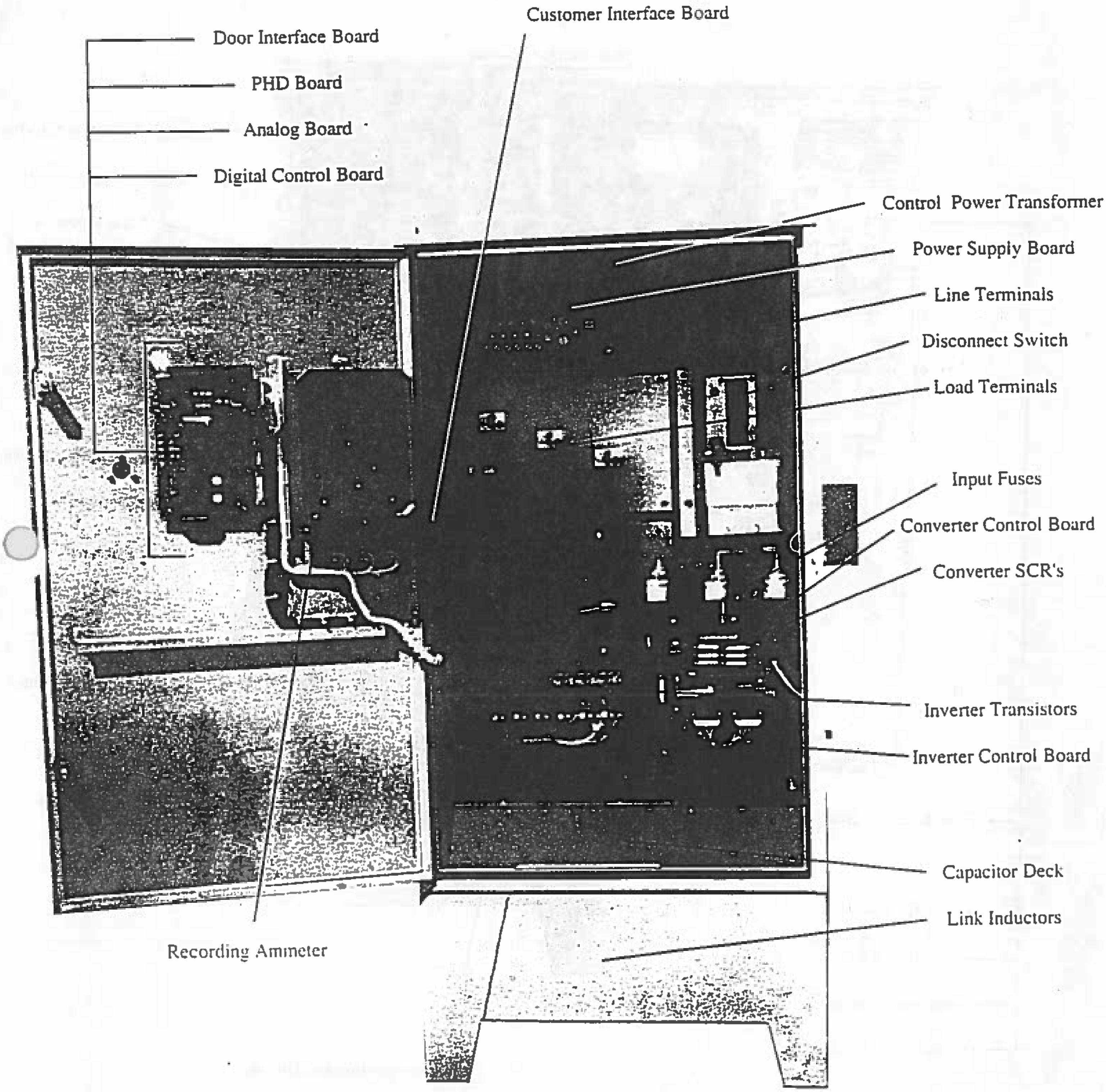


Figure 1.1 Major Components, NEMA 3, 4000 Series

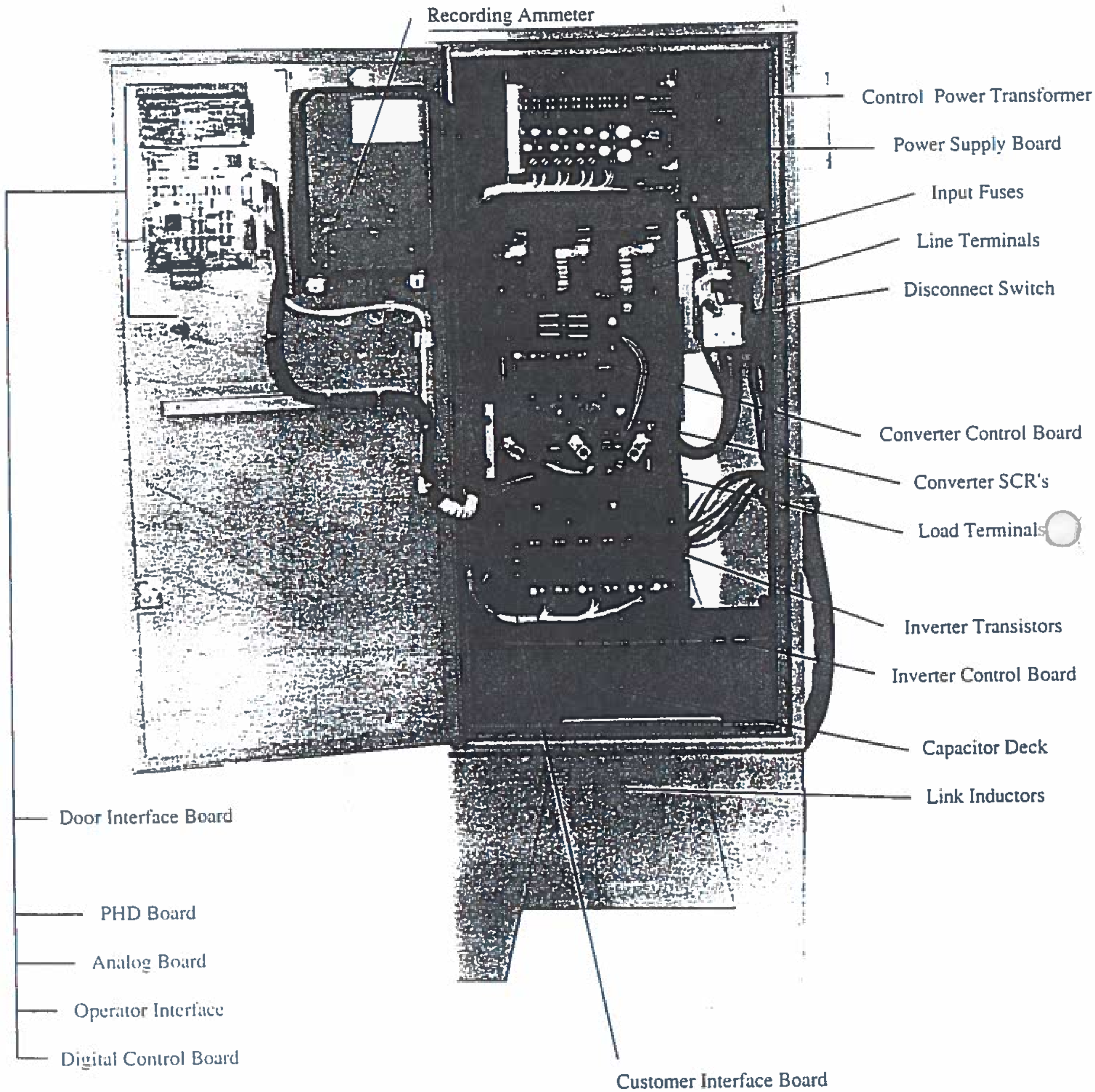


Figure 1.2 Major Components, NEMA 3, 2000 Series

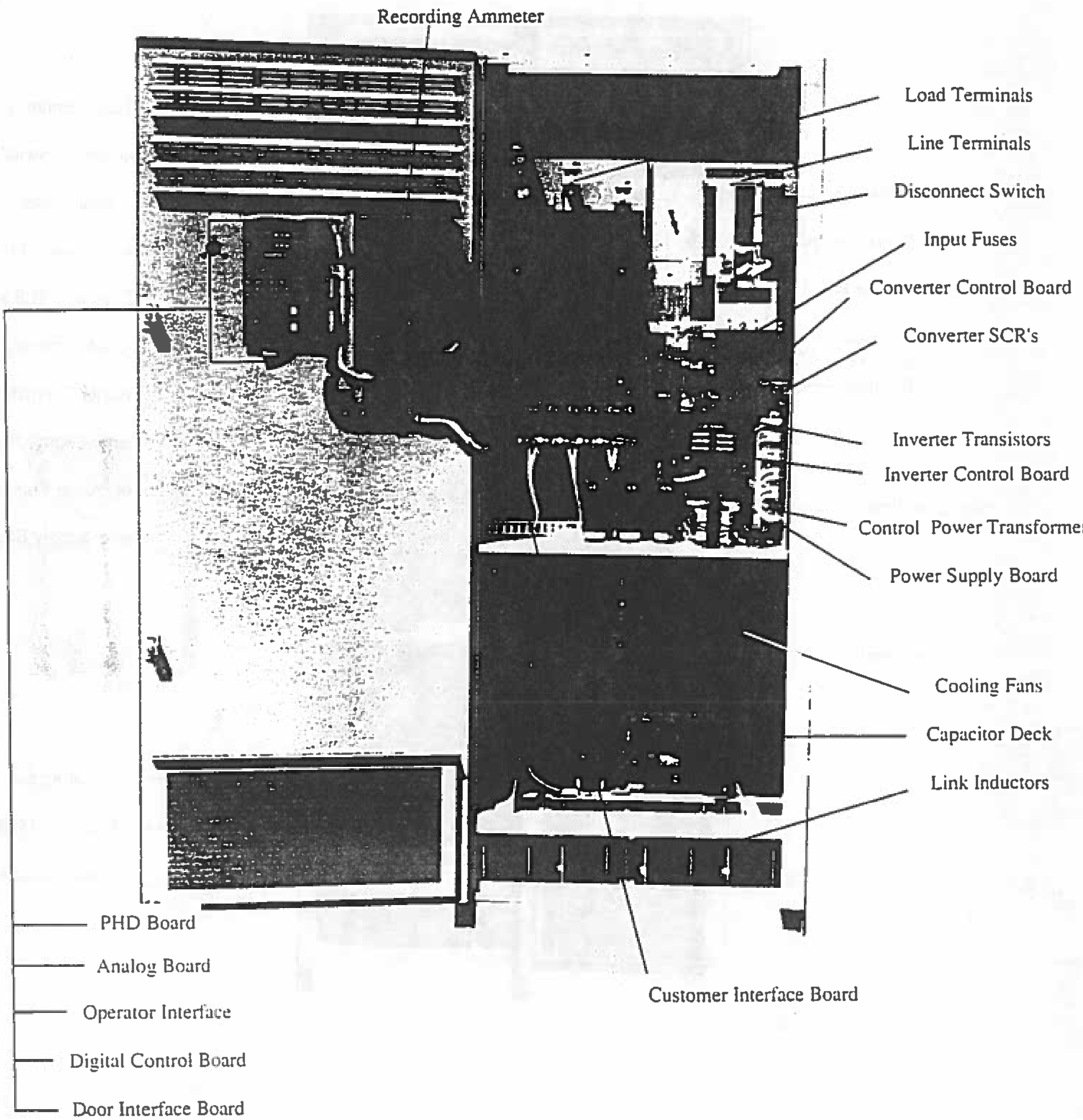


Figure 1.3 Major Components, NEMA 1, 4000 Series

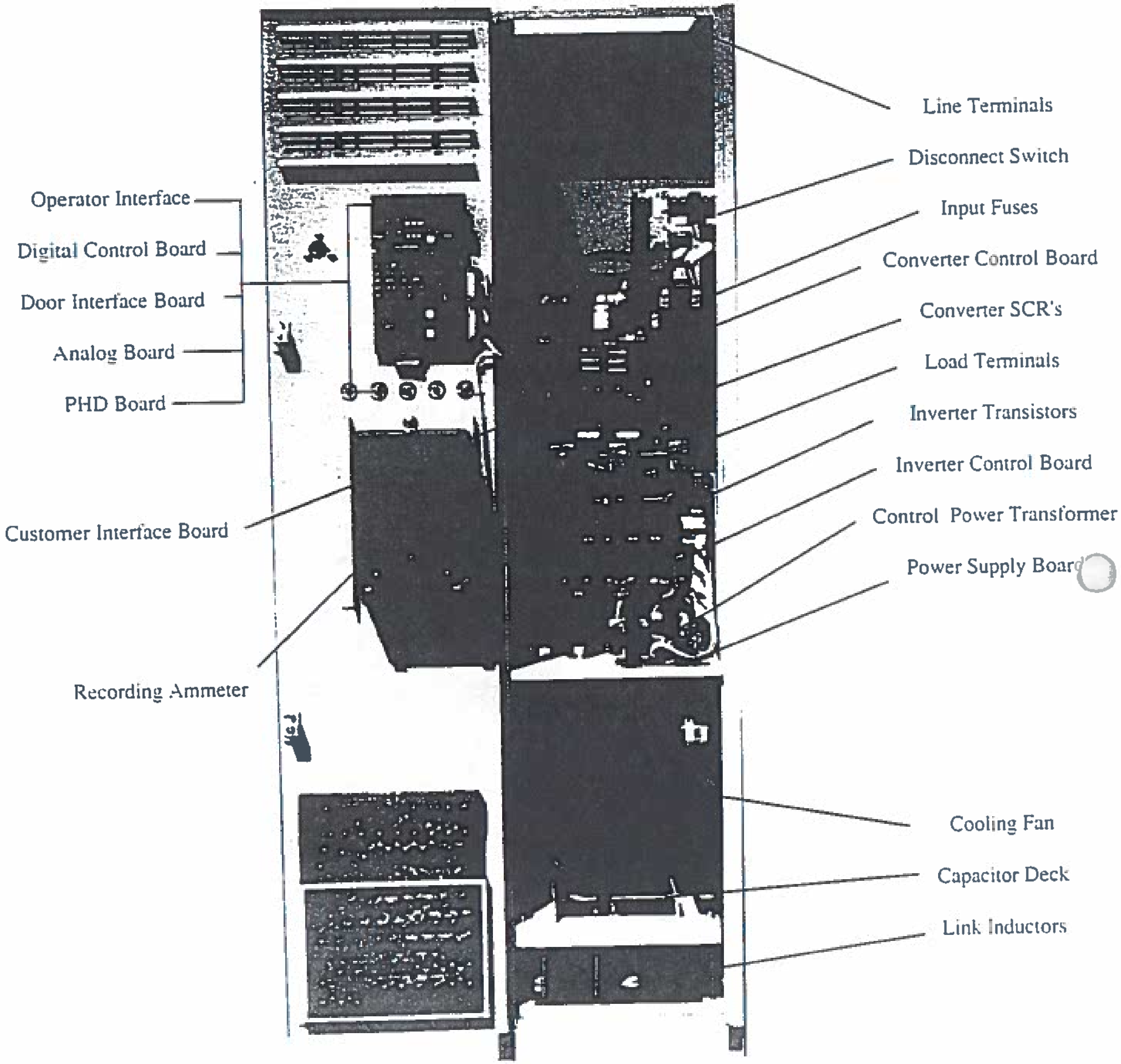


Figure 1.4 Major Components, NEMA 1, 2000 Series

SECTION 2

SPECIFICATIONS & RATINGS

2.1 SPECIFICATIONS

Output Frequency:	10 to 120 Hz. at 480V AC
Output Voltage at 60 Hz.:	40 to 480V AC
Start Frequency:	3 to 20 Hz.
Sync Delay Time:	0 to 60 sec.
High Speed Clamp:	40 to 120 Hz.
Frequency Stability	± .1 Hz.
Volts/Hertz:	.7 - 10 Volts
Low Speed Clamp:	5 to 90 Hz.
Voltage Boost:	0 to 200V AC
Voltage Boost Sync:	0 to 200V AC
Instantaneous Over Current (IOT):	170% of Full Load Rating
Current Limit:	0 to 150% of VSC Rating
Current Limit Sync:	
Variable torque:	0 to 150% of VSC Rating
Constant torque:	0 to 200% of VSC Rating
Voltage Clamp:	240 to 550V AC
Accel Time:	3 to 200 Sec.
Decel Time:	3 to 200 Sec.
Slip Compensation:	0 to 7.5%
Contol Power:	24V DC
Efficiency:	> 98% at Rated Load
Power Factor:	.96 at Full Speed

2.2 RATINGS

Input Voltage:	
(Standard):	460V AC ± 10%, 60 Hz
(Optional):	460V AC ± 10%, 50Hz
(Optional):	380V AC ± 10%, 50Hz
Trips:	300V AC
Frequency:	± 2 Hz
Input Current:	See Table 2.1
Output Ratings:	See Table 2.1
Operating Temperature:	
NEMA 1 (IP 20):	0 to 40° C (32 to 104° F)
NEMA 3 (IP 54):	0 to 50° C (32 to 122° F)
w/Heater:	-40 to 50° C (-40 to 122° F)
Storage Temperature:	-50 to 70° C (-58 to 158° F)
Humidity:	
NEMA 1 (IP 20):	95% Non-Condensing
NEMA 3 (IP 54):	Suitable for use outdoors in all climatic conditions.
Elevation:	To 5000 Ft. without derating.

OUTPUT RATINGS (AT 480V AC)					INPUT RATINGS (AMPS) @ 460V AC	
MODEL*	KVA	Cont. Current RMS Amps	Overload Current 60 Sec.	Start Current 7 Sec.	FUSE RATING	INPUT CURRENT
2060-VT	66	79	95	119	100	80
2075-VT	83	100	120	150	200	111
2100-VT	111	133	160	200	200	135
2125-VT	130	156	187	250	200	160
2150-VT	163	196	235	314	300	200
2200-VT	200	241	281	375	300	245
2250-VT	260	313	376	501	400	315
4300-VT	325	391	469	626	500	400
4350-VT	390	469	563	750	600	470
4400-VT	454	546	656	875	700	550
4500-VT	518	624	750	1000	800	625
8600-VT	700	842	1011	1348	**	852
8700-VT	815	983	1181	1574	**	995
8800-VT	932	1123	1349	1798	**	1136

TABLE 2.1 VARIABLE TORQUE VSC RATINGS

*When applying variable speed controllers to constant torque loads, the continuous output current and output KVA are derated by 20%. The overload and start currents remain the same. The model number listed does not include the enclosure identifier (i.e. 2200-1VT or 2200-3VT) or the ICS suffix distinguishing the ICS controllers from previous Electrospeed controllers. (** Drives are two units operated in parallel.)

2.3 FEATURES

2.3.1 Standard Features

Input Disconnect Switch

Current Limiting Fuses (200,000A RMS Sym.)

General Purpose or Weatherproof Enclosure

Option Panel for factory or customer installed options

Isolated 24V DC (.75 amp) supply for customer options

120 VAC @ 3 amp (for muffin fans and 120 volt options)

LED Indicators

Digital Control Board
+15V, -15V, +5V
Communication Error

Inverter Control Board
+15V, -15V, +5V
+7V & -7V for each of 6 Inverter circuits (12 LED's)

1 Signal for each of 6 Inverter circuits (6 LED's)
1 IOT for each of 6 Inverter circuits (6 LED's)

Converter Control Board
- +24V, -24V, +8V, +15V, -15V, +5V
- 1 Signal for each of 6 Converter SCR's (6 LED's)
- Over-Temperature

Operator Interface Mounted on Front Panel Consisting of:
- 16 Character Alphanumeric Display which displays:
  - Set up parameters
  - VSC status
  - Three Phase Output Current (True RMS)
  - Output Voltage
  - Output Frequency
  - Faults and Fault History for Diagnostics
  - External Analog Inputs
- Led Indicators displaying:
  - Power On
  - Run
  - Fault
  - Underload
  - Overload
- Control Keys for:
  - START
  - OFF
  - MODE 1
  - MODE 2
- Basic Setup Parameter Input Keys for:
  - DRIVE MODEL/OVERLOAD PARAMETERS
  - VOLTS AT 60 Hz/START FREQUENCY
  - SYNC DELAY/HIGH SPEED CLAMP
  - LOW SPEED CLAMP/V BOOST
  - I LIMIT/I LIMIT SYNC
  - V BOOST SYNC/V CLAMP
  - ACCEL TIME/DECEL TIME
  - REGULATOR GAIN/SLIP COMP
- Control Setup Parameter Input Keys for:
  - FAULT RESTART PARAMETERS
  - UNDERLOAD PARAMETERS
  - SET FREQUENCY
  - CONTROLLER SETPOINT/JOG FREQUENCY
  - ANALOG CONTROL SETUP
  - FREQUENCY AVOIDANCE/OUTPUT ROTATION
- Display Keys for:
  - CLOCK/DRIVE HISTORY
  - DISPLAY OUTPUT AMPS/VOLTS
  - DISPLAY ANALOG INPUTS
  - DISPLAY STATUS
- Miscellaneous Keys:
  - "Up Arrow" for incrementing input parameter
  - "Down Arrow" for decrementing input parameter
  - ENTER for entering changed parameter

Door Interface Board--Provides inputs/outputs for the following door mounted controls. All door mounted controls are separate options.

Indicator Lights
- Run
- Underload
- Overload
- Overtemperature
- Wrong Voltage
- At Set Frequency
- I-O-T (Instantaneous Overcurrent Trip)

Selector Switches
- Local/Remote
- Hand-Off-Auto
- Forward/Reverse
- Analog Select

Push-button Switches
- Start
- Stop
- Emergency Stop
- Jog

Meters (Analog)
- Output Current (Three Phase Switch Optional)
- Output Voltage
- Output Frequency

Speed Pot

2.3.2 Optional Features

Door Mounted Options

Indicator Lights
- Run
- Underload
- Overload
- Overtemperature
- Wrong Voltage
- At Set Frequency
- I-O-T (Instantaneous Overcurrent Trip)

Selector Switches
- Local/Remote
- Hand-Off-Auto
- Forward/Reverse
- Analog Select

Pushbutton Switches
- Start
- Stop
- Emergency Stop/Auxiliary Stop
- Jog

Meters (Analog)
- Output Current (Three Phase Switch Optional)
- Output Voltage
- Output Frequency

Speed Pot

Control Power Transformer (115 vac, 3 Amp)

Customer Interface Board--Provides terminals for the following remote inputs and outputs.

Relay Outputs (more than 3 requires Aux. Relay Board)
- Run
- Underload
- Overload
- Overtemperature
- Wrong Voltage
- At Set Frequency
- I-O-T (Instantaneous Overcurrent Trip)
- Fault
- Auxiliary Input A

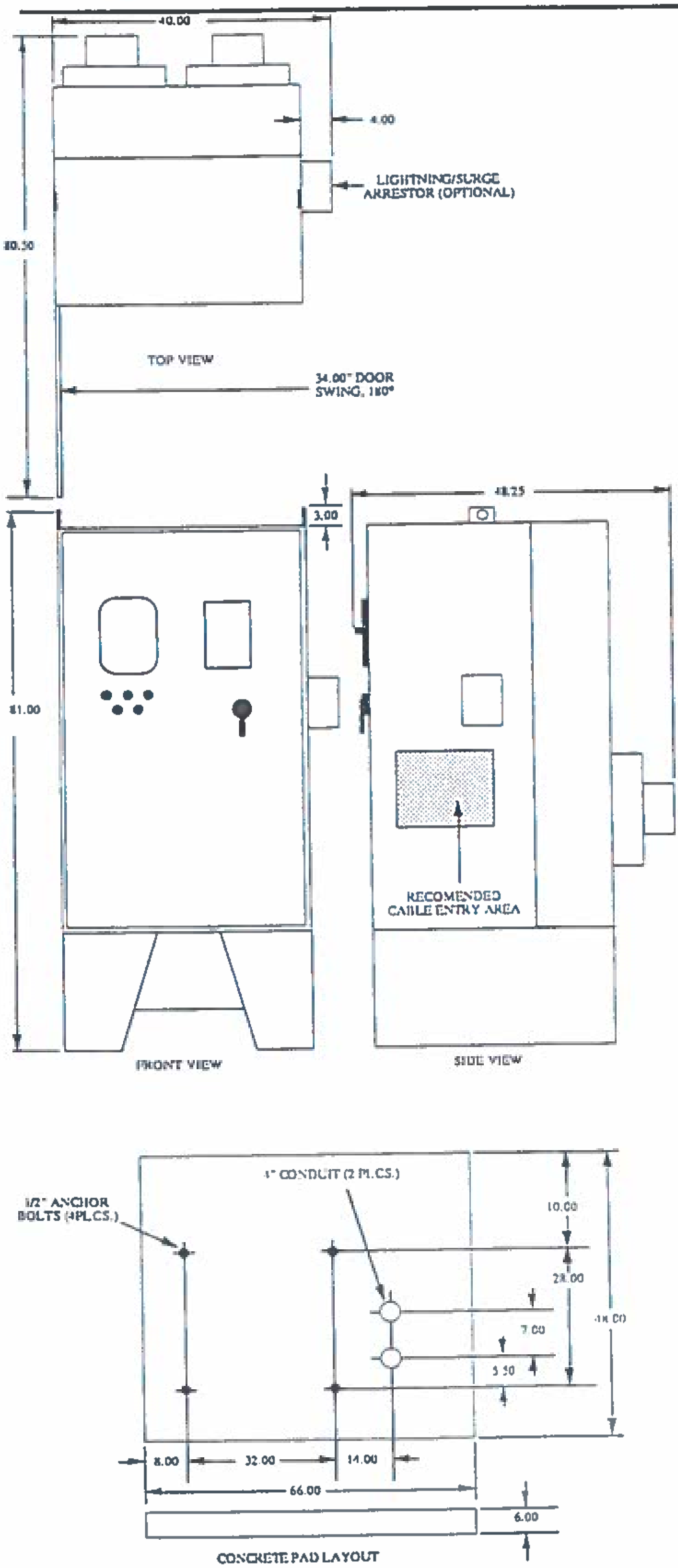
Digital Inputs (Dry contact to ground)
- Start
- Stop
- Emergency Stop/Auxiliary Stop
- Forward/Reverse
- Jog
- Analog Select

Analog Outputs (programable 0-10V or 0-1ma for meter)
- Three Phase Output Currents
- Output Voltage
- Frequency (0-75 Hz. or 0-150 Hz.)

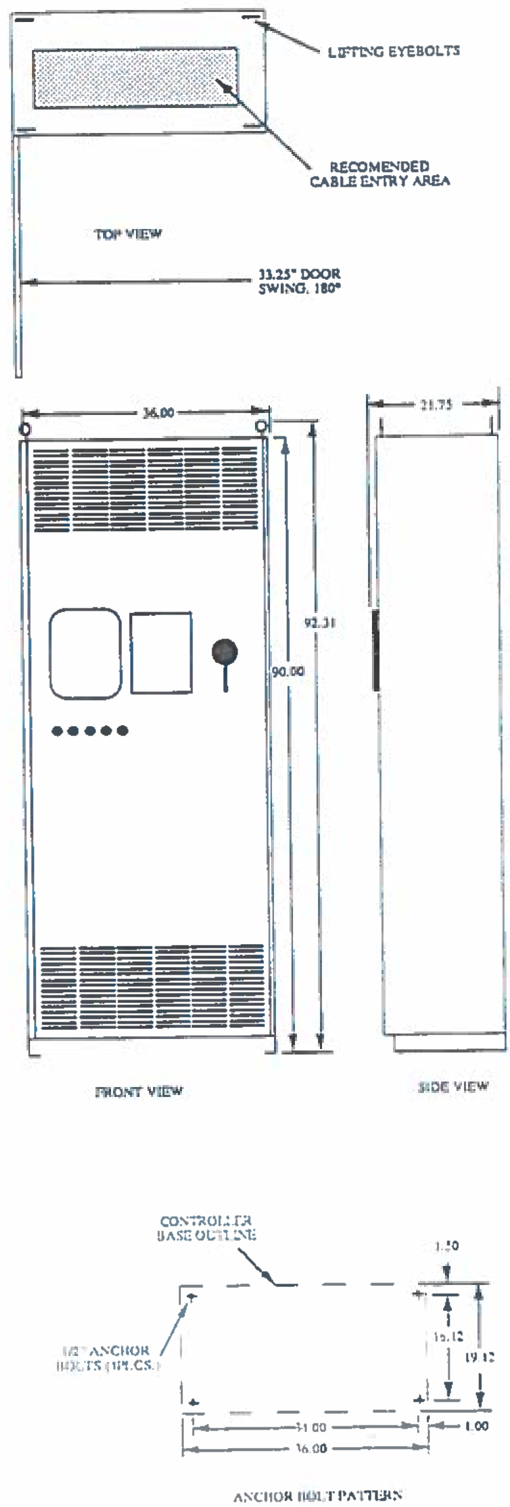
Analog Inputs (programable 0-5V, 0-10V, 4-20ma, 10-50ma)
- Analog A
- Analog B

Analog Input Board

PHD Board

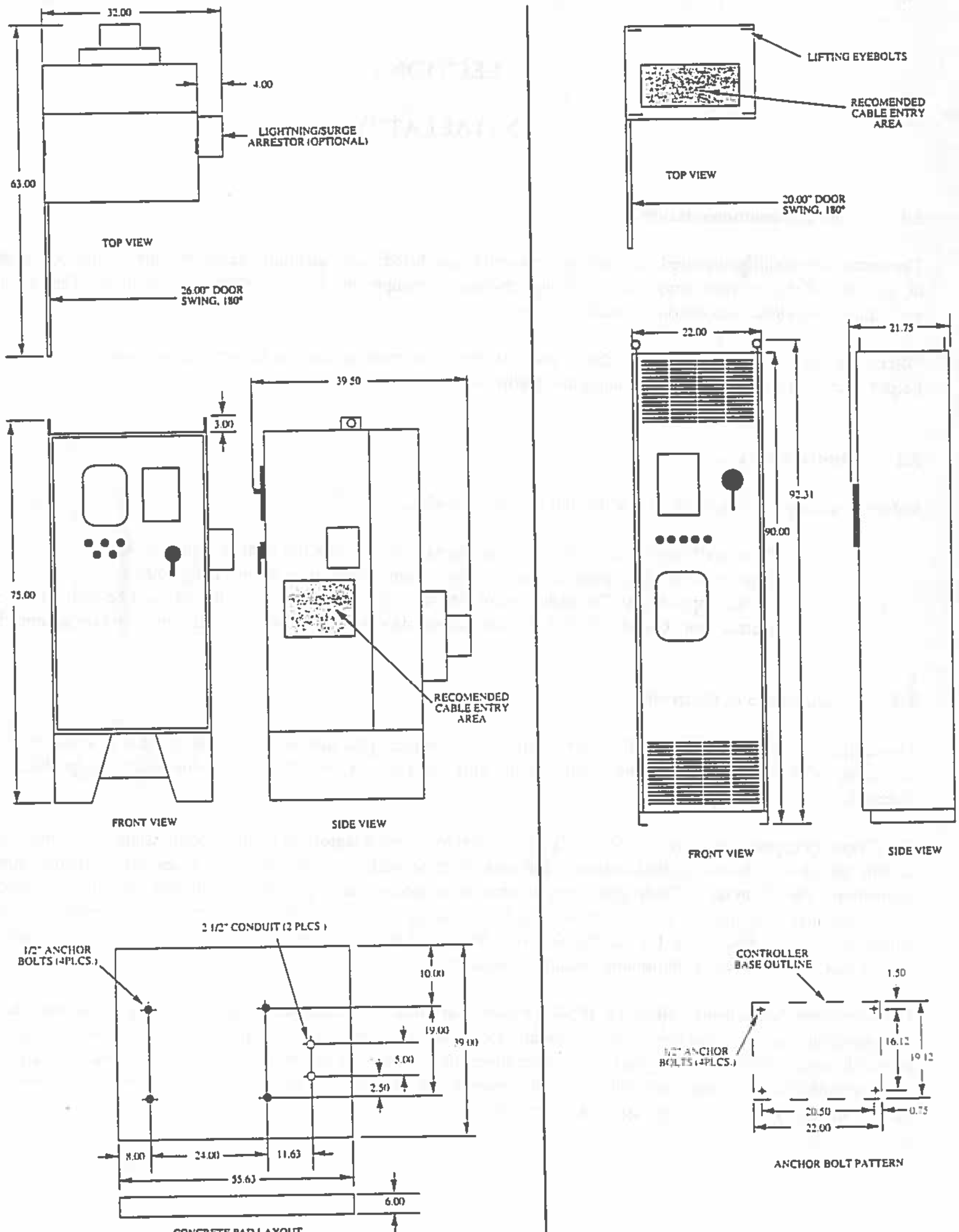


NEMA 3



NEMA 1

Figure 2.1 Overall Demension (inches) 4000 Series



NEMA 3

NEMA 1

Figure 2.2 Overall (inches) Dimension 2000 Series

SECTION 3

INSTALLATION

3.1 Safety Recommendation

The controller should be installed, adjusted and serviced by qualified electrical maintenance personnel. Improper installation or operation of the controller may cause injury to personnel or equipment. The controller must be installed and grounded in accordance with local and national electrical codes.

Potentially lethal voltages exist within the cabinet. Extreme care must be taken to insure all power sources are disconnected before starting installation or maintenance and repair jobs.

3.2 Initial Checks.

Before installing the controller, check the unit for the following:

* Physical damage to controller. Visual damage to the shipping container or cabinet.
* Remove all packing materials such as tape, foam, shipping restraints, and padding.
* Correct application. The controller nameplate data, transformers, and load must be compatible.
* Internal connections. Insure that all circuit boards, cables, components, and connectors are securely in place.

3.3 Installation of Controller.

The cabinets are specially designed for safe handling using a spreader bar placed through the lifting lugs at the top of the unit. Lift capacity should be checked prior to moving the unit into place. Check Section 2.4 for weight of specific unit being installed.

The General Purpose enclosure (NEMA 1, IP20) is suitable for most factory or control room installations, however, care should be taken in choosing the location. The area must be well ventilated to allow unrestricted air flow through the controllers filtered intake. Cooling air entry and exit is located on the front of the controller, therefore, no side, back, or top clearance is required. A minimum of 36 in. (1 m) clearance in front of the enclosure is recommended for servicing, which is more than adequate for cooling air flow. Areas with oil vapors or mists, excessive moisture, or with fumes or vapors that are corrosive or flammable should be avoided.

The Weatherproof enclosure (NEMA 3, IP54) is suitable for outdoor installations in non-hazardous locations. In extreme high ambient temperatures a sun shade is recommended. Allow a minimum of 36 in. (1 m) clearance in the front and the rear of the enclosure for servicing and air flow requirements. Never install the controller close to heat generating sources, such as transformers or other controllers. It is necessary to have an unrestricted supply of cooling air (50° C maximum) to the cooling fan(s) mounted to the back of the enclosure.

3.4 POWER WIRING

Cable entry is through the top on the general purpose enclosure and through the right side on the weatherproof enclosure. Refer to figures 2.1 or 2.2 for recommended conduit locations. Table 3.1 below lists recommended cable sizes, based on 40° C ambient temperature, and minimum cable temperature rating of 75° C. To find the recommended cable size, first obtain the controller fuse size from table 2.1. These are recommendations only. Power wiring must be sized to meet local and national electrical codes, based on maximum ambient temperatures. For sizing power wiring refer to table 2.1 for actual current ratings. Connect cable to terminals of the input disconnect switch. This controller is not phase sensitive to input power.

FUSE SIZE (AMPS)	CABLE SIZES PER PHASE	LUG SIZE (per phase)	
		INPUT	OUTPUT
100	# 2 AWG	1ea. 14-1/0	1ea. 6-250 MCM
200	# 3/0 AWG	1ea. 4-300 MCM	1ea. 6-250 MCM
300	2-2/0 AWG	1ea. 4-250 MCM & 1ea. 2/0-500 MCM	2ea. 6-250 MCM
400	2-4/0 AWG	1ea. 4-250 MCM & 1ea. 2/0-500 MCM	2ea. 6-250 MCM
500	2-300 MCM	3ea. 250-500 MCM	3ea. 3/0-400 MCM
600	2-400 MCM	3ea. 250-500 MCM	3ea. 3/0-400 MCM
700	3-350 MCM	3ea. 250-500 MCM	3ea. 3/0-400 MCM
800	3-400 MCM	3ea. 250-500 MCM	3ea. 3/0-400 MCM

TABLE 3.1 CONTROLLER RECOMMENDED CABLE

3.5 Customer Interface Wiring

Remote control inputs and outputs wire to the Customer Interface Panel (refer to figure 3.1). Care should be taken to insure the Customer Interface Board is installed properly and all program header plugs are in the proper positions. AC control wiring should be a minimum of 14 AWG, and run in conduit separate from DC control wiring. Analog inputs (Analog A, Analog B) should be connected with a shielded, twisted pair cable. minimum 20 AWG.

All control signals are brought to the unit via the customer interface board. Special care must be taken when wiring options to ensure that all header plugs, signals and switches are wired in accordance with this drawing. Use of the customer interface board provides protection to the variable speed controller against transients that may be induced on signal wires.

Terminals 1,2,3 and 5,6,7 are used for analog A and analog B inputs respectively, and connects to customer set point or follower signal. Selection of set point or follow mode is made from the Operator interface board. Ensure that JMP5 is properly set for incoming signal, current or voltage mode, 10-50 or 4-20 mA range, 0-10V or 0-5V range.

Terminal 4, 10 VDC output, to be used in conjunction with terminals 1, 2, and 3 when setting up analog B input as a remote speed pot. See figure 3.2 speed pot detail for proper connection.

Terminals 8, 9, 10, and 11 are used for output amp metering. A panel switch can be placed in the circuit to provide selection of output phase monitoring with one meter, see figure 3.1 phase ammeter option detail for proper connection. Connect ground return to terminal 8. Output amps 9, 10, and 11 are A, B, and C phase respectively. Required meter movement 0-1 mA DC.

Terminals 12 and 13 are used for output frequency metering. Select the 0-75 or 0-150 Hertz range and calibrate loop from door interface board. Required meter movement 0-1 mA DC.

Terminals 13 and 14 are used for output voltage metering. Connect a 0-600 volt 0-1 mA DC meter as required.

Terminals 15 through 29, use JMP4 to select mode of operation of each switch. Switches may be individually set to function in both local and remote or in remote only.

Terminals 15, 16, and 17 digital input A and B are designated for future use.

Terminals 18 and 19 are used for selecting analog A or analog B input.

Terminals 20 and 21 are used to connect a jog switch (N/O contacts).

Terminals 22 and 23 are used to connect a forward reverse switch.

Terminals 24 and 25 are used to connect an auxiliary stop switch (N/O contacts).

Terminals 26 and 27 are used to connect a stop switch (N/O contacts).

For remote emergency stop, connect a switch as indicated in figure 3.2. To insure that Emergency Stop functions in all modes select Local/Remote with jumper JMP4 for Auxiliary Stop and Stop.

Terminals 28 and 29 are used to connect a start switch (N/O contacts).

Terminals 30 and 31 connect to the power supply providing an isolated +24 VDC.

Terminal 32 provides connection point for the isolated +24 VDC supply.

The Customer Interface Board provides three contact closures (N/O or N//C) for external indicator/alarm circuits, terminals 33, 34, 35 or 36, 37, 38 or 39, 40, 41. If installation requires more than three relays an auxiliary relay board may be used. To connect customer indicator/alarm circuits select any combination of functions (Run, Underload, Overload, Over Temperature, Wrong Voltage, Set Hertz, Instantaneous Overload Trip, Fault, Set Point Alarm, or Digital Input A or B Alarm) with RJMP 1-3. Relay contacts are rated 5A 120 VAC or 30 VDC.

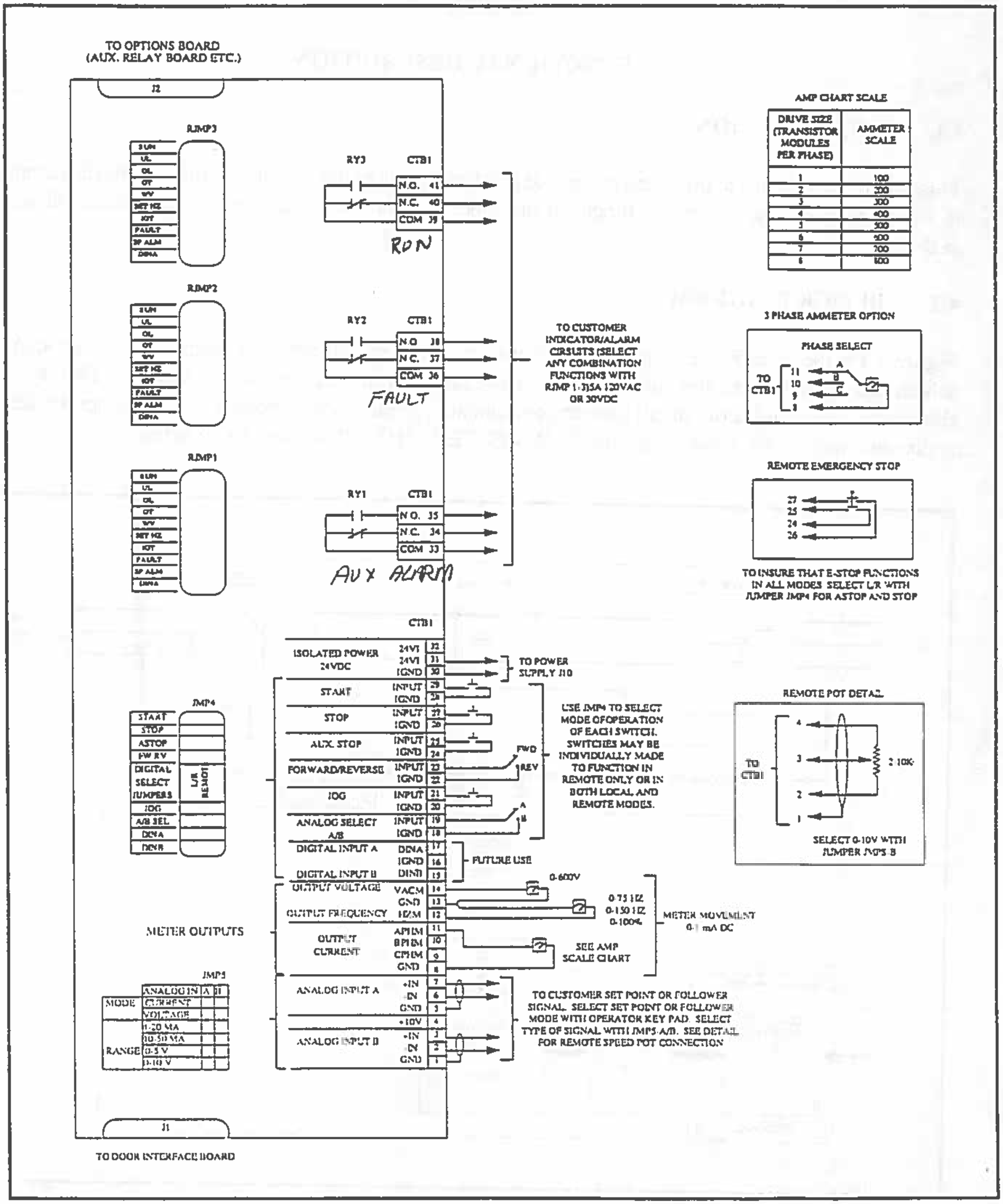


Figure 3.1 Customer Interface Board Wiring Diagram

SECTION 4

FUNCTIONAL DESCRIPTION

4.1 INTRODUCTION

This section is intended to provide a more in depth description of the Electrospeed. The basic schematic is used to show the functional blocks of the Electrospeed ICS Controller.. Each block is discussed in detail.

4.2 BLOCK DIAGRAM

Figure 4.1 is the Basic Power Circuit Schematic for the Electrospeed ICS controller. This diagram schematically represents the power circuit, while representing the controls as blocks. This drawing shows the interconnection of all power components, printed circuit boards etc.. The power section is divided into three basic sections, CONVERTER, DC LINK, and INVERTER.

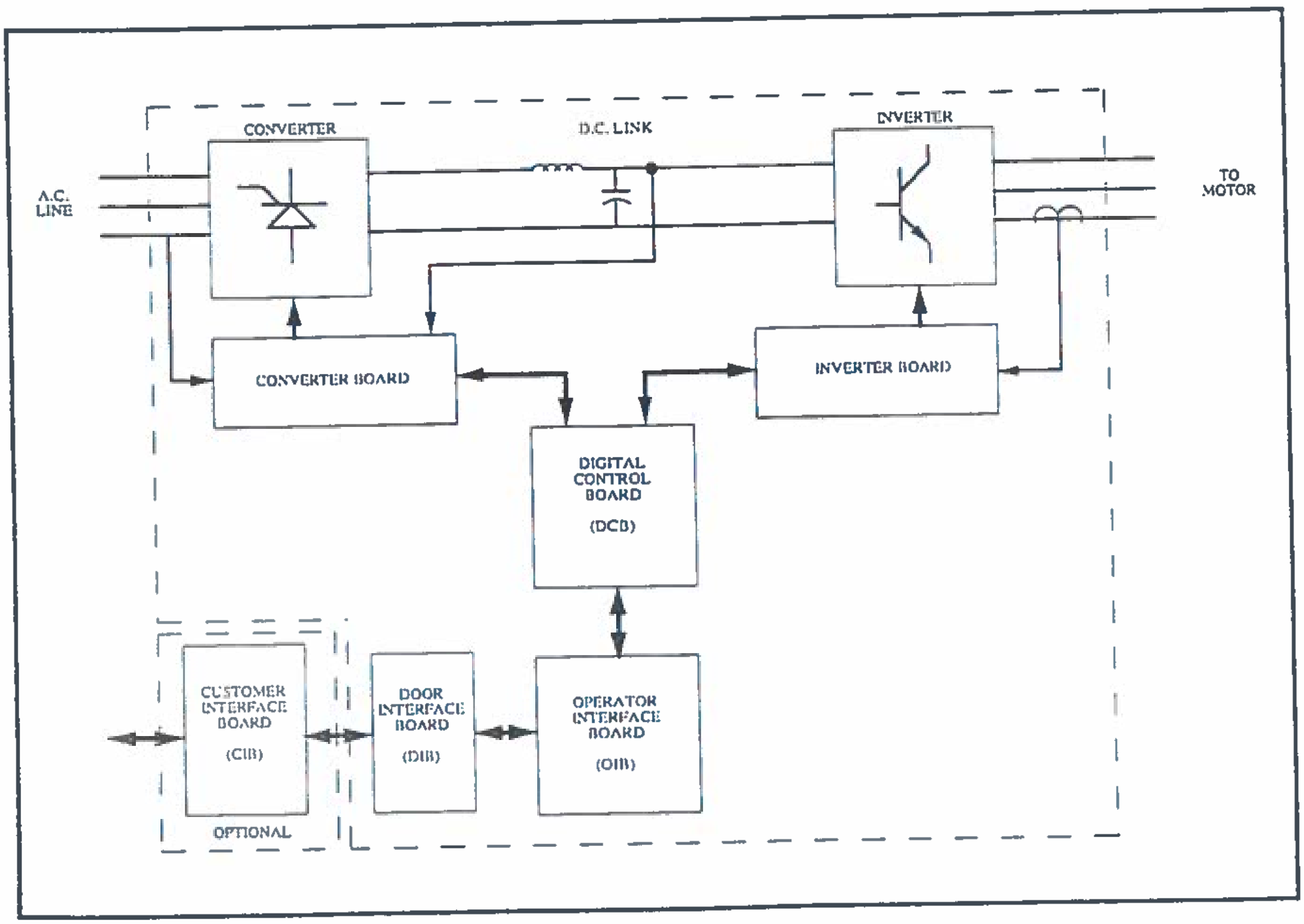


Figure 4.1 Basic Block Diagram

4.3 CONVERTER

4.3.1 Introduction

The Converter consists of 6 SCR's connected in a three phase full wave bridge. The SCR's both rectify the input 3-phase power and regulate the DC bus voltage. This type of converter is commonly referred to as a six pulse converter, a controlled converter, or simply as an SCR converter. The converter SCR's are controlled by the Converter Control Board (CCB). The CCB contains all the circuitry to operate the converter section. On larger controllers, the converter SCR's are paralleled to achieve the required ratings. When this is done, a second converter board called the Auxiliary Converter Board (ACB) is used to provide the additional gate connections.

4.3.2 Converter SCR's

The Converter SCR's used on all Electrospeed controllers are in modules. These modules are designed to mount directly to the heatsink, and provide 2500 VAC isolation between the internal SCR's and the base of the module. Each module contains two SCR's. Refer Figure 4.2 for internal schematic of the SCR module. Within the module, the anode of one SCR is connected to the cathode of the other. This point of interconnection is designated as terminal 1 (AK). AC power connects to this point. The remaining cathode, terminal 2 (K), and anode, terminal 3 (A), are connected to the positive and negative buses respectively. The SCR that connects to the positive bus is referred to as the positive SCR, while the one connected to the negative bus is referred to as the negative SCR. Terminals 4, 5, 6, and 7 are for gate firing signals which originate on the Converter Control Board, connectors J1 and J2.

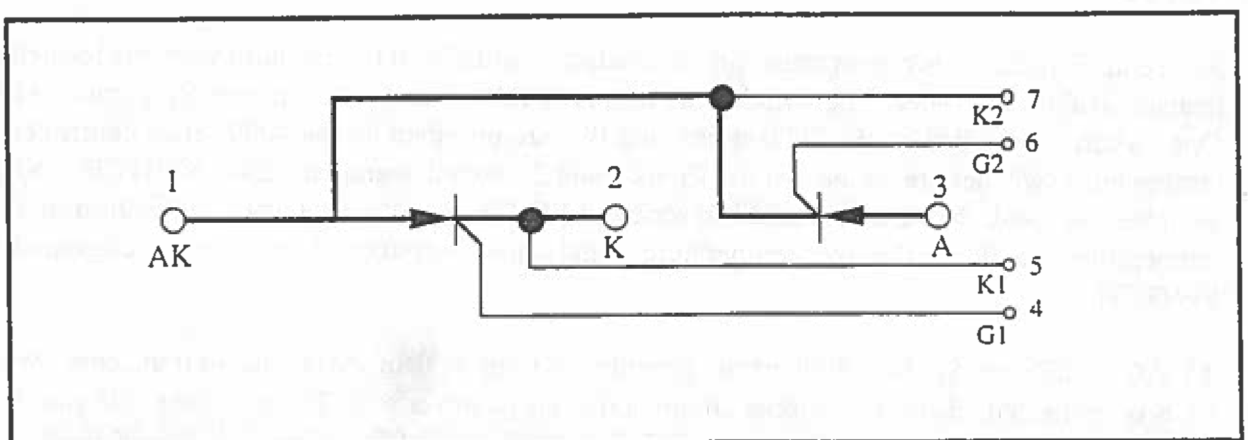


Figure 4.2 Internal Schematic for SCR Modules

4.3.3 Converter Control Board

The Converter Control Board contains circuitry for: (a) providing the gate signals to the converter SCR's, (b) sensing A/B, B/C, C/A input voltages, (c) sensing DC bus voltage, and (d) receiving the heatsink temperature switch input. Converter snubbers are also included on this board to eliminate nuisance firing of converter SCR's, from transients caused by lightning or switching. The CCB performs seven basic functions, which are listed and described in detail below. (Refer to figure 4.3)

1.) Converter Firing Circuit: The inputs to the converter section enter on J3, pins 1 through 6. These are labeled: A PHASE + INPUT, B PHASE + INPUT, C PHASE + INPUT, A PHASE - INPUT, B PHASE - INPUT, and C PHASE - INPUT. These signals originate from the Digital Control Board, consisting of a pulse train, 0-5 VDC. The inputs are active low signals for noise immunity. A resistor array acting as pull up resistors for the converter input. Another resistor array provides isolation for the converter inputs to the CCB, to prevent damage in the event the inputs are inadvertently shorted. Then each signal is inverted to provide the proper input for the transistor driver arrays. J4 is the connection point for the Auxiliary Converter Board, discussed below. The transistor driver array drives the primaries of pulse transformers. LED's CR3, 6, 9, 12, 15, and 18 provide a visual indication that the converter signals are reaching the pulse transformers. The secondaries of the pulse transformers connect to J1 and J2 to provide gate to cathode current for the positive and negative SCR's respectively. JP1is a jumper provided to disable the converter for troubleshooting.

2.) Phase-To-Phase Voltage detector: This portion of the CCB detects the three phase to phase input voltages, attenuates them, and transmits them to the DCB. The input voltages are picked up at J2 from the cathode connections for the negative SCR's. Input voltages from phase A and B are subtracted using an operational amplifier, connected as a differential amplifier. The output is sinusoidal, 7.07 volts peak with 500 VAC into the controller (100:1 attenuation). Two identical circuits are connected B to C and C to A, providing signals representing all three phase to phase voltages. These signals then output on J3 pins 8, 9, and 10, and are designated; C/B PHASE VOLTS, B/A PHASE VOLTS, and A/C PHASE VOLTS.

3.) Temp Switch: This circuit transmits the contact closure from temperature switches located on the heatsinks of the controller. The switches are normally closed, and open on over-temperature (180° F). One switch is provided on the 2000 series, and two are provided on the 4000 series controllers. The temperature switches are connected to J7 pins 1 and 2, both designated TEMP SWITCH. When two switches are used, they are connected in series. LED CR19 provides a visual indication of an over-temperature condition. The over-temperature signal is then output on J3 pin 7 and is designated TEMP SWITCH.

4.) AC Snubbers: Six RC snubbers are provided to limit SCR misfiring due to transients. When the CCB is connected, there is a snubber circuit across each converter SCR, connected to J6 pins 4, 8, 12, 16, and 20. These points are designated + DC BUS (UNFILTERED), A PH. SNUBBER INPUT, B PH. SNUBBER INPUT, C PH. SNUBBER INPUT, AND - DC BUS.

5.) DC Bus Voltage: This circuit detects the DC bus voltage, and transmits a signal to the DCB. The input to the circuit comes from J6 pins 1 and 20 designated + DC BUS (FILTERED) and - DC BUS. These inputs are fed into a differential amplifier, and the conditioned output signal is on pin 11 of J3.

6.) DC Bus Current: This circuit is for special application only, and is not covered in this manual.

7.) Power Supply: The power supply receives unregulated voltages from the DCB, and regulates them for use on the CCB. Unregulated +8 VDC, +24 VDC, and -24VDC are supplied to the CCB through J3 pins 25/26, 27/28, and 29/30. Solid state regulators are used to regulate these voltages to 5 VDC, 15 VDC, and -15VDC. Six LED's provide visual indication of the presence of both the unregulated (CR22, 27, and 25) and regulated supplies (CR23, 24, and 26). Analog and digital grounds are also provided from J3 on pins 31/32, and 33/34/35/36, designated A GND and D GND.

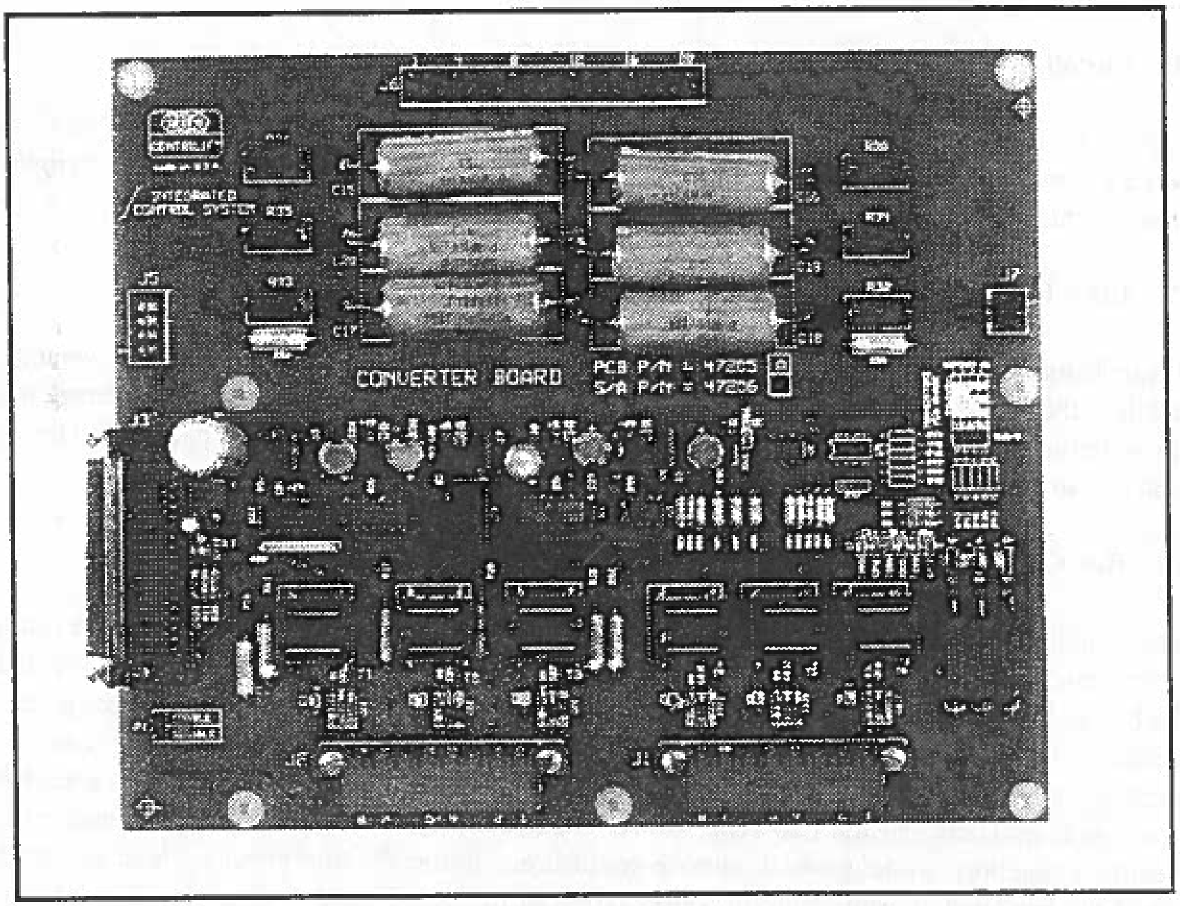


Figure 4.3 Converter Control board

4.3.4 Auxiliary Converter Board

The Auxiliary Converter Board (ACB) mounts to the Converter Control Board with stand-offs. A cable assembly interconnects the two boards, from J4 on the Converter Control Board to J4 on the Auxiliary Control Board.

The ACB is identical to the Converter Control Board's Converter Firing Circuit from J4 out to the SCR gate lead connectors, J1 and J2. As on the Converter Control Board. there are six LED's which provide visual indication of the presence of SCR gate signals.

4.4 DC LINK

4.4.1 Introduction

The DC Link consists of an inductor, bus capacitors, and auxiliary bus capacitors. The Converter converts three phase power into DC power, however, there is still a significant amount of ripple. The purpose of the DC Link components is to filter the ripple from the DC bus voltage.

4.4.2 Link Inductors

Multiple Link Inductors are used in parallel to achieve the required ratings. In the weatherproof controller. the inductors are located in the base of the controller enclosure, and are immersed in oil for cooling. In the general purpose enclosure, the inductors are located in the bottom just behind the cooling air entry point. (See figure 1.1 - 1.4)

4.4.3 Bus Capacitors

The bus capacitors are paired together and connected in series to achieve the required voltage rating. and the pairs paralleled to achieve the capacitance required. To insure neither capacitor has more than 50% of the bus voltage across it, bleeder resistors are used. The resistors are connected across the capacitor terminals. The resistance of the bleeder resistors is much smaller than the leakage resistance of the capacitors, making the leakage resistance insignificant, allowing the bleeder resistors to establish how the voltage is split between the two capacitors connected in series. The resistors are connected directly across the capacitors in the general purpose enclosures. In the Weatherproof enclosures. the bleeder resistors are mounted to printed circuit boards (Bleeder Resistor Board) located in the enclosure base along with the link inductors. A cable assembly connects the Bleeder Resistor Boards to the Cap Deck Boards, which connect directly to the bus capacitors. In the weatherproof version, the bus capacitors are located in the bottom of the enclosure, just above the base. In the General purpose unit, the bus capacitors are located behind the link inductor in the bottom of the enclosure.

4.4.4 Auxiliary Bus Capacitors

Auxiliary bus capacitors are used only with the general purpose enclosure. The main bus capacitors in these models are located too far from the inverter section for proper operation of the controller, making it necessary to move a portion of the capacitance closer. Therefore, some of the bus capacitors are located on the horizontal panel called the "Air Dam", located just below the heatsinks. The bleeder resistors for these capacitors are lugged, and fastened directly to the capacitor terminals. (See figure 1.4)

4.5 INVERTER

4.5.1 Introduction

The Inverter consists of six bipolar transistor switches, and the "Inverter Control Board".

4.5.2 Transistors

The transistors used are contained in modules consisting of two triple darlington transistors, and two antiparallel diodes. The transistors and diodes are internally connected to provide a single leg of the inverter. Figure 4.4 is the internal schematic of the module, showing how transistors and diodes interconnect. The emitter of one transistor is connected internally to the collector of the second transistor. This point is designated C2E1, and is the output of the inverter section. The remaining collector (C1) and emitter (E2) are connected to the positive and negative buses respectively. The transistor connecting

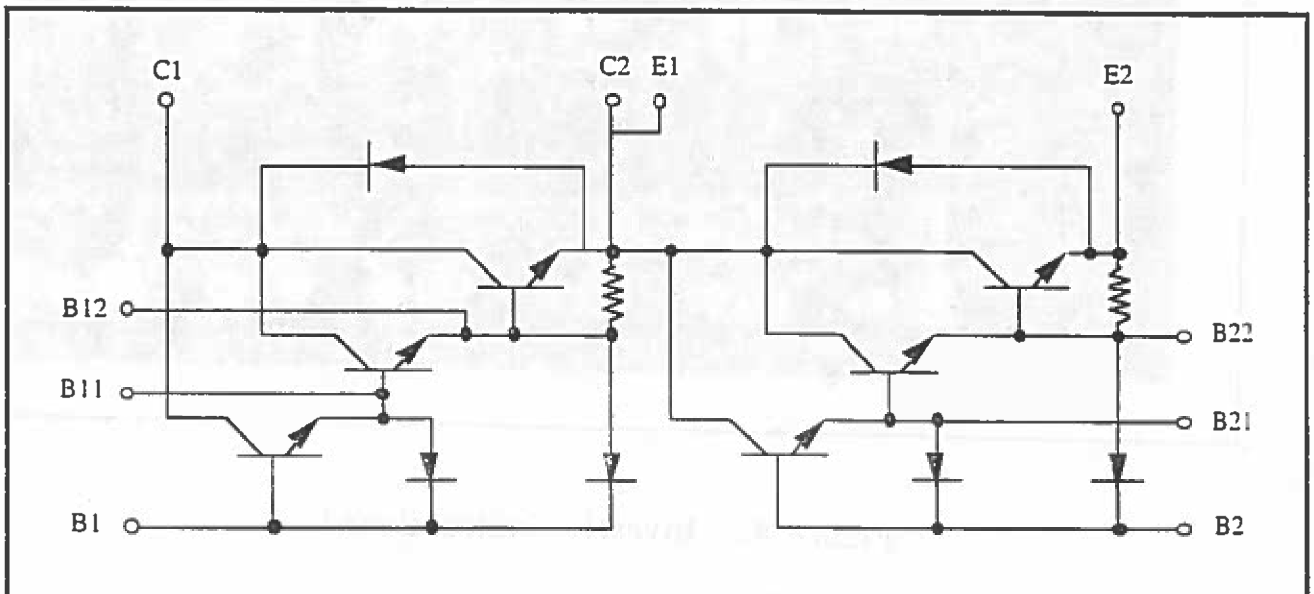


Figure 4.4 Internal Schematic for Transistor Modules

to the positive bus is generally referred to as the positive transistor, while the one connecting to the negative bus is referred to as the negative transistor. The antiparallel diodes are connected directly across each transistor, cathode to collector, and anode to emitter. The diodes provide a circuit for the reactive current on inductive loads.

The transistors used are designed to be used in parallel. Parameters critical for parallel operation are matched in every transistor, so any one device can be replaced by any other. The module itself is designed to mount directly to the heatsink, and provides 2500 VAC isolation between the module base and the internal components.

4.5.3 Inverter Control Board

The Inverter Control Board (ICB) provides the link between the Digital Control Board (DCB) and the Inverter section of the controller. The ICB performs five basic functions, which are listed and described in detail below. (Refer to figure 4.5)

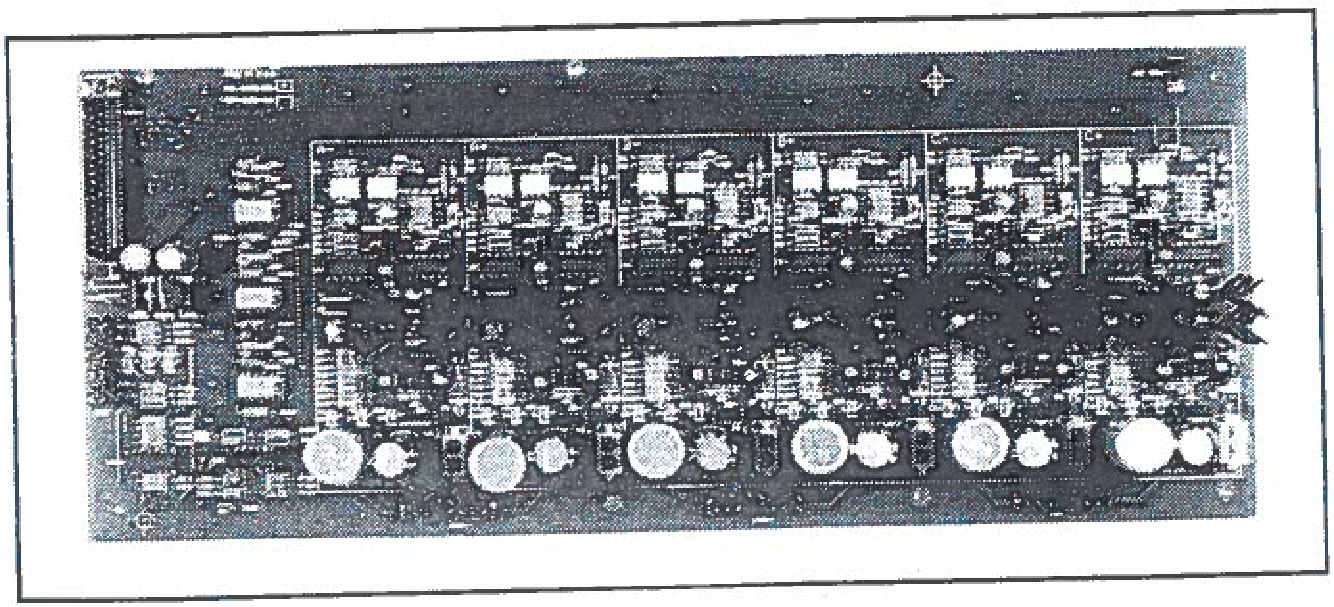


Figure 4.5 Inverter Control Board

1.) Inverter Signals: The ICB provides interface and isolation for inverter signals to and from the DCB. There are six signals from the DCB to the Inverter Control Board that determine the state of the six inverter power switches. They are designated, A+, A-, B+, B-, C+, and C-. These correspond to the positive and negative switches in each phase respectively. Each of these signals is optically isolated from the inverter driver circuitry, because these circuits are at an elevated potential with respect to the DCB. These optical isolators provide 2500 volts RMS isolation preventing inverter problems from being coupled back into the DCB. Fault signals from the driver circuits are also optically coupled in the same manner for the same reasons. Fault signals are discussed later.

2.) Proportional Base Drive: The ICB provides proportional base drive for transistor power switches. The base drive circuit for the transistors functions as a current regulator that supplies only as much base current as is needed, based on output current. This is done by monitoring the collector to emitter voltage drop across the transistor and supplying just enough base current to maintain the transistor in saturation, approximately 2.0 to 2.5 volts, collector to emitter.

The input signals to the ICB from the DCB are active low. When the DCB signals the inverter power transistor to turn on, the input of the opto-isolator is pulled low turning on the output transistor, which pulls the input to an inverter low. The signal is then fed into two more inverters which are paralleled to activate the proportional base drive circuit, then to the emitter of the inverter power transistor via connector J1. The collectors of the negative power transistors are the same points as the emitters of the positive transistors, as they are internally connected in the modules. The inverter power transistor collectors are connected to the proportional base drive circuit through D3 and R7. For the negative transistors the connection is made via J1 on the positive circuit of the same phase. For the positive transistors, the collector connection is the DC bus which is connected to J108. The collector to emitter voltage is detected through the connections previously described, and is converted into a current demand signal, then amplified. The amplified signal is then applied to the base lead of the inverter power transistor via connector J1. As the collector to emitter voltage increases, the base drive to the inverter power transistor is increased to compensate.

When the input signal from the DCB is high, the proportional base drive circuit is deactivated. This produces a short duration negative base current to turn off the inverter power transistor quickly, and then maintains a negative bias on the base to insure the transistor stays off.

3.) Transistor Over-Current Fault Detection: The ICB provides transistor over current fault detection and protection. The collector to emitter voltage on the inverter power transistor is monitored to detect for over-current. If the collector to emitter voltage ever increases significantly over the normal range of 2 to 3 volts, the transistor is out of saturation. This is an indication that there is insufficient base current to maintain the demanded collector current. The amount of heat generated by the transistor is the product of the collector current and the collector to emitter voltage drop, therefore it is important to maintain the transistor in saturation, which produces the minimum voltage drop. For this reason, the ICB continually monitors the collector to emitter voltage, while the transistor is on, to detect an "out of saturation" condition. The "out of saturation" condition is detected and then determined by the threshold voltage of the "set" input. If a high collector to emitter voltage is detected, while the transistor is on, three things are accomplished: sets the base drive circuit to the off state no matter what the input signal from the DCB demands; turns on an LED to indicate that an over-current trip has occurred; and sends a signal to the DCB through an opto-isolator indicating a fault has occurred. This signal can also be used to reset the detection circuit after a short period of time. This is done by placing JP1 in the "AUTORESET" position. Automatic reset for this fault is provided for applications in remote areas to keep nuisance faults from preventing automatic restarting of the system.

4.) Output Current Sensing: The controller's output current is sensed by three current transformers. These current transformers are mounted such that the controller's output bus bars provide the primaries. The secondaries are connected to the ICB connector J102. The CT secondaries have taps for each inverter rating. Refer table 4.1 to determine the tap setting for selected inverter rating. Resistors then provide an A.C. voltage proportional to the controller's output current. Each voltage signal is scaled and buffered by an opamp. Each of the three buffered signals are fed into both a true RMS converter and a precision rectifier. The outputs of the true RMS converters are sent to the DCB via J102 pins 13, 14, and 15 for A, B, and C phases respectively.

Transistors Modules Per Phase	CT Tap
1	125
2	250
3	375
4	500
5	625
6	750
7	875
8	1000

TABLE 4.1

5.) Power supplies provided to operate the ICB can be categorized into two basic groups. The first being the six isolated, unregulated supplies used to power the individual proportional base drive circuits. These power supplies come directly from the power supply board, and provide the base drive current for the inverter power transistor switches. These supplies provide approximately + 6.5 VDC for each proportional base drive circuit. These supplies are connected to J105, 106, and 107 for A, B, and C phases respectively. Pins 1, 2, and 3 are the connections for the positive, common, and negative supplies for the positive transistors, and pins 6, 7, and 8 provide the positive, common, and negative supplies for the negative transistors. LD3 and 4 on each of the six inverter circuits provide a visual indication these supplies are present.

The second group of power supplies come from the Digital Control Board, and is for the control logic. These supplies consist of unregulated +8 V and ±24V provided on pins 25/26, 27/28, and 29/30 of J101. Power supply common is supplied on pins 35/36. The three logic supplies are regulated with solid state regulators to provide +5V and ±15V regulated. LD101, 102, and 103 provide a visual indication the supplies are present. Analog ground is provided on pins 31/32 of J101, and digital ground is provided on pins 33/34 of the same connector.

4.6 DIGITAL CONTROL BOARD (DCB)

4.6.1 Introduction

The Digital Control Board is the primary control block for the power circuit. It's main function is the basic variable frequency controller operation. The DCB connects directly to both the Converter Control Board, and the Inverter Control Board, and provides the signals indicating when to fire the input SCR's and the signals determining when the output transistors are off or on. The DCB communicates with the Operator Interface to receive setup and operating parameters, and transmits status, faults, etc. for display. See figure 4.6 for the Digital Control Board.

4.6.2 Microcomputer

The DCB uses an 8097 microprocessor operating at 12 MHZ. The 8097 has an onboard analog to digital converter, with multiplexer for eight analog inputs. The 8097 has common address and data lines, requiring two octal latches to latch the address. Two 128K by 8 EPROM's are used for program storage. The DCB's address and data buses connect externally to the Operator Interface Board. Eight bits of the data bus, and ten bits of the address bus are buffered and provided at J1 for connection to the OIB, along with handshaking signals. All necessary operating parameters for the controller are received from the OIB through this parallel communications port. The DCB in turn sends feedback data to the OIB for display on the front panel of the controller. A LOST COM output is provided from the microprocessor to drive D23, an LED to indicate the loss of communication between the DCB and OIB. The DCB includes a power reset circuit to insure the microcomputer is properly reset when power is applied.

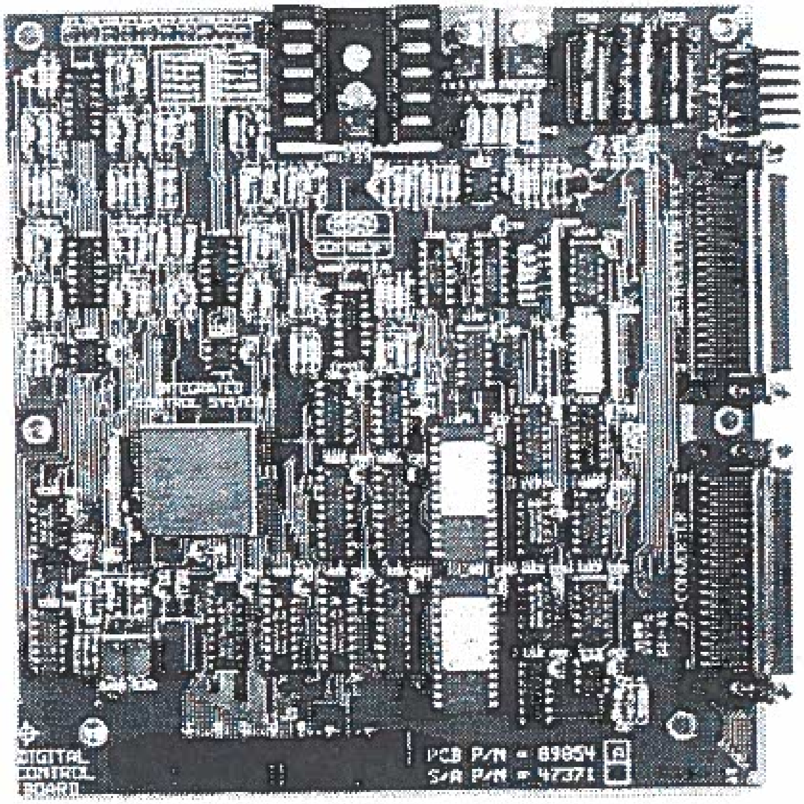


Figure 4.6 Digital Control Board

4.6.3 Converter Operation

The DCB receives the three phase-to-phase voltages detected by the CCB on J3 pins 9, 8. and 10, designated A/B PHASE, B/C PHASE, and C/A PHASE respectively. Each of these inputs is buffered, and then rectified with a precision rectifier, and fed into a comparitor. The comparitors indicate the presence of the signals, if the input voltages to the controller are above approximately 300 VAC. The outputs of the comparitors are connect to the microprocessor. These inputs to the microprocessor are used to determine if all three voltages are present, and if there is sufficient voltage for proper operation of the controller.

The outputs of the buffers for inputs A/B PHASE, and B/C PHASE, before being rectified, are fed into a comparator which provides a squarewave out with the zero-crossings coincident with the sinewave in. The squarewave output associated with A/B PHASE is designated Z-XING, it connects directly to the microprocessor, and is used to determine the zero crossing for the input voltage to the controller. This is critical for the operation of the converter. The point in time at which A and B input voltages cross is used to determine the delay angle for firing the converter SCR's. The delay angle determines the DC bus voltage. The squarewave output associated with B/C PHASE is designated ROTATION. This also ties directly to the microprocessor, and is used in conjunction with Z-XING to determine the phase rotation of the input power. This allows the controller to be insensitive to input phase rotation.

With the input voltage signals, the DCB determines the appropriate delay angle based on "SET FREQUENCY", "VOLTS AT 60 HZ.", etc., and outputs six digital signals used for firing the converter SCR's. These signals originate from the microprocessor, and are gated into a series of pulses using AND gates, and an oscillator. The output of the oscillator is synchronized with the leading edges of the digital outputs from the microprocessor with the inverted SYNC signal. The inputs to the six AND gates coming from the oscillator can be inhibited, which will disable the converter outputs. The outputs of the six AND gates are inverted to provide the outputs sent to the Converter Control Board. These outputs terminate at connector J3, pins 1, 2, 3, 4, 5, and 6.

The converter can be enabled or disabled by the CNVEN output from the microprocessor. When the converter is to be enabled, the output is low. The inverse of the signal status is transferred to the output of a flip-flop and makes the transition from low to high. The flip-flop output is the signal which, when low, inhibits the converter. The RESET input originates from the power up reset circuit, and insures the flip-flop is preset to the converter disabled state on power-up. A hardware inverter disable input is used for fault conditions, and is discussed in detail under the "Fault" portion of this section.

The DC bus voltage is detected by the Converter Control Board, and the signal enters the DCB on pin 11 of J3, and is designated VDC. VDC is scaled and buffered, and connects to J1 pin 17, which is designated VAC. VAC is proportional to the AC output voltage of the controller, and is routed through the Operator Interface Board to the Door Interface and Customer Interface Boards to provide analog outputs for local or remote indication. The same buffered signal that provides for VAC feeds two other circuits. One is the VCO circuit which will be discussed in the "Regulation" portion of this section. The other circuit rescales the signal, and then connects the analog input of the microprocessor.

The TEMP SW (temperature switch) input originates from the converter board, and enters the DCB on J3 pin 7. This input is inverted, and connected to the eight bit latch, which in the event of a fault will be latched and interrogated by the microprocessor. The inverted input is also combined with other fault inputs to provide a common fault signal, which is discussed in the "Fault" portion of this section.

4.6.4 Inverter Operation

Three outputs on the microprocessor are used to determine the status, on or off, of the six inverter power transistor switches. The DCB determines the operational frequency from the parameters entered into the

Operator Interface, and switches these outputs in the proper sequence at the frequency demanded. These three outputs determine the switching of the three positive inverter power transistor switches. Each of these signals is also inverted, to provide outputs which determine the switching of the three negative inverter power transistor switches. Each of these six signals, three non-inverted and three inverted, is connected to a separate dual input AND gate. The second input of each AND gate is connected together to allow all six inverter signals to be inhibited by a single input. The output of each AND gate is inverted, and terminated at J2 pins 1, 2, 3, 4, 5, and 6 to provide outputs to the Inverter Control Board.

The inverter can be enabled or disabled by the INVEN output from the microprocessor. When the inverter is to be enabled, the output is low. The inverse of the signal status is transferred to the output of a flip-flop and makes the transition from low to high. The flip-flop output is the signal which, when low, inhibits the inverter. The RESET input originates from the power up reset circuit, and insures the flip-flop is preset to the inverter disabled state on power-up. A hardware inverter disable input is used for fault conditions, and is discussed in detail under the "Fault" portion of this section.

In the event of an Inverter fault, the fault signal is transmitted from the Inverter Control Board to the DCB on J2 pins 7, 8, 9, 10, 11 and 12; these inputs are connected to the eight bit latch, which will be latched and interrogated in the event of a fault.

Three analog signals originate from the Inverter Control Board for use by the Digital Control Board. See the "Regulation" portion of this section for details on these signals.

4.6.5 Fault Handling

Fault recognition and response times for protective circuits are critical. A significant portion of the Digital Control Board is for handling faults. When a fault occurs, a flip-flop is reset. When this happens, two other flip-flops are set, disabling the converter and inverter. The Converter and Inverter portions of this section describes disabling the converter and inverter outputs. The fault signal that disables the converter and inverter is the output of a flip-flop whose fault status can be set by any one of eight fault signals.

The seven fault signals consist of the six inverter fault signals along with the inverted TEMP SW (temperature switch). These inputs are connected to an eight input AND gate constructed from two quad input AND gates. Under normal operating conditions, all eight inputs to this AND gate are high, therefore the output is high. If any one of the inputs goes low, indicating a fault input, the output of the AND goes low, resetting the flip-flop. This sets the FAULT line high which connects directly to the microprocessor. The other output sets the eight bit latch, latching the status of all eight fault inputs, which are then interrogated by the microprocessor. This output also provides an input into the converter and inverter enable circuits discussed in the "Converter Operation" and "Inverter Operation" portions of this section.

The clear fault line from the microprocessor is used to set the flip-flop after being cleared by any one of the eight fault inputs. The clear fault line also inhibits the resetting of the flip-flop, while it is being set.

4.6.6 Regulator

As described in the "Converter Operation" portion of this section, a signal representing DC bus voltage enters the DCB on J3 pin 11. This signal is buffered and scaled, and ties to various circuits. The DC bus voltage signal is fed through another operational amplifier, where it is rescaled.

This type of voltage and frequency regulator is referred to as a "Bus Follower Regulator". This means the output frequency will follow the bus voltage to insure the proper voltage to frequency ratio. The microprocessor uses the VCO to help monitor bus voltage. Three other analog inputs are monitored by the microprocessor for proper regulation. These are the three true RMS output current signals. The three true RMS signals enter the DCB on J2 pins 13, 14, and 15 for phases A, B, and C. The same signals are connected to J1 pins 16, 15, and 14 respectively, for connection to the Operator Interface Board. These signals are routed through the OIB to the Door and Customer Interface Boards for local or remote indication of the three phase output currents. All three of these signals are filtered. clamped and are connected to analog inputs on the microprocessor.

4.7 OPERATOR INTERFACE

4.7.1 Introduction

The Operator Interface is the "window to the world" for the Electrospeed ICS controller. Everything the operator does. is through the Operator Interface. The Digital, Converter, and Inverter control boards make up the basic controller; however, they do not provide any means to communicate with the real world. The Operator Interface provides the means for interfacing with the basic controller. A 25 key keyboard, and 16 character alphanumeric display provide for communications with the operator. An output port provides for, analog and digital, inputs and outputs when connected to the Door Interface Board.

The operator Interface is mounted to the outside of the controller door in a separate weatherproof enclosure (See figure 4.7). The door of the enclosure is transparent, allowing the display to be viewed without opening the door. The door is provided with a lockable latch.

There are two basic parts to the Operator Interface: the Operator Interface Panel. and the Operator Interface Board. The primary function of the Operator Interface panel. is to support the keypad. The operation of the keypad is discussed below in the keypad decoder section of the description of the Operator Interface Board. The Operator Interface Board (OIB) can be broken down into seven basic sections. These sections are listed and described below.

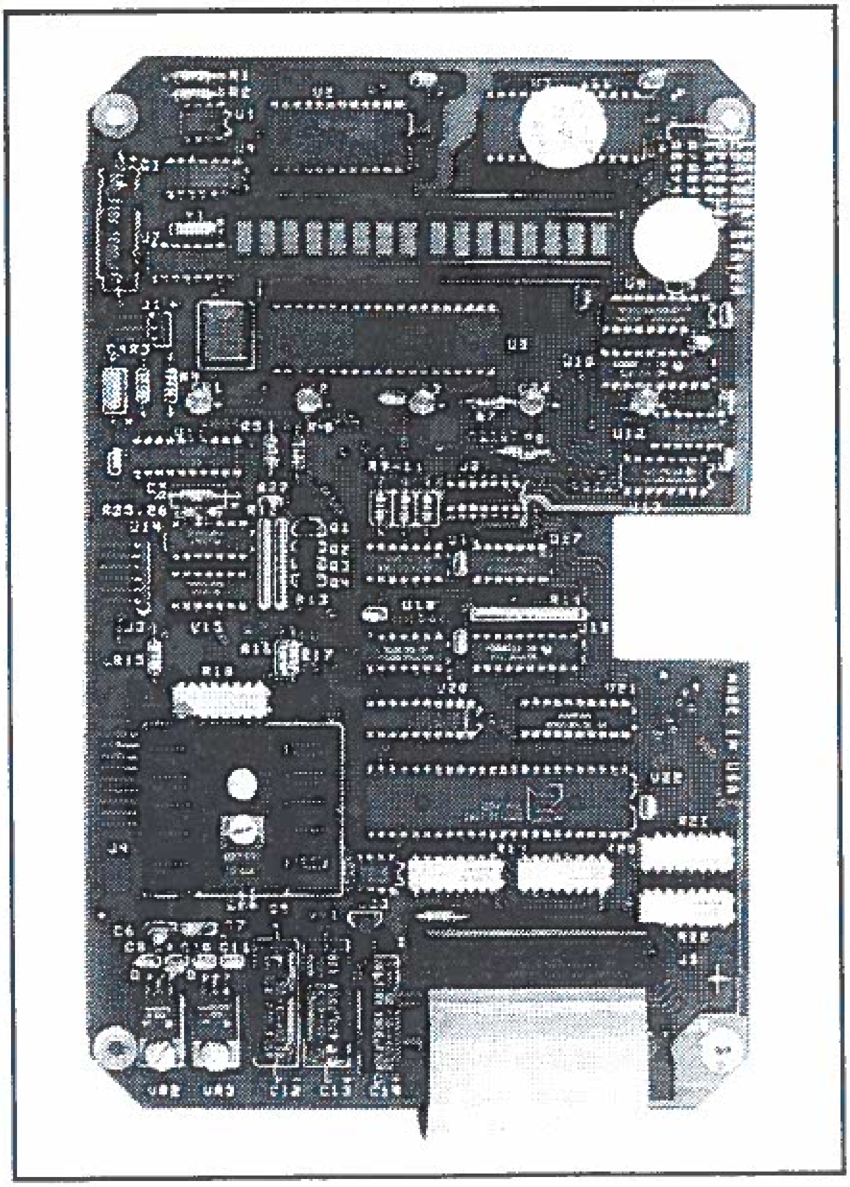


Figure 4.7 Operator Interface Board

4.7.2 DIB Output Port

This section is the connection point for the Door Interface Board. Connector J6 provides for: nine digital outputs, nine digital inputs, five analog outputs, one frequency output, and three analog inputs.

The nine digital outputs exit through J6 pins 1 through 8, and pin 26. The outputs are designated; RUN, UNDER LOAD, AT SET HZ, OVER TEMP, WRONG VOLTAGE, OVER LOAD, I.O.T., FAULT, and ALARM. The first eight of these signals are latched into an octal latch, which is connected to the data bus of the microprocessor. The ninth digital output is connected to a port on the microprocessor through an inverter. The microprocessor controls the status of each of the nine outputs.

The nine digital inputs enter through J6 pins 9 through 17. The inputs are designated: START, STOP, EMERGENCY STOP/AUXILIARY STOP, FWD/REV, F/R KEYBOARD DISABLE, JOG, LOCAL/ REMOTE SELECT, ACCESS, and ANALOG A/B SELECT. The first eight signals connect to the inputs of an octal buffer. The buffer is tied to the data bus of the microprocessor. The ninth input is connected to a port on the microprocessor through an inverter. The nine inputs can be read on demand by the microprocessor.

The four analog and the one frequency outputs exit the OIB through J6 pins 18 through 22. These signals enter the OIB on J5 pins 17 through 13, and exit unchanged.

The three analog inputs enter the OIB through J6 pins 23, 24, and 25, and are designated; ANALOG A INPUT, LOCAL POT, and ANALOG B INPUT. These three inputs are buffered, and fed into an analog to digital converter. The output of the analog to digital converter connects to the microprocessor, allowing the analog inputs to be selected and read on demand.

4.7.3 Keypad/Decoder

The keypad consists of 25 membrane type switches, which are located on the Operator Interface panel. The keypad is made up of two switch arrays, one being 1X 5, and the other 4 X 5. The two switch arrays connect to the OIB through connectors J3 and J4 respectively. The five rows of switches are selected by the address bus from the microprocessor through inverters, and the status of the switches are latched one column at a time into an octal latch. This allows the microprocessor to scan the rows of the keypad, and read each row of five switches from the data bus, which is connected to the output of the latch.

4.7.4 Display

The display consists of two "intelligent" eight character alphanumeric LED displays. Each of the 16 characters can be addressed directly by the address bus of the microprocessor, and the appropriate data transferred from the data bus into latches internal to the display modules.

4.7.5 Microcomputer

The microcomputer section consists of: the microprocessor; a bidirectional buffer to control the data bus; a decoder to decode the higher address lines to provide enable lines to enable peripheral IC's: an octal latch to store the lower bits of the address bus, which is multiplexed with the data bus; an EPROM to store the program; and an EEPROM as nonvolatile memory for setup parameters etc..

4.7.6 Real Time Clock

A real time clock chip is provided along with a crystal to allow the OIB to determine actual times and dates. This allows the Electrospeed ICS to display the "DRIVE HISTORY" with actual times for starts, stops, faults, etc.. The real time clock is powered by a lithium battery. The output of the clock chip is connected to the data bus, allowing the microprocessor to read the current date and time on demand.

4.7.7 DCB Port

Connector J5 is the connection point for the DCB. As stated in the section describing the DCB: eight data bus lines, 10 address bus lines, and various handshaking signals connect from the DCB to the OIB. The OIB contains a device called a "Dual Port RAM", which provides the link between the microcomputers on the DCB and the OIB. The Dual Port RAM is basically random access memory, with two ports, both having address and data lines. Both microprocessors can address their assigned ports, and read or write data into the memory. The handshaking signals prevent the two microprocessors from reading or writing data at the same time. Pins 33 through 40 (J5) are the data lines from the DCB, pins 23 through 32 are the address lines, and pins 18 through 22 are the handshaking signals.

As discussed in the portion of this section about the DIB output port, five analog signals enter the OIB from the DCB. These signals are Hz OUT, C ph Iout, B ph Iout, A ph Iout, and Vac Out. These signals are routed across the OIB to J6 for connection to the DIB. These signals enter the OIB on pins 13, 14, 15, 16, and 17 of J5.

4.7.8 Power Supply

As with all other boards in the Integrated Control System, the required power is regulated on the board. Unregulated supplies: ±24VDC, and +8VDC enter the OIB from the DCB on J5. Solid state regulators regulate the +24VDC to ±12VDC for the analog circuitry on the board. The +8VDC is regulated to +5VDC, which provides the reference for the analog to digital converter. An opamp and a pass transistor function as a high current regulator, using the 5 volt reference, to provide+5VDC for the digital circuitry, including the alphanumeric display.

4.8 SYSTEM POWER SUPPLY

4.8.1 Introduction

The System Power Supply provides all DC power for the ICS, including the base drive for the inverter power transistor switches. The System Power Supply utilizes ferroresonant transformers to supply constant voltages for a wide span of input voltages. The System Power Supply is located on the back wall above the heatsinks in the weatherproof enclosures, and on the air dam, along with the auxiliary bus capacitors, in the general purpose enclosures. For clarity, the System Power Supply is discussed as three sections. Each section includes components mounted to a panel plus a portion of the Power Supply Board (PSB). See figure 4.8 System Power Supply Board.

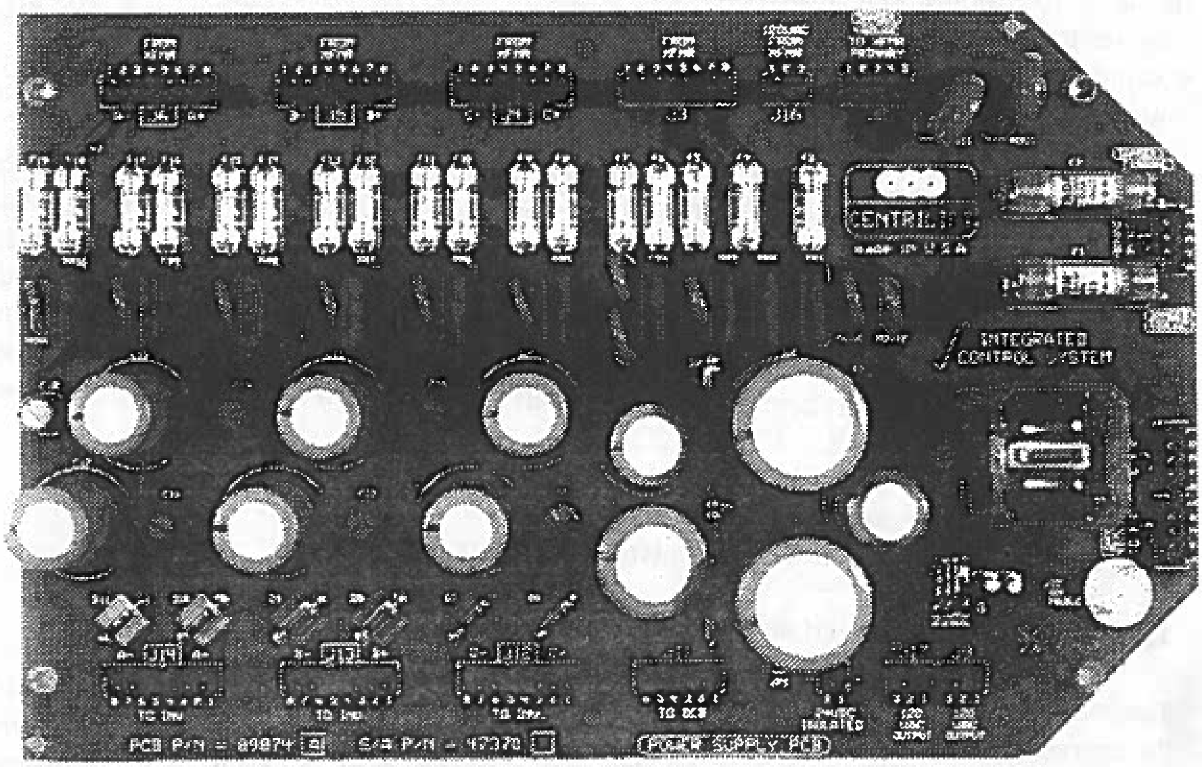


FIGURE 4.8 SYSTEM POWER SUPPLY BOARD

4.8.2 Input Power Section

Power into the Power Supply comes from phases A and B, downstream of the main input fuses. The input power connects to a two winding inductor. The inductor provides attenuation for common mode voltages, such as transients caused by lightning or switching. The output of the inductor connects to J1 on the PSB. The input power is fused on the PSB with fuses FU1 and FU2. Two metal oxide varistors MOV1 and MOV11 are connected from the outputs of the fuses to ground to further protect the controller from transients overvoltages. The fused power is connected directly to J2 for the System Power Supply transformer inputs, which are discussed later. One leg of the fused power connects directly to pins 1 on connectors J7 and J8, while the other leg connects through the output contacts of relay RY1 to pins 5 on the same connectors. Connectors J7 and J8 provide power to the cooling fan motors. Relay RY1 is controlled by the DCB, which is connected to pin 6 on J11.

4.8.3 Inverter Supply Section

The inverter supply section provides the DC supplies used by the Inverter Control Board to supply the base drive for the operation of the inverter power transistor switches. This section consists of a ferroresonant transformer with four center-tapped secondary windings. Three of the secondaries provide the base drive for the three positive inverter switches, and the fourth secondary winding has three sets of wires to provide the base drive for the three negative switches. The three negative switches have a common supply since all three reference to the negative bus. One isolated winding for a positive switch, and one common winding for a negative switch is connected to one of three input connectors on the PSB, connectors J4, 5, and 6. The positive switch supply winding connects to pins 6, 7, and 8 (7 is the common), and the negative switch supply winding connects to pins 1, 2, and 3 (2 is the common). Each of the six inputs is fused, protected by a metal oxide varistor, rectified by a full wave bridge, and filtered with capacitors to provide unregulated +6VDC for the operation of the inverter. Zener diodes are connected across each of the six supplies to clamp the output voltage during the unloaded condition that exists when the output is disconnected. The DC supplies exit on connectors J12, J13, and J14, for phases C, B, and A respectively. Each connector provides one of the three isolated supplies for the positive inverter switches on pins 1, 2, and 3, and one of the three common supplies for the negative inverter switches on pins 6, 7, and 8.

The primary of the ferroresonant transformer connects to J2, which is the fused input power. The ferroresonant winding connects to a 3 microfarad capacitor.

4.8.4 Control Power Section

The control power section provides unregulated ±24VDC, +8VDC, 24VDC isolated, and 110VAC, for the operation of the controls. The control power section receives power from a second ferroresonant transformer, whose primary is connected to screw terminals on the primary of the inverter supply transformer. A second transformer is used to isolate the control power from switching noise present in the inverter supply transformer. A 110VAC winding from the transformer, not regulated by the ferroresonant circuit, is connected to J16 on the PSB, where it is fused and protected with a metal oxide varistor. The fused 110VAC output is parallelled onto J9 and J17, for use to power the heat exchanger fan and enclosure heater on the weatherproof units. The ferroresonant winding is connected to a 3 microfarad capacitor. The remaining three secondary windings enter the PSB on J3, where they are fused, protected with metal oxide varistors, rectified with bridge rectifiers, and filtered with capacitors to provide ±24VDC, +8VDC, and +24VDC isolated. The ±24VDC and the +8VDC exit the PSB on J11 which connects to the DCB. The +24VDC isolated terminates at J10 for use with options. Zener diodes are connected across each supply to clamp the output voltage during the unloaded condition that exists when the output is disconnected.

4.9 DOOR INTERFACE BOARD (DIB)

4.9.1 Introduction

The Door Interface Board(Figure 4.9, below) provides all inputs and outputs for door mounted controls. Indicator light drivers provided on the DIB are also suitable for driving relays. The DIB mounts on the inside of the enclosure door, opposite to the Operator Interface Board, and just above the Digital Control Board. The DIB connects to the Operator Interface Board via a flat cable assembly through connector J1. Connector J2 provides all terminals for door mounted input and output devices. Connector J3 connects to the optional Customer Interface Board through a mass terminated shielded cable assemby.

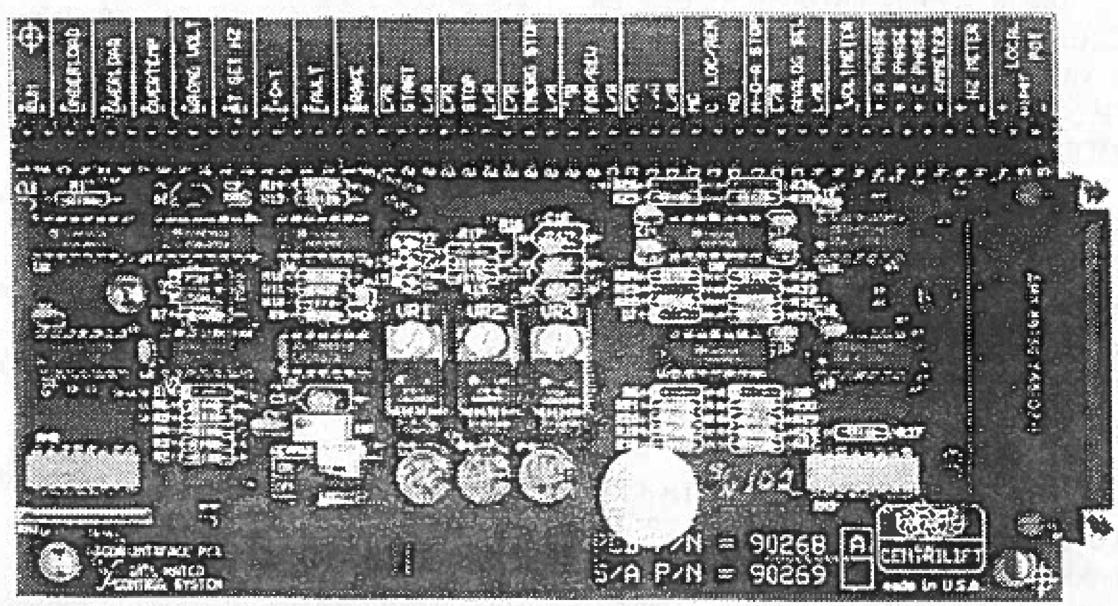


Figure 4.9 Door Interface board

4.9.2 Light/Relay Drivers

Nine digital inputs enter through J1 pins 1 through 8, and pin 26. These inputs are designated; RUN, UNDER LOAD, AT SET HZ, OVER TEMP, WRONG VOLTAGE, OVER LOAD, I.O.T., FAULT, and ALARM1`. All nine inputs are pulled high with a resistor network and buffered with inverters. Each inverted signal connects to J3, through another inverter, and to a high current transistor array. Connector J3 is provided for interconnection to the Customer Interface Board, which is discussed below.

The outputs of the transistor array are used to drive lights and/or relays. Connector J2 provides the connection points for lights and/or relays to be operated by the nine digital outputs. The light and/or relay is connected between +24VDC and the output of the transistor array. When a digital input into J1 goes low, the associated output transistor in the transistor array turns on, pulling its output low. This energizes the load. Each of the nine light/relay outputs on J2 consists of an output pin connected to a driver transistor output and a pin connected to +24VDC. Refer to figure 4.10, the DIB wiring Diagram for connection of the digital outputs from the DIB.

4.9.3 Contact Closure Inputs

Nine digital outputs exit the DIB through J1 pins 9 through 17. The inputs are designated: START, STOP, EMERGENCY STOP/AUXILIARY STOP, FWD/REV, KEYBOARD DISABLE, JOG, LOCAL/REMOTE SELECT, ACCESS, and ANALOG A/B SELECT. These output points are normally held high by pull-up resistors located on the OIB. The DIB provides a means for pulling each input low to activate the input to the OIB. The outputs designated KEYBOARD DISABLE and ACCESS, are controlled by jumpers PGH1 and PGH2. PGH1 selects operation of either the MODE 1 and MODE 2 keys on the Operator Interface keypad (ON) or a door mounted selector switch (OFF). PGH2 selects either parameter ACCESS enabled (ON) or parameter ACCESS CODE REQUIRED (CODE).

Connector J2 provides inputs for switches to control the remaining seven digital outputs. The LOCAL/REMOTE input is on pins 34 (NC), 35 (C), and 36 (NO). This input performs three functions: 1.) A contact closure between C and the NO input activates the LOCAL/REMOTE SELECT output to the OIB; 2.) The same input is connected to J3 to signal the CIB to provide the appropriate signals for the local or remote mode. A contact closure between C and the NC input selects which contact closure inputs are to be used when in the local or remote mode.

Each of the remaining six inputs; START (J2 terminals 19,20,21), STOP (22,23,24), EMERGENCY STOP/AUXILIARY STOP (25,26,27), FORWARD/REVERSE (28,29,30), JOG (31,32,33), and ANALOG SELECT (38,39,40); are each provided with three terminals. In each case, the center terminal is the actual input. The input is activated by being pulled to ground with a contact closure (switch, relay, etc). Two ground terminals are supplied. One ground terminal is switched by the LOCAL/REMOTE switch through the C and NC inputs. The other ground terminal is hardwired to ground. If the contact

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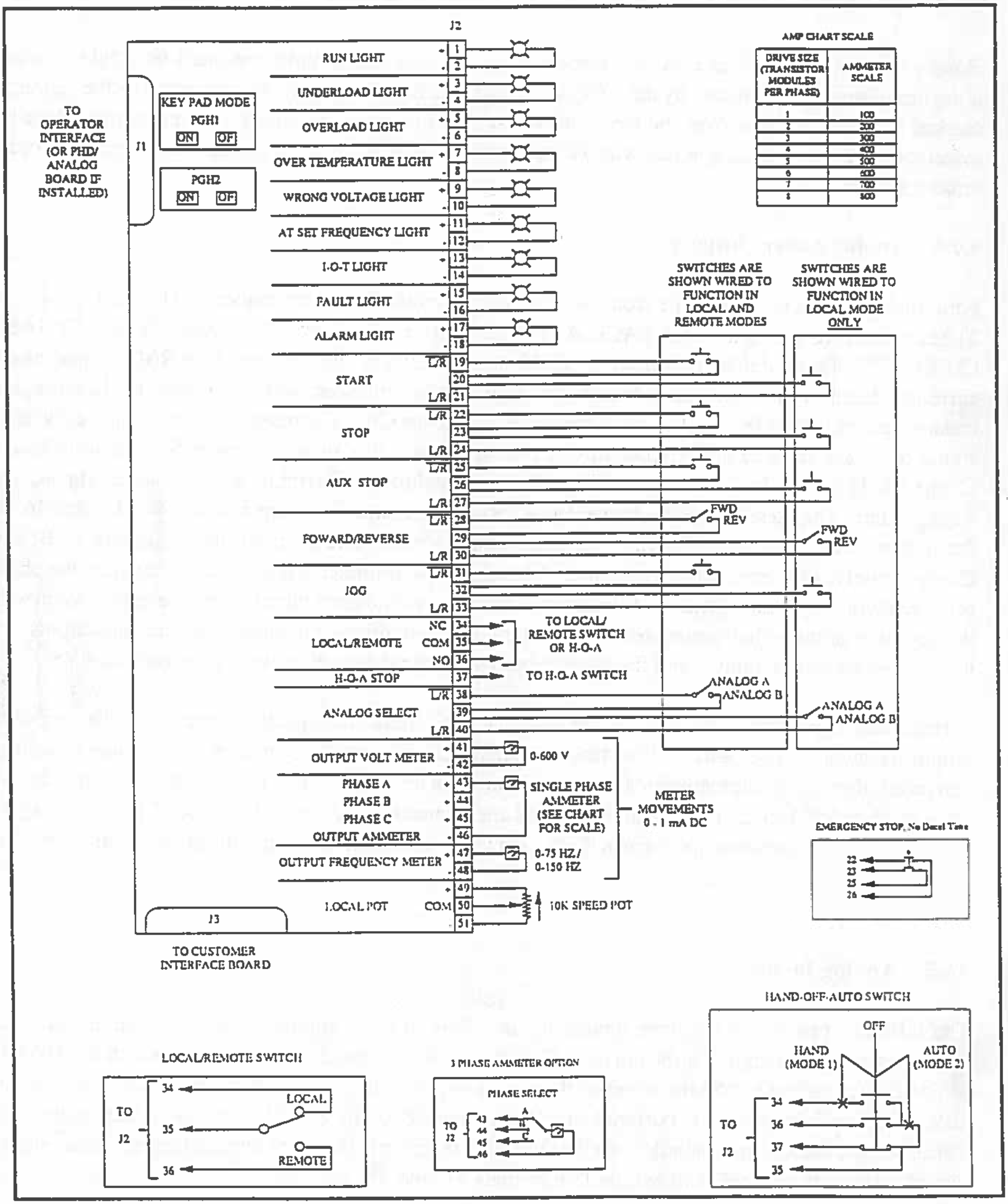


DRIVE SIZE (TRANSISTOR MODULES PER PHASE)	AMMETER SCALE
1	100
2	200
3	300
4	400
5	500
6	600
7	700
8	800

Figure 4.10 Door Interface Board Wiring Diagram

closure is to be selectable as a local or remote input, the switched ground terminal L/R would be used. If the input is not to be affected by the LOCAL/REMOTE switch, it would be connected to the terminal marked L/R with the line over the top. This allows each of these six inputs to be programmed: to be selectable as local or remote inputs with a local/remote switch, or as fixed inputs unaffected by a local/ remote switch.

4.9.4 Analog Meter Outputs

Four analog inputs enter the DIB from the Operator Interface Board on connector J1 pins 18, 19, 20, 21 designated AC OUTPUT VOLTAGE, A PHASE CURRENT, B PHASE CURRENT, and C PHASE CURRENT. These signals represent the RMS output voltage, and the three true RMS output phase currents. Each of these signals is buffered with an opamp follower, which connects to J2 through a resistor, and to J3 pins 18, 37, 20, and 21 for connection to the CIB. The resistors connecting the buffered signal to J2 are sized to provide 0-1 mA to analog meters with an approximate 50 ohm impedance. Connector J2 terminals 41 and 42 provide for an output voltmeter. Terminal 41 is the actual signal, and 42 is ground. The meter would be connected across these terminals. Terminals 43, 44, 45, and 46 are for the three output currents. The first three terminals are for the actual output current signals; A, B, and C respectively, and terminal 46 is ground. A single phase ammeter would connect between the phase selected (typically A) and ground. A three phase ammeter would use a three position selector switch with the common of the switch connected to the meter positive terminal, the three phase current outputs tied to the selector switch inputs, and the meter negative terminal connected to ground (terminal 46).

A frequency signal enters the DIB on pin 22 of J1. The frequency signal is three times the controller output frequency. The signal is inverted, and converted to an analog signal by a frequency to voltage converter, then a potentiometer for factory calibration of the circuit. PGH3 selects the output to be full scale at 75 or 150 Hertz. The signal is buffered and connected to J3 pin 22, and to J2 pin 47 through a resistor. The resistor is selected to provide 0-1 ma to a 0-1 ma analog meter with an approximate 50 ohm impedance.

4.9.5 Analog Inputs

The DIB has provisions for three analog inputs. One of these inputs is for a door mounted speed potentiometer. The input for the pot is on J2 terminals 49, 50, and 51. Pin 49 is connected to +10VDC, pin 51 is ground and pin 50 the wiper of the pot. The pot is used as a voltage divider, and provides 0-10VDC into pin 50, which is buffered and then connected to pin 24 of J1 which connects to the OIB. The other two analog input signals enter the DIB on J3 from the Customer Interface Board. These signals just pass through the DIB, and exit on J1 terminals 23, and 25.

4.9.6 Power Supply

As with all boards in the ICS, all power supplies are regulated within themselves. The DIB receives unregulated ±24VDC from the OIB on terminals 27/28 and 29/30. The +24VDC supply is regulated to +5VDC and +15VDC. The 24VDC supply is regulated to -15VDC. The -24VDC supply is also used to supply a +10VDC reference used by the speed pot input (J2 term. 49) and is also connected to J3 for use by the Customer Interface Board. Light emitting diodes, D3, D4, and D5 are provided to provide a visual indication of the presence of the -15VDC, +15VDC and +5VDC regulated supplies respectively.

4.10 PHD OPTION

4.10.1 Introduction

The PHD option provides a means to interface the Electrospeed Controllers to the Centrilift down-hole pressure monitoring system. The PHD consists of two basic components: the surface inductor package, and the PHD Signal Conditioner.

4.10.2 Surface Inductor Package

The Surface Inductor Package typically mounts to the fan shroud on weatherproof controllers, and is remote mounted with units housed in general purpose enclosures. The Surface Inductor Package consists of a weatherproof enclosure containing three inductors connected in series. The input to the inductors is the A phase of the surface voltage (step-up transformer secondary), and the output of the inductors is connected to a capacitor which connects to ground, and to a variable resistor through a fuse. The inductor and capacitor form a "low pass filter" which allows only DC to flow. The variable resistor is a "zero adjustment for the PHD system, and is the output for the Surface Inductor Package.

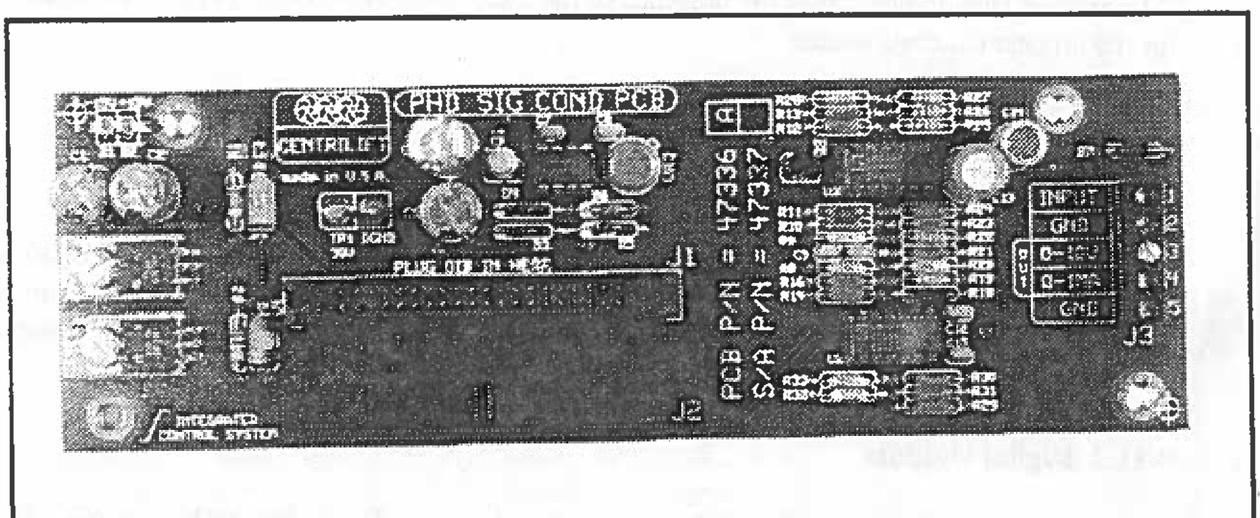


Figure 4.11 PHD Signal Conditioner

4.10.3 PHD Signal Conditioner

The PHD Signal Conditioner (see figure 4.11) is a printed circuit board, that mounts to the Door Interface Board. The PHD Signal Conditioner is connected between the Operator Interface Board and Door Interface Board. The flat cable that would normally connect the OIB to the DIB is used to connect the OIB to the PHD Signal Conditioner (J1). An additional flat cable assembly is used to connect the PHD Signal Conditioner (J2) to the DIB. All inputs/outputs to the PHD Signal Conditioner that enter through J1, exits through J2, except the analog A input. The analog A input from the DIB is interrupted on the PHD Signal Conditioner, and the analog A output is used for the PHD signal. The DIB functions the same as without the PHD Signal Conditioner.

The PHD signal is sent to the OIB as analog A, and is generated from a pressure transducer located in the down hole motor. A constant 1.0 ma source is generated on the PHD Signal Conditioner and outputs on J3 terminal 1. Terminal 1 (J3) is connected to the surface inductor package. The path for the 1.0 ma source is through the inductors in the surface inductor package, through the down hole cable, through a down hole inductor package, through a transducer, and to ground via the production tubing. The resistance of this path is constant, except for the pressure transducer, which changes significantly in resistance with pressure. As the downhole pressure increases, so does the resistance. The voltage at terminal 1, J3 is the product of this resistance and the 1.0 ma current. This voltage is the input to the PHD Signal Conditioner. At zero pressure this voltage is set to 8.2 volts by adjusting the variable resistor in the surface inductor package. This voltage is fed through an active low pass filter, the 8.2 volt zero input is subtracted, and the resultant is scaled to provide 0 to 6.84 volts, which becomes the analog A input into the Operator Interface Board.

The power supplies for the operation of this board consist of two solid state regulators whose input is the unregulated ±24VDC entering on J1 and exiting on J2. The regulators provide +15VDC. LED's D1 and D2 provide visual indication of the presence of the ±15VDC. A 30VDC supply is generated on board for the constant current source.

4.11 CUSTOMER INTERFACE BOARD (CIB)

4.11.1 Introduction

The Customer Interface Board mounts to the Customer Interface Panel located on the left wall of the enclosure, and connects to the Door Interface Board. The CIB is the termination point for all remote inputs and outputs to the Electrospeed ICS controller. The CIB has provisions for: digital outputs, digital inputs, analog outputs, and analog inputs. Figure 4.12, Customer Interface Board.

4.11.2 Digital Outputs

The digital outputs are in the form of relay contact closures. Three relays (N/O or N/C) are provided on the base CIB, and an Auxiliary Relay Board is available to provide three additional relays, which are

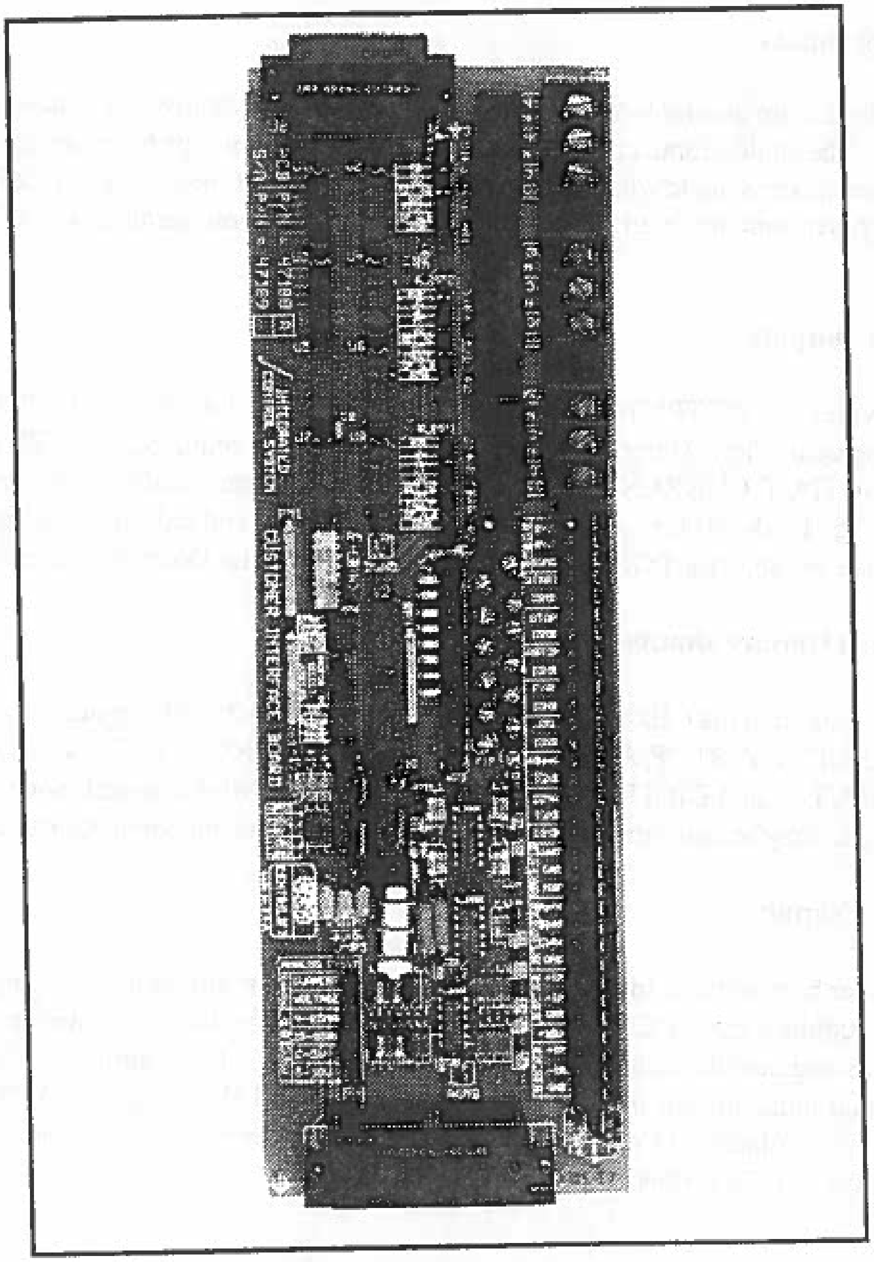


Figure 4.12 Customer Interface Board

also driven from the CIB. One set of form "C" contacts are provided from each relay, rated 5A 120VAC or 30 VDC. Each relay can be selected to operate for any combination of: RUN, UNDERLOAD, OVERLOAD, OVER TEMPERATURE, WRONG VOLTAGE, INSTANTANEOUS OVERLOAD TRIP, FAULT, SETPOINT ALARM, or DIGITAL INPUT ALARM on RJMP 1-3.

4.11.3 Analog Inputs

Two analog signals are available with inputs of 0-5V, 0-10V, 4-20mA, and 10-50 mA selectable with jumper JMP5. The analog inputs connect to the customers set point or follower signal. Selection of set point or follower mode is made with Analog Control Setup on the Operator Interface Board. For a remote speed control potentiometer, a +10VDC supply is provided for on terminal 4 of CTB1 (refer to figure 3.2 for detail.

4.11.4 Meter Outputs

The CIB provides for OUTPUT CURRENT, OUTPUT VOLTAGE, and OUTPUT FREQUENCY metering of the controller. Meter movement of 0-1- mA DC is required. OUTPUT VOLTAGE range 0-600 volt, OUTPUT CURRENT (refer to figure 3.2 for Amp Scale Chart), and OUTPUT FRE-QUENCY (0-75 Hz, 0-150 Hz, or 0-100%). Range selection and calibration of the output frequency meter is provide by selector PGH3 and potentiometer R8 on the Door Interface Board.

4.11.5 Contact Closure Inputs

Nine digital inputs enter the CIB through CTB1 pins 15 through 30. The inputs are designated: START, STOP, EMERGENCY STOP/AUXILIARY STOP, FWD/REV, JOG, ANALOG A/B SELECT, DIGITAL INPUT A, and DIGITAL INPUT B. Use jumper JMP4 to select mode of operation of each switch. Switches may be individually made to function in remote only or in both local and remote modes.

4.11.6 Power Supply

As with all other boards in the Integrated Control System, the required power is regulated on the board. Unregulated supplies: ±24VDC, and +8VDC enter the CIB from the Door Interface Board on J1. Solid state regulators regulate the ±24VDC to ±15VDC and +5VDC. Light emitting diodes, D7, D8, and D9 provide a visual indication of the presence of the+5VDC, +15VDC, and -15VDC regulated supplies respectively. An Isolated +24VDC power supply can be input directly from the System Power Supply J10 if connected to CTB1, pins 30 and 31.

4.12 ANALOG INPUT BOARD

4.12.1 Introduction

The Analog Input Board is a low cost alternative to the CIB for analog inputs only. The Analog Input Board mounts to the DIB, and connects between the Operator Interface Board and Door Interface Board. The flat cable that would normally connect the OIB to the DIB is used to connect the OIB to the Analog Input Board(J1). An additional flat cable assembly is used to connect the Analog Input Board (J2) to the DIB.

4.12.2 Analog Inputs

Both A and B analog signals are available with inputs of 0-5V, 0-10V, 4-20mA, and 10-50 mA selectable. All inputs/outputs to the Analog Input Board that enter through J1, exits through J2. The DIB functions the same as without the Analog Input Board. Both A and B analog signals are sent to the OIB. Refer to Figure 4.13.

4.12.3 Power Supply

The power supplies for the operation of this board consists of two solid state regulators whose input is the unregulated ±24VDC entering on J1 and exiting on J2. The ±24 is regulated to provide +15VDC. Light emitting diodes, D2 and D1 provide a visual indication of the presence of the -15VDC and +15VDC regulated supplies respectively.

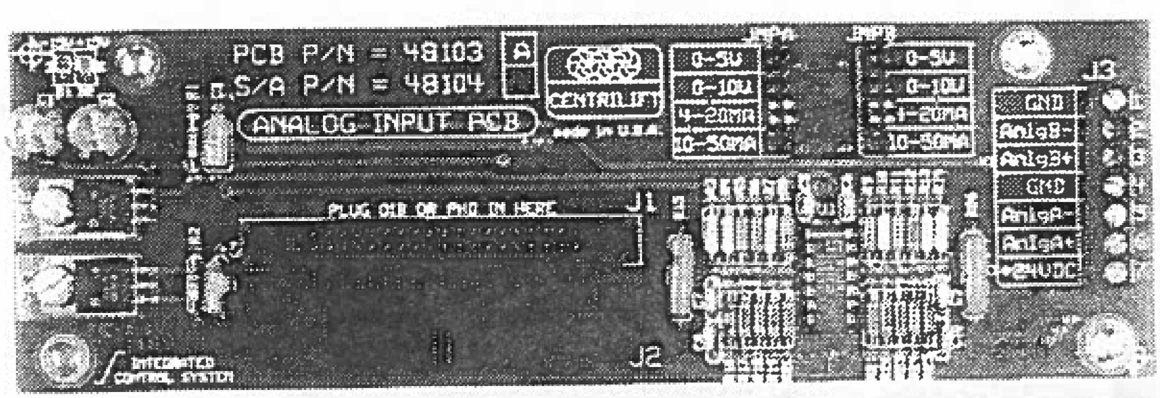


Figure 4.13 Analog Input Board

SECTION 5:

START-UP & OPERATION

5.1 INTRODUCTION

This section provides a procedure for an initial set-up and start-up of the Electrospeed ICS controller. Additional information is provided to explain how to change the setup for different loads or modes of operation. Unusual applications may require a more in depth understanding of the Electrospeed than can be provided here. The Functional Description Section (section 4) of this manual provides a more detailed description of the workings of the Electrospeed ICS. Centrilift also offers classroom training which covers operation and maintenance of the Electrospeed Variable Speed Controller.

5.2 GENERAL

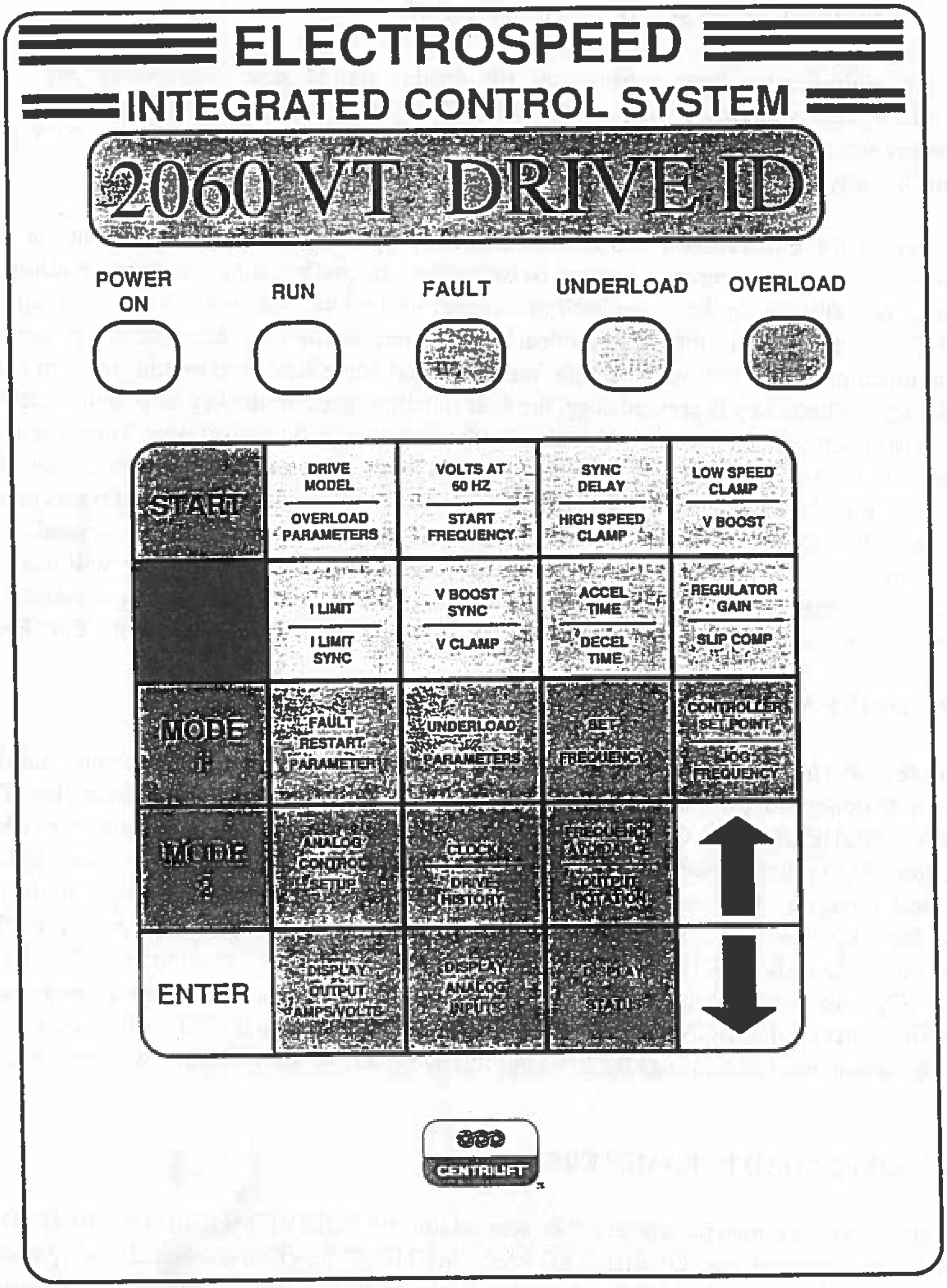
After the Electrospeed is installed, before applying power, verify the following.

* All field wiring is connected properly.
* All mechanical and electrical connections are tight.
* SCR gate, and transistor base lead push-on connectors are fully engaged and tight.
* The interior of the VSC is free from all foreign materials (wire scraps, metal filings, etc.).
* Output current transformers are connected to the correct tap for the VSC rating, and the push-on connectors are fully engaged and tight.

WARNING
THE ELECTROSPEED CONTROLLER CONTAINS 480V AC. INSURE ALL POWER IS DISCONNECTED, AND CHECK FOR VOLTAGE ACROSS THE DC BUS CAPACITORS BEFORE REPLACING ANY COMPONENTS. ONLY QUALIFIED SERVICE TECHNICIANS SHOULD ATTEMPT THE FOLLOWING PROCEDURES.

For initial start-up or troubleshooting it is recommended, where practical, that the load be disconnected, and the VSC operated no-load to verify correct operation before a load is applied.

Apply power to the controller, and turn on the input disconnect switch. On power up, the Operator Interface should display "F18 POWERUP". The POWER ON and FAULT LED's should be on. If this is the case, proceed to section 5.3 (setup). If not, refer to section 6 (maintenance & diagnostics/repair).



ICS OPERATOR INTERFACE KEYPAD

Figure 5.1

5.3 FUNCTIONAL DESCRIPTION, KEY PAD

Once the controller has been powered up, the display should read "F18 POWERUP". The "F18 POWERUP" indication will alternate with "LOCKOUT" if the unit is not timing for an automatic restart. Before any setup can start, the STOP key must be pressed. The display will indicate "STOPPED", and the unit is ready for setup.

The setup of the Electrospeed ICS is done from the Operator Interface located on the door of the enclosure. Each parameter that needs to be defined is selected by using the corresponding key on the keypad. We will start in the upper left hand corner of the block of yellow keys, just adjacent to the START key, and describe the purpose of each parameter, and how to determine the proper setting for your application. Each key has multiple functions, and some functions require the entry of multiple parameters. When a key is pressed once, the first function listed on the key label will be activated, and the first parameter with its last active setting for that function will be displayed. Subsequent keystrokes will step through each parameter that needs to be set for that function. The keystroke following the last parameter for a function will activate the next function for the key. If a parameter needs to be changed, press the UP or Down arrow keys, located in the lower right hand corner of the keypad, to increment or decrement the parameter. Once the displayed value has changed, the display will flash, indicating the parameter has changed, but has not yet been entered. The new setting can be aborted at this point by pressing any key other than the ENTER key. To enter the new value, press the ENTER key.

5.3.1 DRIVE MODEL

The base model number for each Electrospeed VSC is stored in memory on the Operator Interface Board, along with upper and lower limits for parameters affected by the ratings of the controller. Pressing the "DRIVE MODEL/OVERLOAD PARAMETERS" key one time will select the "DRIVE MODEL" function. The model number should agree with the nameplate model number on the controller (refer to table 2.1, page 6). If it needs to be changed, use the arrow keys to select the proper model number and press the ENTER key. For protection of the controller; once the drive model is changed the "OVERLOAD PARAMETERS", "I-LIMIT", and "I-LIMIT SYNC" reset to zero. The basic Electrospeed ICS controller models are set up for variable torque loads. For constant torque applications, select the DRIVE DESIGNATOR with the CT suffix, rather than the VT suffix. This will derate the output current and KVA ratings by 20%, but the overload and start currents will remain the same.

5.3.2 OVERLOAD PARAMETERS

This sets motor overload parameters. The second time the "DRIVE MODEL/OVERLOAD PARAMETERS" key is pressed, the "OVERLOAD PARAMETERS" function is selected. Two parameter entries are required, the overload setpoint and overload time (requires a third keystroke). The overload setpoint establishes the maximum output current that can be delivered to the motor without engaging the overload routine. The overload time is the time in seconds (1-60) to trip off with 150% overload setpoint current. The relationship between time and current is established by a constant I^2t, which simulates motor heating. In a typical submersible installation the overload time might be set up for 2 seconds at 150% current. The I^2t would be $(1.5)^2 * 2 = 4.5$. If the overload current was to reach 200%, the time to trip would be $4.5/(2.0)^2 = 1.125$ seconds. If the VSC is heavily loaded, the I.O.T. will trip to protect the controller before 200% current is reached.

The typical setting for the overload setpoint is the motor nameplate current, or motor nameplate current multiplied by the transformer ratio (voltage out/voltage in), when a transformer is connected between the controller and motor. The overload time should be set between two and five seconds for a submersible motor, and 30 to 45 seconds for conventional motors. Both the overload setpoint, and overload time should be set as low as practical for the application.

5.3.3 VOLTS AT 60 HZ

This sets the voltage to frequency ratio. Pressing the "VOLTS AT 60 HZ/START FREQUENCY" key once selects the "VOLTS AT 60 HZ" function. Select the voltage required for 60 Hz. operation and enter. For surface motors, this would typically be the nameplate voltage for 60 Hz.. If the motor nameplate voltage is for 50 Hz. Multiply by 1.2 to arrive at the proper voltage for 60 Hz. operation. When an output transformer is used, i.e. with a submersible motor, divide the nameplate voltage by the transformer ratio (input voltage/output voltage). If 50 Hz. rating, multiply by 1.2 as before. In some cases the "VOLTS AT 60 HZ" parameter will exceed the 480 volt rating of the controller, however, this only sets the voltage to frequency ratio, and the VSC output will not exceed its ratings.

Motors exhibit the characteristic of having a minimum current point, established by voltage and load. The "VOLTS AT 60 HZ" parameter can be adjusted while the system is operating to determine the minimum current point. The "VOLTS AT 60 HZ" can be incremented or decremented a few volts at a time, while the current is monitored to determine the minimum current point.

5.3.4 START FREQUENCY

This sets the output frequency for starting the motor. The "START FREQUENCY" function is selected by pushing the "VOLTS AT 60 HZ/START FREQUENCY" key two times. Select the desired setting, and press the "ENTER" key. When the system is started, the VSC will ramp up to the set "START FREQUENCY" very quickly. The output will be held at the "START FREQUENCY" for a period of time referred to as "SYNC DELAY". The "SYNC DELAY" time allows the motor to accelerate to the starting frequency. At the end of the "SYNC DELAY" time, the VSC will accelerate the motor to the preset operating frequency. The "START FREQUENCY" should be set as low as practical for the application. Typical settings would be 10 to 12 Hertz for submersible motors and 3 to 5 for surface motors. The available motor starting torque is directly proportional to the square of the starting current, and inversely proportional to the starting frequency. This shows the first criteria for successful starting is to be able to deliver the maximum current available to the motor, and the second criteria is to start at the lowest possible frequency.

5.3.5 SYNC DELAY

"SYNC DELAY" is displayed in seconds, and is the time allowed for the motor to accelerate to the starting speed established by "START FREQUENCY". "SYNC DELAY" is adjustable from 0 to 60 seconds. The "SYNC DELAY" function is accessed by pressing the "SYNC DELAY/HIGH SPEED CLAMP" key one time. Use the up/down arrow, and "ENTER" keys to select the value desired. Typical settings for submersible installations would be 2 to 5 seconds. Surface motors require more time due to higher inertia, typically 10 to 15 seconds. At the end of "SYNC DELAY" the controller will accelerate the motor at the "ACCEL RATE", or will follow the motors acceleration limited by "I LIMIT", to the preset frequency. If "SYNC DELAY" is too short, the motor may not start. If this happens, the controller will typically shut down in overload. As additional protection, the Electrospeed ICS will shut down on an underfrequency trip if it is operating in "I-LIMIT", below "LOW SPEED CLAMP", and the output frequency is not increasing. This provides a positive means for detecting a stalled motor.

5.3.6 HIGH SPEED CLAMP

"HIGH SPEED CLAMP" sets the maximum operating frequency, programmable 40 to 120 Hertz. The "HIGH SPEED CLAMP" function is selected by pressing the "SYNC DELAY/HIGH SPEED CLAMP" two times. Use the up/down and "ENTER" keys to select the desired value. The maximum operating frequency should not be allowed to exceed the maximum operating speed for the equipment operated, as recommended by the manufacturer. Operating rotating equipment above maximum rated speeds, may result in damage to equipment and injury to personnel.

5.3.7 LOW SPEED CLAMP

"LOW SPEED CLAMP" sets the minimum operating frequency, programmable 0 to 60 Hertz. The "LOW SPEED CLAMP" function is selected by pressing the "LOW SPEED CLAMP/V BOOST" key one time. Use the up/down and "ENTER" keys to select the desired value. For submersible motors, the "LOW SPEED CLAMP" should not be set below the speed that provides adequate flow rate by the motor, for proper cooling. The flow of cooling air for conventional motors decreases with speed creating potential cooling problems, especially in constant torque applications where high input currents are needed at low speeds. The minimum operating speed should be based on the motor manufacturer's recommendations.

5.3.8 V BOOST

At low frequencies it is sometimes desirable to increase the output voltage above the normal base voltage. "V BOOST" allows an offset voltage, adjustable 0 to 200 VAC, to be added to the "zero speed" voltage, which would otherwise be zero. The volts-per-hertz ratio is then internally modified to decrease the effect of "V BOOST" linearly with speed, and at maximum speed the effect is zero. "V BOOST" is not active during "SYNC DELAY". To select the "V BOOST" function, press the "LOW SPEED CLAMP/VBOOST" key two times. Use the up/down and "Enter" keys to select the desired value.

At low frequencies the resistive portion of the motor impedance becomes more significant when compared to the reactive portion. This can limit the motor excitation current, preventing optimum performance at low speeds. By adding "V BOOST", performance can be improved. "V BOOST" can also compensate for the effect of output cable and/or transformer voltage drop, which will also be more pronounced at low frequencies.

Initial setup should typically be done without any "V BOOST", and then increase the "V BOOST" as needed. Generally "V BOOST" is not used with variable torque loads, since the motor load decreases so dramatically with speed. The effective decrease in voltage that is experienced may even improve the efficiency of the underloaded motor. Constant torque loads, however, require full torque even at low speeds, making the use of "V BOOST" necessary in many applications. One way to determine the proper amount of voltage boost in a constant torque application would be to operate the controller at minimum speed, and adjust "V BOOST" to obtain minimum current, similar to the technique described in the "VOLTS AT 60 HZ" section.

5.3.9 I LIMIT

"I LIMIT" limits the maximum output current for the application. "I LIMIT" is adjustable 0 to 150% of the controller's output current rating. To set the "I LIMIT" parameter, press the "I LIMIT/I LIMIT SYNC" key one time, and use the up/down and "ENTER" keys to select the desired value. "I LIMIT" is not effective during "SYNC DELAY". If the controller is operating in "I LIMIT", the output frequency will change within the "HIGH SPEED CLAMP" and "LOW SPEED CLAMP" range to maintain the output current to the "I LIMIT" value. "I LIMIT" is frequently used in submersible pump applications to limit the motor input current to its nameplate rating. When gas is ingested into the pump, the load will decrease, allowing for higher frequency operation at the "I LIMIT" current. The higher speeds will help force the gas on through the pump, at which time the load will increase, and the frequency will drop.

5.3.10 I LIMIT SYNC

"I LIMIT SYNC" sets the maximum output current during "SYNC DELAY", adjustable 0 to 150% of the controller's output current rating. To set the "I LIMIT SYNC" parameter, press the "I LIMIT/ I LIMIT SYNC" key two times, and use the up/down and "ENTER" keys to select the desired value. A good initial setting for "I LIMIT SYNC" would be 150% motor nameplate current. If an output transformer is used, as with submersible pumps, set to 150% of the motor current multiplied by the transformer ratio (output voltage divided by input voltage).

5.3.11 V BOOST SYNC

"V BOOST SYNC" is adjustable 0 to 200 VAC, and allows the output voltage during "SYNC DELAY" to be increased above the base voltage at the starting frequency. "V BOOST SYNC" performs the same basic function as "V BOOST", but is present only during starting, to allow the appropriate compensation for the higher voltage drop associated with starting currents. To access the "V BOOST SYNC" function, press the "V BOOST SYNC/V CLAMP" key one time. Use the up/down and "ENTER" keys to select the desired value. "V BOOST SYNC" should be set to zero for the initial start-up, and increased only if difficulties in starting are encountered. The output current should be monitored during the initial start attempts to determine the maximum output current delivered in the event the start is unsuccessful. The output current not reaching the "I LIMIT SYNC" value is an indication that increasing "V BOOST SYNC" could increase output current.

5.3.12 V CLAMP

"V CLAMP" sets the maximum output voltage. Adjustable from 240 to 550 VAC. To access the "V CLAMP" function, press the "V BOOST SYNC/V CLAMP" key two times. Use the up/down and "ENTER" keys to select the desired value. Typical settings would be 480VAC for 460/480VAC input or 400 VAC for 380/400. The maximum obtainable output voltage will be approximately 5% higher than the input voltage, but cannot exceed 550 VAC.

5.3.13 ACCEL TIME

Adjusts the time for the controller to make a 60Hz. increase in output frequency. Adjustable from 5 to 200 seconds. To determine actual rate (Hz./sec), divide 60 by the set time in seconds. To access the "ACCEL TIME" function, press the "ACCEL TIME/ DECEL TIME" key one time. Use the up/down and "ENTER" keys to select the value desired. The motor acceleration will be limited by this setting if the controller supplies sufficient current to maintain the rate, otherwise the acceleration rate will be limited by available current. When operating in the set point control mode, the "ACCEL TIME" should be set to the minimum value (5 seconds) to allow the response of the controller to be regulated by the set point control algorithm.

5.3.14 DECEL TIME

Adjusts the time for the controller to make a 60Hz. reduction in output frequency. Adjustable from 5 to 200 seconds. To determines the actual rate (Hz./sec), divide 60 by the set time in seconds. To access the "DECEL TIME" function, press the "ACCEL TIME/DECEL TIME" key two times. Use the up/ down and "ENTER" keys to select the value desired. If the controller is operating a high inertia load, the deceleration rate may be limited by regeneration. An overdriving load will in effect become an induction generator, and supply power to the DC bus. To prevent an overvoltage condition on the DC bus, the controller will continue switching the inverter at a rate to provide the voltage/frequency ratio set in on the "VOLTAGE AT 60 HZ" parameter. The controller will follow the motor down in speed. When operating in the set point control mode, the "DECEL TIME" should be set to the minimum value (5 seconds) to allow the response of the controller to be regulated by the set point control algorithm.

5.3.15 REGULATOR GAIN

"REGULATOR GAIN" controls the response of the bus voltage control loop to changes in input voltage, load, and output frequency. "REGULATOR GAIN" is adjustable from 0 to 100%. To access the "REGULATOR GAIN" function, press the "REGULATOR GAIN/SLIP COMP" key one time. Use the up/down and "ENTER" keys to select the value desired. The initial setting should be 70%. Increasing the gain, speeds up the regulator response. If system stability problems are encountered, the "REGULATOR GAIN" should be increased. When operating no-load, the gain should be set to 50% or higher to obtain a stable output voltage.

5.3.16 SLIP COMP

"SLIP COMP" provides output speed correction proportional to the output current, to increase inverter frequency and voltage to offset induction motor slip with load. "SLIP COMP" is adjustable 0 to 7.5% in 0.1% increments. To access the "SLIP COMP" function, press the "REGULATOR GAIN/SLIP COMP" key two times. Use the up/down and "ENTER" keys to select the value desired. "SLIP COMP" is used where precise speed control under widely varying load conditions is desired. Set "SLIP COMP" to the full load slip (in percent) for the motor.

5.3.17 FAULT RESTART PARAMETERS

~~The~~ "FAULT RESTART PARAMETERS" makes provisions for the input of three parameters controlling automatic restarts in the event of a fault (refer to table 5.1 for list of faults). Pressing the "FAULT RESTART PARAMETERS" key will access the function and display the first parameter. Subsequent keystrokes will display the remaining two parameters. The first parameter is the number of restarts allowed before the controller will lock out. If set to zero, no fault restarts are allowed. The display will indicate "0000 FLT RESTARTS", and can be adjusted from 0000 to 0005. The second parameter is the time delay before the attempted restart. The display will indicate "0002 MIN RESTART" after the second keystroke, and can be adjusted from 0002 to 0300 minutes. The third parameter is the successful run time required before the restart counter will be reset to zero, to again allow the full number of restart attempts. The display indicates "0005 MIN FLTRESET", and can be adjusted from 0005 to 0300 minutes. Use the up/down and "ENTER" keys to select the desired values when the parameter is displayed (refer to table 5.1).

One of the following messages will be displayed when a FAULT occurs. The words LOCKOUT will alternate with the message when the maximum number of restarts have occured that were set on the Key Pad Fault Restart Parameters. Pressing the STOP key will remove the message and RESET the VSC for a START attempt. A fault code for engineering use may also be displayed.

CODE	MESSAGE	EXPLANATION
F0	POWER OFF	Input Power was removed
F1	A + IOT	An IOT caused in A phase + Inverter section
F2	A - IOT	An IOT caused in A phase - Inverter section
F3	B + IOT	An IOT caused in B phase + Inverter section
F4	B - IOT	An IOT caused in B phase - Inverter section
F5	C + IOT	An IOT caused in C phase + Inverter section
F6	C - IOT	An IOT caused in C phase - Inverter section
F7	-15V LOSS	Loss of the Negative 15 volt supply
F8	+15V LOSS	Loss of the Positive 15 volt supply
F9	OVER VOLT	DC Bus voltage exceeded 736 volts
F10	OVER TEMP	SCR heat sink temp. exceeded 190°F
F11	INPUT A - B	A/B phase voltage went below 304 volts
F12	INPUT B - C	B/C phase voltage went below 304 volts
F13	INPUT C - A	C/A phase voltage went below 304 volts
F14	OVERLOAD	Exceeded setting for Overload Amps
F15	DCB COM	Loss of Digital Control Board communication
F16	INPUT ZC	Loss of sync with AC Input zero crossing
F17	INPUT PHASE	Input phase rotation changed
F18	POWER UP	Normal when power is turned on
F19	LOW SPEED	Drive speed forced below minimum speed setting by I Limit
F20	OIB COMM	No Operator Interface Board communications
F21	UNDERLOAD	Shut down from underload setting
F22	EEprom FLT	There is a problem with the EE Prom
F23	DRIVE MODEL	Drive Model selection was cha;nged
F31	SET UL	Underload setting was changed
F32	SET OL	Overload setting was changed
F33	START	A normal START was initiated
F34	STOP	A normal STOP was initiated
F35	AUX STOP	An AUXILIARY STOP was initiated
F36	E STOP	An EMERGENCY STOP was initiated

Table 5.1 **Fault Messages Displayed**

5.3.18 UNDERLOAD PARAMETERS

The "UNDERLOAD PARAMETERS" makes provisions for the input of four parameters controlling automatic restarts in the event of an underload condition. Pressing the "UNDERLOAD PARAMETERS" key will access the function and display the first parameter. Subsequent keystrokes will display the remaining three parameters. The first parameter is the underload set point. When the controller output current becomes less than this set point, the underload routine is activated. The display will indicate "0000 AMPS UL SET", and can be adjusted from 0000 to the current rating of the controller.

The second parameter is the underload restart time, which is the delay to restart after the underload shutdown. The display will indicate "0002 MIN RESTART", and can be adjusted from 0002 to 1000 minutes. The underload restart time is also used as the minimum successful run time required for the restart counter to be reset to zero, to again allow the full number of restart attempts. The third parameter is the number of unsuccessful restart attempts before lockout. The display will indicate "0000 UL STARTS", and can be adjusted from 0000 to 0030 or infinite restarts designated by "INF". The fourth parameter is the delay time between when underload is first detected to when the controller actually shuts down. The display will indicate "0000 SEC UL TRIP", and is adjustable from 0001 to 0100 seconds. Use the up/down and "ENTER" keys to select the desired value when the parameter is displayed.

5.3.19 SET FREQUENCY

"SET FREQUENCY" sets the operating frequency of the controller. "SET FREQUENCY" is adjustable in 0.1 Hz. increments between "LOW SPEED CLAMP" and "HIGH SPEED CLAMP". Operating speed is also limited by the current limit.

5.3.20 CONTROLLER SETPOINT

The Electrospeed Integrated Control System contains an integral setpoint controller. The "CONTROLLER SETPOINT" input is for entering the setpoint at which the controller is to operate. Before the setpoint controller can be used, the "ANALOG CONTROL SETUP" must be performed, which is discussed below. The setpoint range is determined by the ZERO and SPAN that is set in the "ANALOG CONTROL SETUP". The "CONTROLLER SETPOINT", parameter is active only for the analog input selected, A or B.

5.3.21 JOG FREQUENCY

The "JOG FREQUENCY" input is basically a frequency set point, which is activated by the JOG input from either the Door Interface Board, or the Customer Interface Board. When the JOG input is activated by a contact closure, the controller will go through a normal start routine, and ramp to the set "JOG FREQUENCY". The controller will operate at this frequency as long as the JOG input is maintained. When the JOG input is removed, the controller will do a controlled stop.

5.3.22 ANALOG CONTROL SETUP

The "ANALOG CONTROL SETUP" provides a means for setting up the analog inputs, and selecting the follower or setpoint control modes. The Integrated Control System is setup for two analog inputs, A and B. When the "ANALOG CONTROL SETUP" key is pressed, the display will indicate "ANALOG A SET UP" or "ANALOG B SET UP", depending on the last selection. The up arrow key will change to B if A is displayed, and the down arrow key will change to A if B is displayed. Use the "ENTER" key to accept any change. The setup of A and B are identical, therefore, only one is described.

When the "ANALOG CONTROL SETUP" key is pressed a second time, the display will indicate "SET POINT MODE" or "FOLLOWER MODE", depending on the last selection. The up arrow key will select the "SET POINT MODE", and the down arrow key will select the "FOLLOWER MODE". Again if a change is made, press "ENTER". If an analog input is to be monitored only, set it up as a set point input, and make provisions to insure the signal is never selected for control.

The third time the "ANALOG CONTROL SETUP" key is pressed, the display will indicate "DIRECT ACTING" or "REVERSE ACTING", in either the setpoint or follower modes. The up arrow key will select "REVERSE ACTING", and the down arrow will select "DIRECT ACTING". "REVERSE ACTING" would be selected if the input signal is inverted.

The fourth time the "ANALOG CONTROL SETUP" key is pressed, the display will indicate "0-5VLTS", "0-10VLTS", "4-20 mA", or "10-50 mA" in either the setpoint or follower modes. This allows the selection of the actual input signal to the controller (refer to the sections describing the Customer Interface Board, and the Analog Input Board). The selections available are stored in the order listed above. The display will indicate the last selection for this parameter. Use the up arrow key to go forward in the list, and down arrow key to back up in the list. Press "ENTER" to accept selection.

The fifth time the "ANALOG CONTROL SETUP" key is pressed, the display will indicate Analog A or B setup if the follower mode was selected, indicating the setup is complete. If the setpoint mode was selected, the display will indicate "RPM", "PSI", "%", "MTRS" (meters), "M3/D" (cubic meters per day), "KGc2" (kilograms per square centimeter), "GPM" (gallons per minute), " FT" (feet), or "BPD" (barrels per day). This selects the units to be displayed for the setpoint control mode. Units are not selectable for the follower mode, as the analog input will always be scaled in percent of speed with the "HIGH SPEED CLAMP" equal to 100%. The selections available are stored in the order listed. The display will indicate the last selection for this parameter. Use the up arrow key to advance in the list, and down arrow key to go back. Press "ENTER" to accept selection.

The sixth time the "ANALOG CONTROL SETUP" key is pressed, assuming the setpoint control mode was selected, the display will indicate "00.0 PSI ZERO", assuming PSI was selected as the units in the previous step. Many times the analog signal represents a portion of the overall range of the parameter being measured. The analog signal's representation of zero may in fact not be the zero for the overall range of the parameter. In a situation such as this, to display the measured parameter in meaningful units, such as PSI, it is necessary to define the zero of the analog input. The "ZERO" can be adjusted with the up/down arrow keys. In most situations, however the "ZERO" will be 00.0.

The seventh time the "ANALOG CONTROL SETUP" key is pressed, the display will indicate "00.0 PSI SPAN" assuming, again, PSI was selected as the units. The "SPAN" can be adjusted with the up/down arrow keys to display the maximum value the measured parameter will be, in the units selected, when the analog input is at its maximum.

The next three times the "ANALOG CONTROL SETUP" key is pressed, three gain adjustments for the setpoint control will be displayed and can be adjusted 0 to 100%. The setpoint control routine uses a PID (proportional, integral, derivative) algorithm, with one gain adjustment associated with each control element. Each control element is summed together to provide the speed demand for the variable speed controller. Each gain adjustment, its purpose, and its setup is described below.

1.) Integral Gain: The output of the integrator is the speed demand for the variable speed controller. The setpoint control algorithm updates the speed demand every 15 milliseconds. At each update, the analog input is compared to the setpoint, and the difference is the "error". The integrator output (speed demand) is incremented or decremented by an amount proportional to the product of the "error" and Integral Gain. For each one percent "error" per one percent gain, the controller frequency will increase (or decrease) approximately 0.1 Hz every five seconds, assuming the other gains are zero. If the "error" or gain is doubled, the time for the 0.1 Hz change is reduced to 2.5 seconds, etc.. The greater the error, the greater the change; and the higher the set gain the greater the change. The effect of the "Integral Term" is accumulative.

2.) Proportional Gain: The Proportional Gain modifies the speed demand to reduce response time. At each 15 millisecond update, an amount proportional to the product of the "error" and Proportional Gain is added to or subtracted from the speed demand. For every one percent of "error" per one percent of gain, the proportional term corresponds to an approximate 0.05 Hz change in speed (the frequency resolution of the variable speed controller is 0.1 Hz, and therefore, the output of the controller will not change in 0.05 Hz increments). The"Proportional Term" is noncumulative. A new "Proportional Term" is calculated for each up date. and is effective for only that update period. The speed demand signal is not affected by any previous "Proportional Terms".

3.) Derivative Gain: The Derivative Gain also modifies the speed demand at each update. An amount proportional to the product of the difference between the analog input readings (of the last two updates) and the Derivative Gain is either added to or subtracted from the speed demand to limit overshoot in systems where fast response is needed. The "Derivative Term" will tend to decrease the speed demand if the difference between the analog signal readings of the present and previous updates is negative, and will tend to increase the speed demand if the difference is positive.

When setting the gains on the PID controller, it is generally best to start with zero proportional and derivative gains. A straight Integral controller will perform adequately in most applications. Set the "Integral Gain" as low as practical for system operation. Add "Proportional Gain" only when system response needs to be faster than practically achievable with "Integral" only. Add "Derivative Gain" to reduce overshoot.

5.3.23 CLOCK

The Integrated Control System is equipped with a "real time" clock that provides the date (month and day) and the time (hours and minutes). When the "CLOCK/DRIVE HISTORY" key is pressed, the time will be displayed. To change the time use the up and down arrow keys to select the time, and press "ENTER". The clock is displayed in the 24 hour format. Pressing the "CLOCK/DRIVE HISTORY" key a second time will bring the date onto the display. To change the date, again use the up/down arrow and "ENTER" keys as before. The primary purpose of the clock is to be able to record the dates and times for the "DRIVE HISTORY".

5.3.24 DRIVE HISTORY

The Operator Interface Board utilizes an EEPROM (electrically erasable programmable read only memory) to store setup parameters. The EEPROM maintains the data stored even when the power is interrupted. A block of this memory is set aside to store up to fifty start/stop events. When the "CLOCK/DRIVE HISTORY" key is pressed three times, the latest start/stop event is displayed. The display consists of the date and time of the occurrence, and a fault or operational code. Subsequent pressing of the down arrow key will scroll through the events in the reverse order of their occurrence.

CODE	DESCRIPTION
000.0 Hz	Frequency of operation
SYNC	Controller operating in "SYNC DELAY"
IL	Controller operating in current limit
FOR	Controller operating in the forward direction
REV	Controller operating in the reverse direction
F	Same as FOR
R	Same as REV
ACCL	Controller accelerating
DECL	Controller decelerating
MODE 1	Controller operating in Mode 1
MODE 2	Controller operating in Mode 2
MOD 1	Same as MODE 1
MOD 2	Same as MODE 2
FREQ AVOID	Controller operating in frequency avoidance
STOP	Controller is stopped
HI BUS VOLTS	Controller's bus voltage is too high for restart

Table 5.2 - Display Status Codes

5.3.25 FREQUENCY AVOIDANCE

There are many times when rotating equipment will have regions of unstable operation within the desired range of operating speeds. The region is centered around a particular speed, referred to as a "critical speed". The Integrated Control System provides a means to prevent operation at critical speeds. The "FREQUENCY AVOIDANCE" input allows center frequencies, and a band width to be programmed. Once programmed to avoid a particular frequency, the controller will not operate in the regions defined by the center frequencies and bandwidth. The controller will ramp through the regions at the set accel and decel rates, and if set to operate within the region, the controller will operate just above the upper limit.

To set up the controller to avoid certain frequencies, press the "FREQUENCY AVOIDANCE/OUTPUT ROTATION" key. The display will indicate whether the function is ON or OFF. Use the up arrow key to turn it on, and the down key to turn it off. Press the "FREQUENCY AVOIDANCE/OUTPUT ROTATION" key a second time, and the display will indicate "000.0 HZ + OR - AVOID". This sets the band width. If 001.0 Hz. is set, the controller will avoid frequencies 1.0 Hz below to 1.0 Hz above the set frequency. Press the "FREQUENCY AVOIDANCE" again, and the display will indicate "000.0 Hz FREQ. #1". Use the up and down arrow keys to set the frequency corresponding to a critical speed, and press "ENTER". Press "FREQUENCY AVOIDANCE" again, and the display will indicate "000.0 Hz FREQ. #2". Set the second frequency in the same way. Five different frequency avoidance settings can be made. The band width setting will apply to all avoidance frequencies.

5.3.26 OUTPUT ROTATION

After cycling through all eight of the "FREQUENCY AVOIDANCE" frequencies, the next keystroke will initiate the "OUTPUT ROTATION" parameter input, which will display either "EXT ROTATION", "REV ROTATION", or "FOR ROTATION" depending on the last entry. The "OUTPUT ROTATION" parameter controls the phase rotation of the controller's output voltage, and can be set for external control (forward/reverse switch, see sections on Door Interface Board and Customer Interface Board). reverse rotation (CBA). or forward rotation (ABC). The three settings are stored in the order listed above. therefore, to return to a setting, use the down arrow key, and to advance, use the up arrow key.

5.3.27 DISPLAY OUTPUT AMPS/VOLTS

This displays the controller's output currents and voltage. This is a display key only. Pressing the key the first three times will step through A, B, and C output currents, and the fourth will display a representative phase-to-phase output voltage. The output voltages from the Electrospeed are inherently balanced, therefore, there is no practical reason for providing all three phase-to-phase voltages.

The DISPLAY OUTPUT AMPS/VOLTS also provides a lockout code. Once a lockout code has been entered only authorized users with the code can alter settings of the drive, except for SET FREQUENCY Key. To gain access to keypad enter correct code and press "**ENTER** ", you will have fifteen minutes to changed settings before keypad automatically goes into lockout. If you have forgotten the code, open controller door and move the jumper on the door interface board (DIB) from Code to Keypad. This will bypass the lockout circuitry.

5.3.28 DISPLAY ANALOG INPUT

This displays analog A and analog B inputs to the controller. Pressing this key will cause analog A to be displayed. Subsequent pressing of the key will alternate between A and B. If the "ANALOG CONTROL SETUP" for an input was the follower mode, that input will be displayed in percent of the set speed range. If the input was setup for the setpoint control mode, the input will be displayed in the units selected. After pressing DISPLAY ANALOG INPUT there is a .5 second delay before the display changes.

5.3.29 DISPLAY STATUS

The "DISPLAY STATUS" is normally selected after the setup and start-up are complete. The "DISPLAY STATUS" will display the present status of the controller.

5.4 SET-UP FOR ESP'S

Before starting the adjustment for set up of the ICS controller the following steps should be taken to prevent damage to the equipment and/or personal injury to the operator.

Complete the start up sheet (see figure 5.2, page 62) and make appropriate adjustments for setup. Set up adjustments are made on the Operator Interface Keypad (see figure 5.1, page 47), by pressing the appropriate function key one or more presses to select the desired function to be adjusted. Press the Up or Down Arrow key to change the value of the selected function then press **ENTER** to keep the change. The display will start flashing when a change is made and stop flashing when the **ENTER** Key is pressed to show the change was accepted by the Computer. Pressing any other key before pressing **ENTER** will abort the selection and no change will be made.

1. Check to insure that power to the controller is off.
2. Check for proper grounding on all surface equipment.
3. Check that the load to the controller is disconnected.
4. Check that power cable connections are mechanically sound and insulated.
5. Check all mechanical and electrical connections on power electronics and circuit boards.
6. Check input power and control voltage fuses.
7. Check input and output transformer rating, connections, and tap settings.
8. Turn power on and check incoming voltage (460 VAC phase to phase, minimum 368 to maximum 506).
9. Turn on input disconnect switch, display should read "F18 POWER UP", push stop button on Key Pad.
10. Ensure that all DC voltage indicator LED's are on (all PC boards).
11. Check that Lost Comm LED on Digital Control Board is off.
12. Check that Converter Board signal LED's are off.
13. Check that Inverter Boards signal LED's are off, and ensure that header plugs are set to the auto-reset position.

Electrospeed ICS Start-Up Work Sheet

Customer: ______________________ **Date:** ______________

Well Number: ____________________ **Drive S/N:** ____________

1. Motor Voltage: _______ Amps: ______ Cable Size: _______ Length: ________
2. Desired Operating Frequency Minimum: _______ Maximum: __________
3. Maximum Volts Available (Input Voltage): __________
4. Transformer Secondary Voltage @ Maximum Hertz:

$$\frac{\text{Motor Voltage \_\_\_\_\_\_ X Max Hz. \_\_\_\_\_\_}}{\text{60 Hz.}} + \text{Cable Drop \_\_\_\_\_\_} = \text{\_\_\_\_\_\_}$$

5. Available Transformer Taps: ______________
6. Transformer Ratio: $$\frac{\text{Available Transformer Voltage \_\_\_\_\_\_}}{\text{Tranformer Primary 480}} = \text{\_\_\_\_\_\_}$$
7. Secondary Voltage @ 60 Hertz:

$$\frac{\text{Secondary Voltage @ Max. Hertz \_\_\_\_\_\_ X 60}}{\text{Maximum Hertz. \_\_\_\_\_\_}} = \text{\_\_\_\_\_\_}$$

8. Required 60 Hertz Voltage:

$$\frac{\text{Secondary Voltage @ 60 Hertz \_\_\_\_\_\_}}{\text{Transformer Ratio \_\_\_\_\_\_}} = \text{\_\_\_\_\_\_}$$

9. Required KVA @ Max Hertz:

$$\frac{\text{Surface Voltage \_\_\_\_\_\_ X Motor Nameplate Amps \_\_\_\_\_\_ X 1.73}}{\text{1000}} = \text{\_\_\_\_\_\_}$$

10. Check for proper controller sizing (refer to table 2.1, page 8).

Figure 5.2 Start-Up Work Sheet ICS Controller

5.4.1 FORMING CAPACITORS

The following step-by-step procedure will set the majority of the parameters required for actual startup of the ICS controller in normal submersible pump operating conditions. Be sure to follow the steps in the order presented.

Turn on the Main Input Power Switch, then press the OFF key on the Keypad.

1. Set DRIVE MODEL to nameplate rating of controller.
2. Set OVERLOAD PARAMETER to maximum rating of controller.
3. Set SEC OL TRIP to 5 seconds.
4. Set VOLTS AT 60HZ to 230.
5. Set START FREQUENCY to 10 Hz.
6. Set SYNC DELAY to 2 seconds.
7. Set HIGH SPEED CLAMP to hertz required for application.
8. Set LOW SPEED CLAMP to hertz required for application.
9. Set V BOOST to zero
10. Set I LIMIT to maximum for rating of contoller.
11. Set I LIMIT SYNC to maximum for rating of contoller.
12. Set V BOOST SYNC to zero.
13. Set V CLAMP to value of incoming voltage, no greater than 480 volts.
14. Set ACCEL TIME to 10 seconds.
15. Set DECEL TIME to 10 seconds.
16. Set REGULATOR GAIN to 70 %.
17. Set SLIP COMP to zero.

18. Set FAULT RESTART PARAMETERS
    a. Set FLT RESTARTS to 5.
    b. Set MIN RESTART to 30 minutes.
    c. Set MIN FLTREST to 30 minutes.
19. Set UNDERLOAD PARAMETERS
    a. Set AMPS UL SET to zero.
    b. Set MIN RESTART to 30 minutes.
    c. Set UL RESTARTS to 5.
    d. Set SEC UL TRIP to 30 seconds.
20. Set SET FREQUENCY to 60 Hz SET SPD.
21. Set CLOCK to current time.
22. Set DATE to current date.
23. Set FREQUENCY AVOIDANCE to OFF.
24. Set OUTPUT ROTATION to FORWARD.
25. Select MODE 1, and ENTER.
26. Press DISPLAY STATUS.
27. Start controller. Controller will ramp to 60 Hertz.
28. Press DISPLAY OUTPUT AMPS/VOLTS to monitor output volts, at 60 Hertz drive should have 230 volts out.
29. Increase VOLTS AT 60 HZ. in 50 volt increments with five minute pauses between each increase until maximum output voltage is reached.
30. Press OFF to stop controller.

(continued next page)

FOR INITIAL START-UP OR TROUBLESHOOTING IT IS RECOMMENDED, WHERE PRACTICAL, THAT THE LOAD BE DISCONNECTED, AND THE VSC OPERATED NO-LOAD TO VERIFY CORRECT OPERATION.

5.4.2 NO-LOAD SET-UP

The following steps are for configuring actual system startup.

1. Set VOLTS AT 60 HZ. per start-up worksheet.
2. Press OVERLOAD PARAMETER and set to motor nameplate X trasformer ratio.
3. Press I LIMIT and set 5% over value set in OVERLOAD PARAMETER.
4. Set I LIMIT SYNC to motor nameplate amps X trasnformer ratio X 110%.
5. Turn off the Main Input Power Switch.
6. Connect a phase sequence meter to output of the controller to the point nearest the well head to confirm proper phase rotation.
7. Turn on the Main Input Power Switch.
8. Start controller, confirm correct phase sequence, then stop the controller.
9. Turn off the Main Input Power Switch and disconnect phase sequence meter.

5.4.3 START-UP

1. Connect down hole cable to junction box.
2. Press DISPLAY STATUS.
3. Start controller and allow to ramp to set speed, 60 Hertz.
4. Confirm 60 Hertz output amps and voltage of controller by pressing DISPLAY OUTPUT AMPS/VOLTS.
5. Press SET FREQUENCY and set to maximum desried frequency per start-up sheet.

(continued next page)

10. Check output amps and voltage of controller by pressing DISPLAY OUTPUT AMPS/VOLTS. Use Meters and measure input output and downhole amps and volts to record on start-up sheet.

11. Press SET FREQUENCY and set to minimum speed per start-up worksheet.

12. Press UNDERLOAD PARAMETER and set AMPS UL SET to 10% under lowest output phase current while running at minimum hertz. Record on start-up sheet.

13. Press SET FREQUENCY and set to desired operating speed.

*** OVERLOAD PARAMETER & UNDERLOAD PARAMETER may need to be reset after well has stabilized.**

OPERATION DURING STARTUP

press the start button. The controller will ramp quickly to the "START FREQUENCY". The controller will remain at the "START FREQUENCY" through the "SYNC DELAY" period. After "SYNC DELAY", the controller will accelerate the motor at the rate established by the "ACCEL TIME" if the controller can provide sufficient current. If the controller cannot provide sufficient current, the load will accelerate at a lower rate determined by the load inertia and the current available.

If the controller is unable to start the load, check the load current during an attempted start. Is it equal to "I LIMIT SYNC"? If not, increase "V BOOST SYNC" and try again. Continue the process of increasing "V BOOST SYNC" and start attempts until the motor starts, or the load current is limited by "I LIMIT SYNC". If the motor still does not start, increase "I LIMIT SYNC". If "I LIMIT SYNC" is at the maximum, decrease "START FREQUENCY".

NOTE: The Electrospeed controller will not restart if voltage is present on the DC bus. There will be a delay of 30 to 60 seconds between starts to allow the bus to discharge.

Be careful in increasing "V BOOST SYNC". If the start voltage is too high for the start frequency, the motor or output transformer, if used, may saturate. This causes the excitation current to dramatically increase. In this situation, "I LIMIT SYNC" current may be reached, but a large portion of the current may be excitation current for the transformer or motor. For this reason it is generally best to initially attempt starting with no "V-BOOST SYNC", and then increase as necessary.

The problem of transformer saturation is particularly evident in submersible pump applications where output step-up transformers are used. Submersible applications typically include long lengths of cable between the step-up transformer and motor. Cable voltage drop is typically high, requiring some "V BOOST SYNC" for motor starting. Output transformers for submersibles are typically designed to allow for intermittent overvoltages of about 33% without significant increases in excitation currents. Even with the capability of boosting output voltage by 33%, problems can still be encountered with transformer saturation. In some cases, though rare, it may be necessary to increase "START FREQUENCY" to obtain maximum available current without saturating the transformer. Since the voltage/frequency ratio will remain constant, neglecting "V BOOST SYNC", the output voltage will be higher at the increased "START FREQUENCY". The load reactance will also increase, but the load resistance will remain constant making the increase in overall load impedance less than the increase in voltage. This will allow for more starting current without saturating the transformer.

5.4.5 PHD SET-UP

The Following procedure for PHD set-up is desinged for operation in the automatic pressure mode, MODE 2. To operate in MODE 1, presure monitor only, ignor step steps12, 13, and 14.

1. Turn power on by closing input disconnect switch.
2. Select ANALOG CONTROL SETUP input "A".
3. Set MODE to SET POINT.
4. Set to REVERSE ACTING.
5. Set INPUT to 0-10 volts.
6. Select PSI INPUT UNITS.
7. Select 00.0 PSI ZERO.
8. Select 5120 PSI SPAN.
9. Set 00.0% PROPORTIONAL GAIN.
10. Set 03.0% INT GAIN.
11. Set 00.0% DERIV GAIN.
12. Set PSI LO ALRM to desired pressure for shut down, if required.
13. Set PSI HI ALRM to desired pressure for shut down, if required.

While operating in MODE 2, the PSI HI or PSI LO ALRM will send a signal to the Door Interface Board to operate BRAKE LIGHT (J2, 17 & 18) and to the Customer Interface Board (if installed) to operte an ouput relay with a header plug programmed for SP ALM (see CIB Wiring diaram, figure 3.1, page 17). To enable controller to shut down in either PSI HI or PSI LO ALRM connect the output of DIB J2, 17 &18 or CIB relay output to energize a contact closure for AUX stop. If the controller has only a DIB, an extra relay must be mounted in the enclosure.

14. Set CONTROLLER SET POINT at desired pressure (i.e. 0250 PSIA SET PT).

15. Open input disconnect switch.

5.4.5.1 PHD HARDWARE SET-UP

1. Connect output signal from surface inductor package to PHD Signal conditioner, input to J3 pin 1 and Ground to J3 pin 2. Insure the three diodes (IN4002 or equivalent) are connected in series with cathode to source.

2. With calibration potentiometer adjusted to surface reading of PHD/Motor "A" phase to ground, approximately 2500 OHMS, connect to surface inductor package and ground.

3. Turn power on with input disconnect switch.

4. Press ANALOG CONTROL SETUP until you reach PSI ZERO, set to 00.1 PSI.

5. Select DISPLAY ANALOG INPUTS, PSI INPUT A should be 00.1 PSI.

6. If not adjust the zero pot on the surfac inductor package for 00.1 PSI.

7. Change the calibration pot to 16.5 K ohm, to represent 3500 PSI. While monitoring Display Analog Input, reading should be 3500 PSI. If not, select PSI Span in the Analog Control Control Setup and increase or decrease the span until the Display Analog Input indicates 3500 PSI.

8. Power down unit with input disconnect switch.

9. Disconnect surface inductor package calibration potentiometer.

10. Connect down hole cable.

11. Turn power on by closing input disconnect switch.

12. Select DISPLAY ANALOG INPUTS, PSI INPUT A will indicate the down hole pressure at setting depth.

13. Start the unit as per previous procedures.

SECTION 6

MAINTENANCE, TROUBLESHOOTING

6.1 Routine Maintenance

Only minor adjustment should be necessary on initial start-up, depending on the application. In addition to setting these, some common sense maintenance need be followed.

Operating Temperatures:

NEMA 1 (IP20) Enclosure:	Keep unit located away from other equipment having a high ambient temperature. Air flow across the heat sinks must not be restricted.
NEMA 3 (IP54) Enclosure:	In extremely high ambient temperatures it may be necessary to place a sun shade over the unit to keep within operating temperature range.

Keep Unit Clean:

As with any electronic equipment, cleanliness will enhance operating life.

Keep Connections Tight:

The equipment should be kept away from high vibration areas that could loosen connections or cause chafing of wires. All interconnections should be re-tightened at initial start-up and at least every six months.

Reform DC Electrolytic Capacitors: after one month in storage.

External Cooling Fan (NEMA 3 Only): Oil every six months with SAE20.

6.2 General Troubleshooting

The following flow charts direct the technician to an appropriate troubleshooting procedure based on the faults indicated on the Operator Key Pad DISPLAY STATUS or HISTORY REGISTER. The technician should record the fault displayed on the panel before troubleshooting the controller. A log of all faults should be maintained to establish a cause/effect history.

6.3 Important Safeguards

All work on this controller must be performed by personnel familiar with its operation and application. Read the functional description, Section 4 and this section before attempting any maintenance or troubleshooting.

WARNING

The following warnings must be heeded. Failure to do so could result in personal injury!

1. Lethal voltages are present within the cabinet when input power is applied.

2. External voltages could be present in the area of the customer interface board even with all power removed from the drive input.

3. Always check for voltages across the DC Bus before performing any troubleshooting, part replacement or removal. Lethal voltages (up to 700V DC) may be present under certain conditions.

4. To prevent component damage, do not remove any cable connectors without removing all power to the controller AND allow sufficient time to discharge any supply capacitors. Usually one minute is sufficient .

6.4 Test Instruments

The following is typical of the maintenance equipment used on this type of equipment:

Item	Manufacture	Model
V.O.M.	Simpson	620
Oscilloscope	Tektronix	545B
DVM	Fluke	8060A
Clamp-On Ammeter	Weston	904

Figure 6.1 Test Instruments

6.5 Troubleshooting

The following steps describe how perform troubleshooting maintenance, periodic testing, or calibration on the controller.

1. Input disconnect switch must be in the "OFF" position.

2. Undo the door locking screws and open door.

3. Check load. Insure all areas around equipment powered by the drive are clear. It is best to set all controls and operating conditions under actual load conditions. Check the load resistance reading against initial start-up or installation report.

4. To troubleshoot controller and control circuit problems, the load should be removed from the controller. All functions may be tested with no load except those that are caused by overload or motor problems.

5. Close the input disconnect switch.

6. Check to insure that the Operator Interface Board display is activated. Power on LED, and display flashing F18 POWER UP, LOCK OUT.

7. Check voltage LED'S on the Digital Control Board for the presence of the +15VDC, -15VDC, and +5VDC. The LOST COMM LED should be off, if LED is on the problem could be with The Digital Control Board or the Operator Interface Board.

8. Check the voltage LED'S on the Door Interface Board and PHD Signal Conditioner or Analog Input Board (if installed) for the presence of the+15VDC, -15VDC, and +5VDC.

9. Check the voltage LED'S on the Converter Control Board for the presence of the +24VDC, +8VDC, -24VDC +15VDC, -15VDC, and +5VDC. The six SCR gate signal LED's should be off.

10. Check the voltage LED'S on the Inverter Control Board for the presence of the +15VDC, -15VDC, and +5VDC. Check the voltage LED's on each phase (+ and -), +6VDC and -6VDC. The six transistor B-E signal LED's should be off.

11. If any of the voltage LED's are not functioning as described, check the fuses on the Power Supply Board.

12. Start the controller without a load. Verify that the six SCR signal LED's, lower right side of Converter Control Board are functioning. Verify that the twelve transistor B-E signal LED's on the Inverter Control Board are functioning. If not functioning proceed with the troubleshooting flow charts.

6.6 Troubleshooting Flow Charts

The following sections provide the information necessary for individual to perform first level maintenance and repair to troubleshooting the controller to board level change out. The Main Flow Chart on the following page is used to direct the technician to immediate remedial action based on the failure indicated on the Operator Interface Boards DISPLAY STATUS or HISTORY REGISTER. The symbols used in the flow chart normally represent a specific action. An example of each and the operation symbolized are located in figure 6.2.

The Main Flow Chart leads the technician to several subroutines. These are located immediately following the Main Flow Chart.

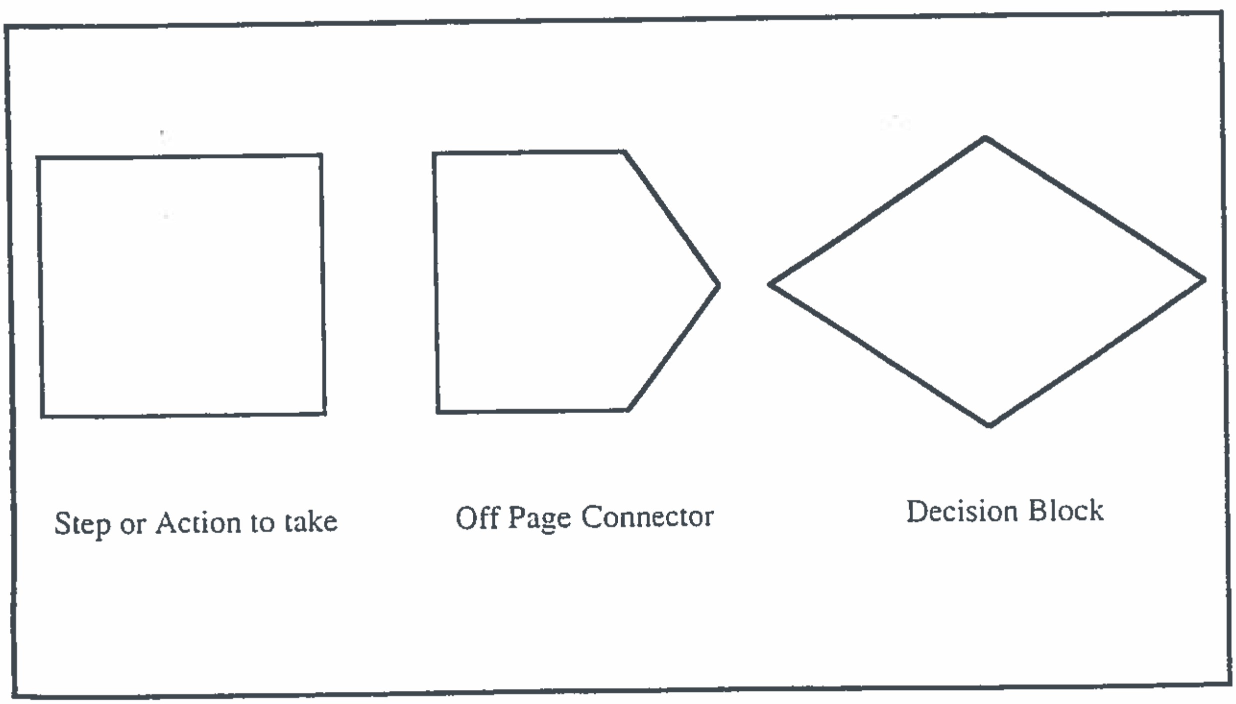


Figure 6.2 Flow Chart Symbols

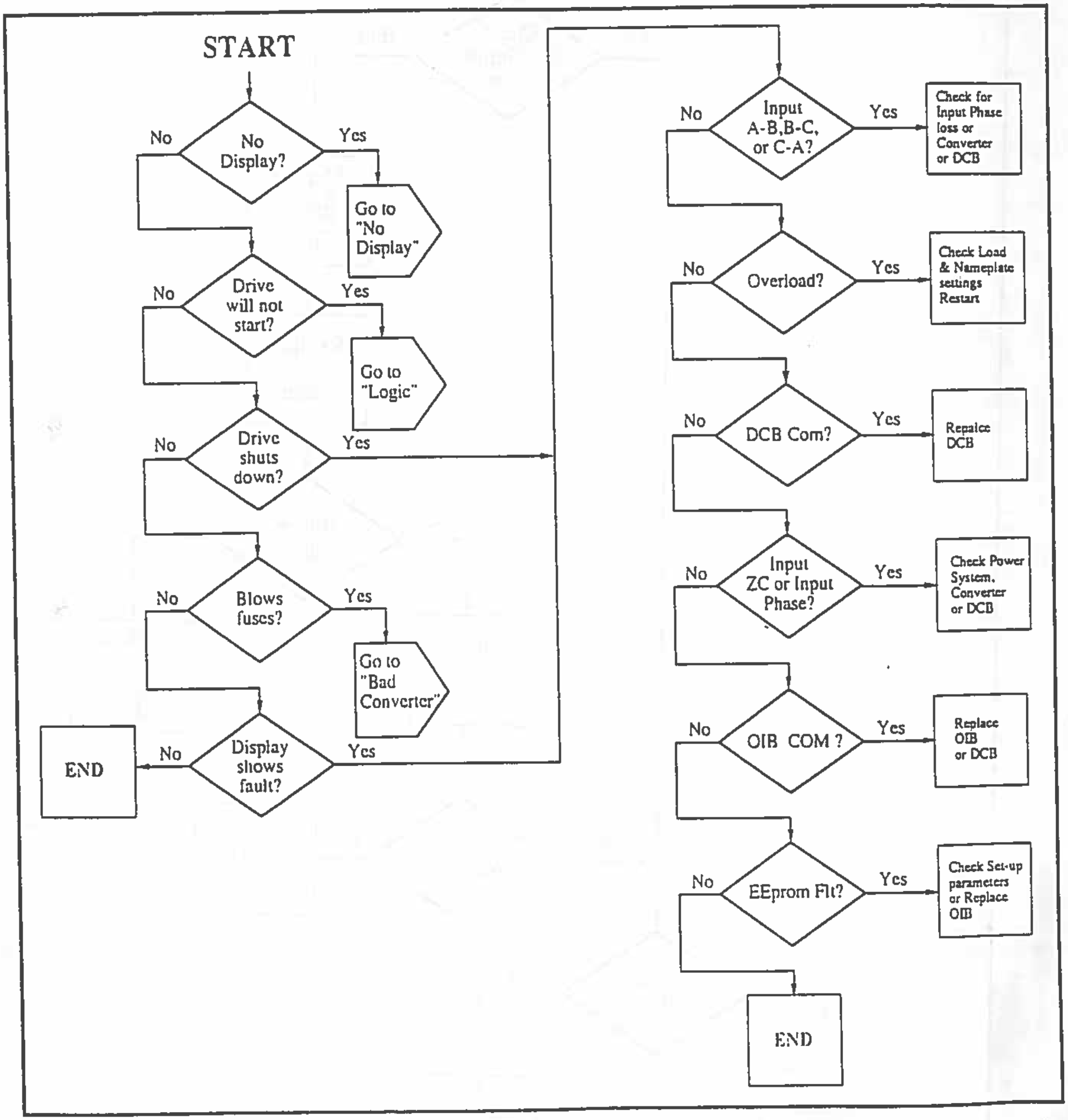


Figure 6.3 Main Troubleshooting Block

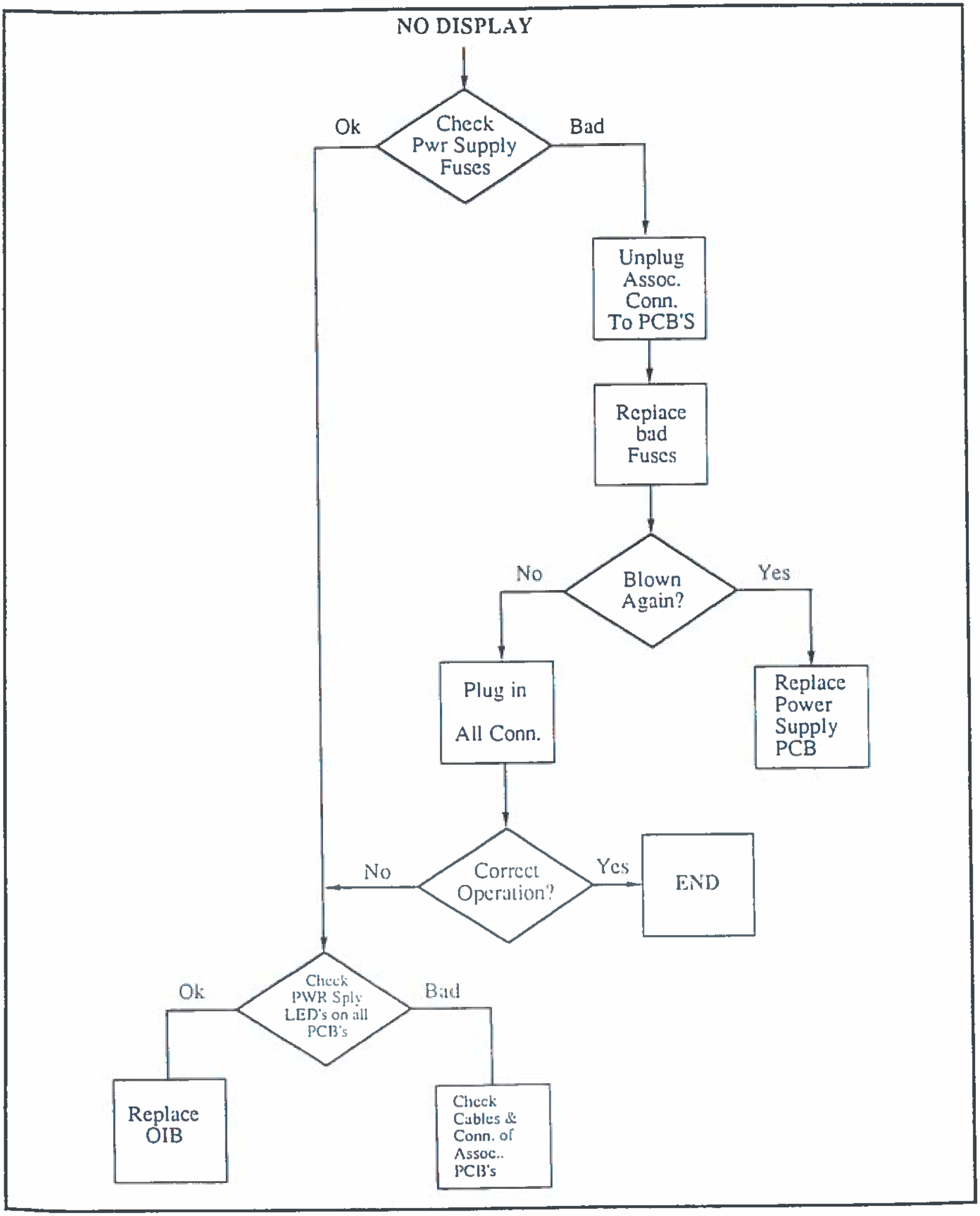


Figure 6.4 No Display Troubleshooting Block

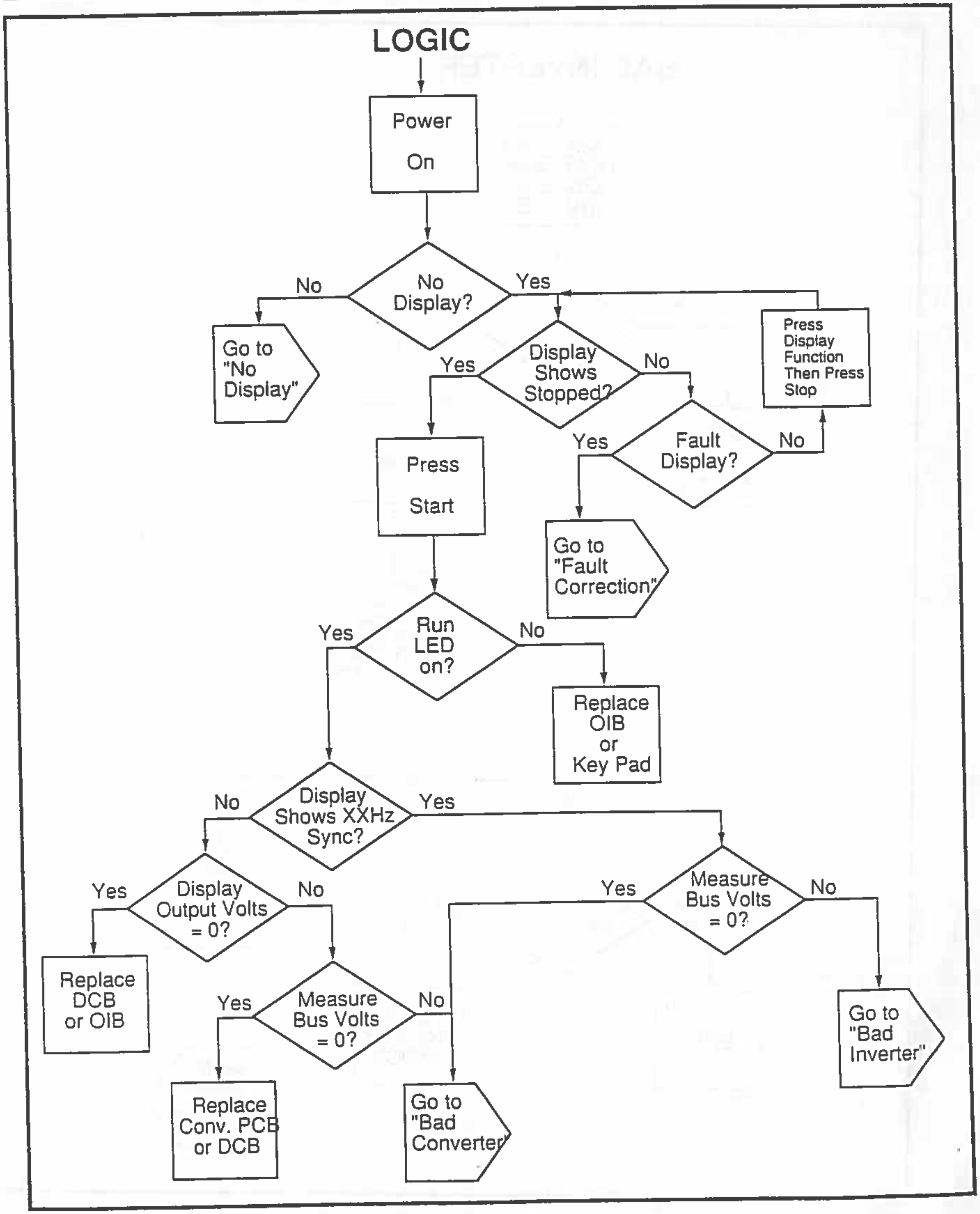


Figure 6.5 Logic Troubleshooting Block

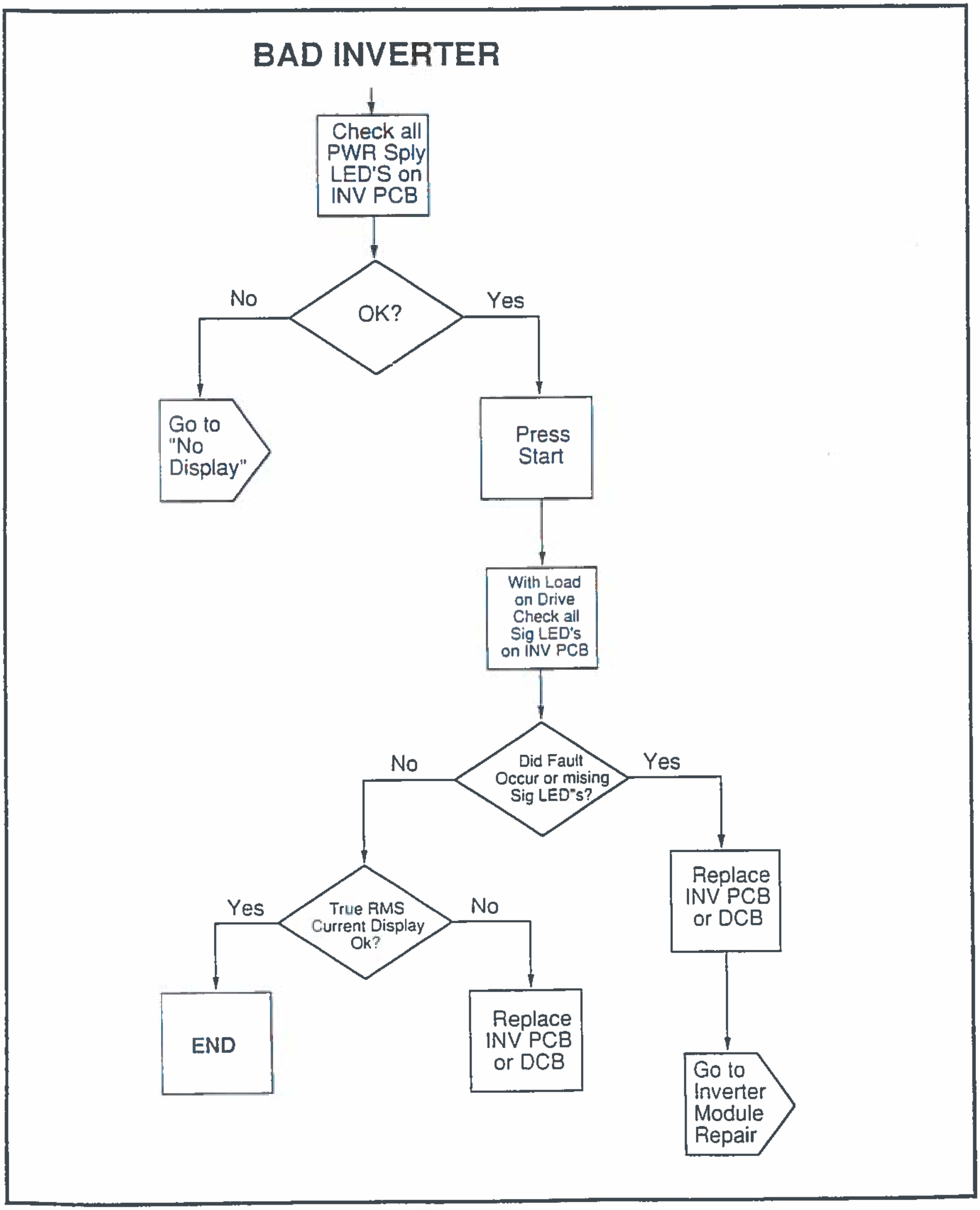


Figure 6.6 Inverter Troubleshooting Block

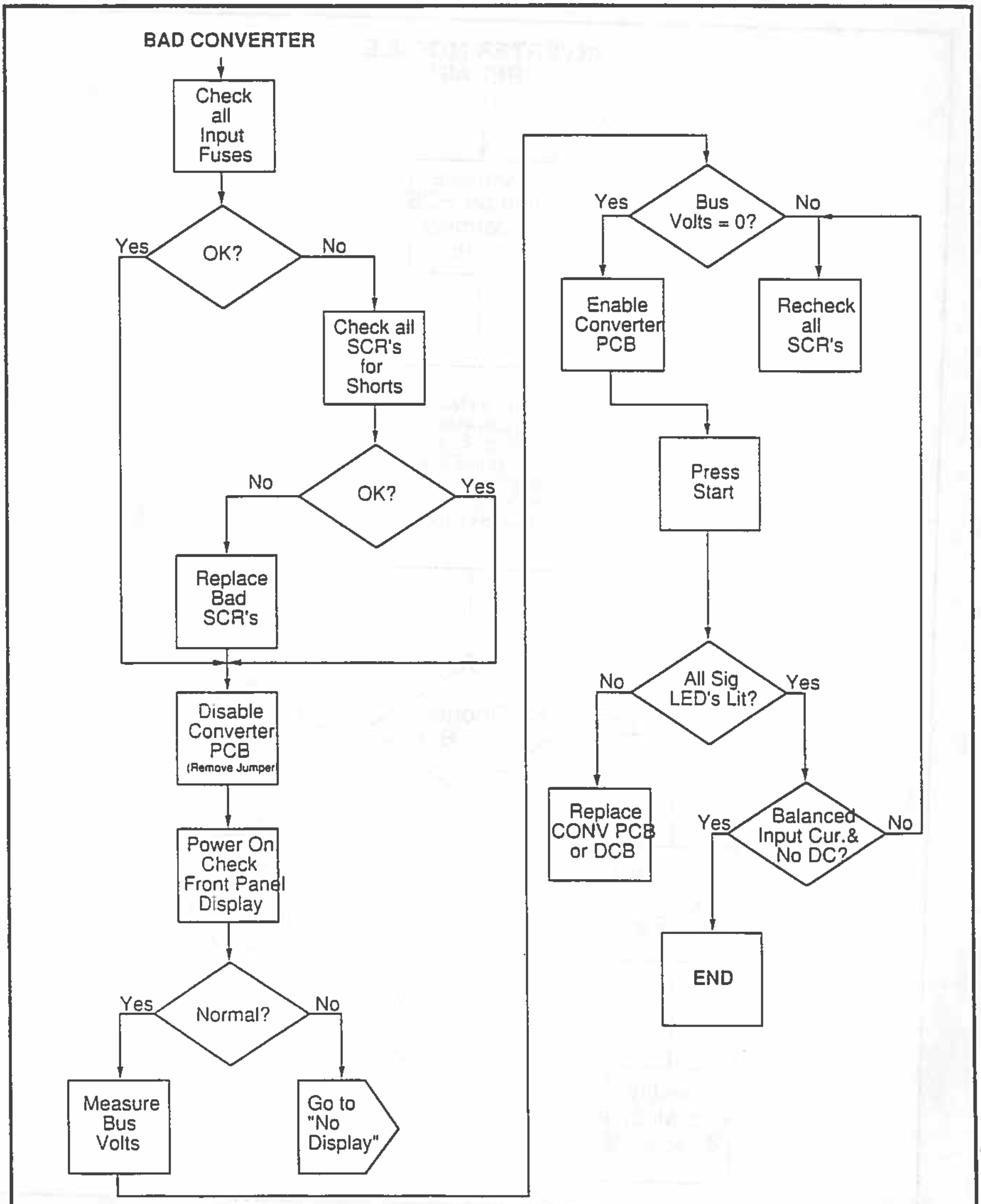


Figure 6.7 Converter Troubleshooting Block

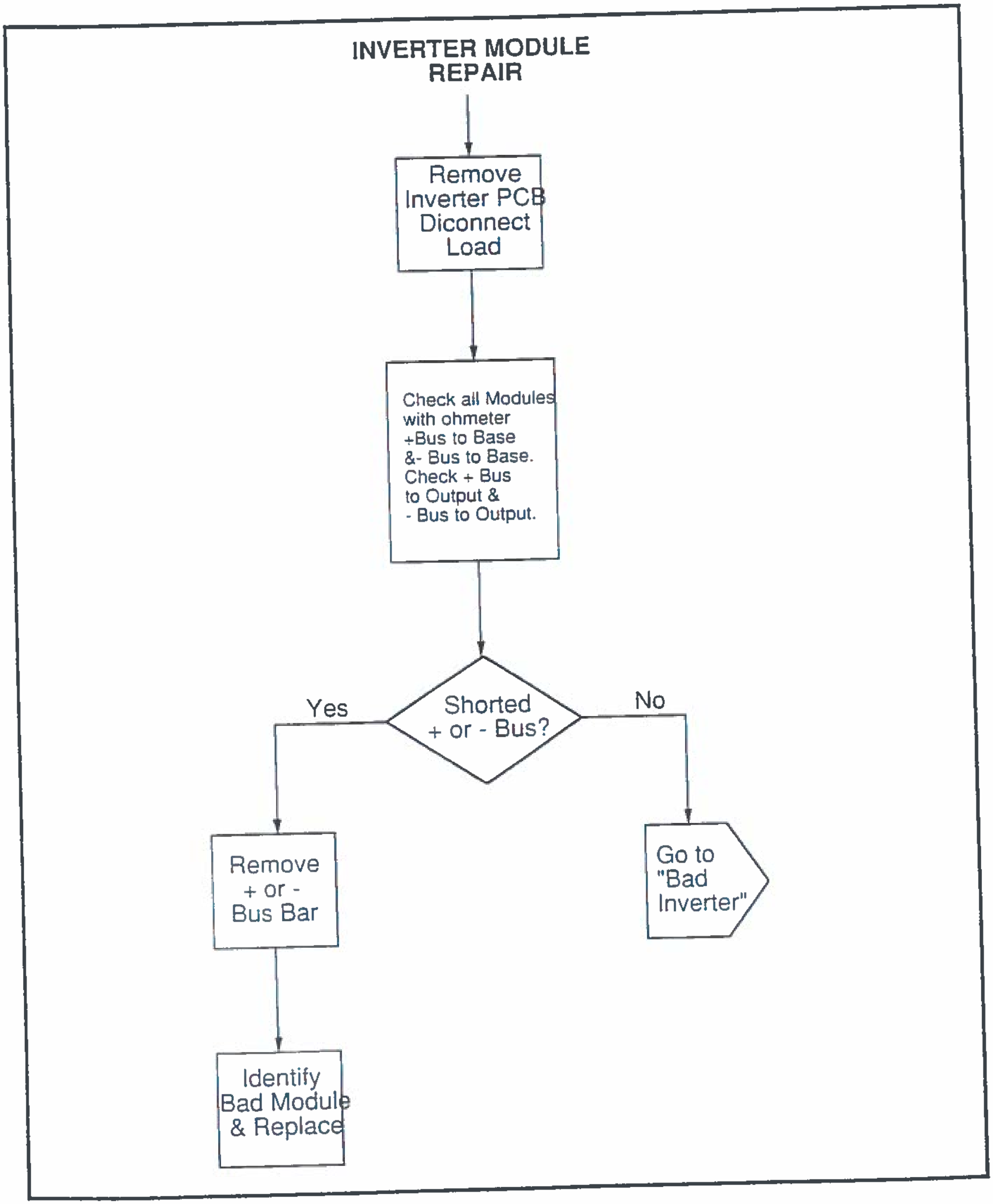


Figure 6.8 Inverter Module Repair Troubleshooting Block

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6.7 Power Semiconductor Resistance Checks

PLUS LEAD THIS SIDE

	B1	C2E1	C1	B2	E2	
B1	0000	.412 .155 16.7	.490 .421 8.75	OL OL INF	OL OL INF	* #
C2E1	.412 .155 160	0000	.361 .318 6.9	OL OL INF	OL OL INF	* #
C1	OL OL INF	OL OL INF	0000	OL OL INF	OL OL INF	* #
B2	.902 .555 275	.490 .422 8.75	.851 .724 33	0000	.415 .157 18	* #
E2	.774 .458 245	.361 .318 6.9	.722 .627 24.3	.415 .156 155	0000	* #

METER TYPE

*	BECKMAN
#	FLUKE 87
	ANALOG

Figure 6.9 Transistor Module Reading, Part No. 85332

NOTES:

1. All values are for one module.

2. * Digital readings taken with a **BECKMAN 3030** on **DIODE** scale.

3. # Digital readings taken with a **FLUKE 87** on **DIODE** scale.

4. Analog readings taken with a Simpson 260 set on **RX1** scale.

5. * # These values are **typical** but may change dramatically from lot to lot compared with known good devices. Digital meters by other manufacturers may also give very different readings.

SCR MODULES Part No 88565 160A and Part No 88465 250A. These devices should show **INF** between all Main terminals. Gate cathode readings should be approximately **.075** with a digital meter and **5** to **20** ohms with an analog meter.

DIODE MODULES Part No 88466 95A and Part No 88523 260A. These devices will read approximately **.5** on a Digital meter and **10** to **20** ohms on an analog meter in the forward direction and **INF** in the reverse direction.

SECTION 7

SPARE PARTS LISTING

ICS 2000/4000 NEMA

PART No.	DESCRIPTION	PRICE	U/M
32215	ARRESTOR, LIGHTNING		EA
48199	BATTERY, OPER. INTERFACE		EA
47747	BLOCK, LOGIC, REED, N.O		EA
47748	BLOCK, LOGIC REED, N.C		EA
48093	BREAKER, 400A, 600VAC, 324 2000 N3		EA
48094	BREAKER, 300A, 600VAC, 323 2000 N3		EA
48095	BREAKER, 200A, 600VAC, 322 2000 N3		EA
48096	BREAKER, 100A, 600VAC, 321 2000 N3		EA
48301	BREAKER, 800A, 600VAC, 348 4000 N3		EA
48302	BREAKER, 700A, 600VAC, 347 4000 N3		EA
48303	BREAKER, 600A, 600VAC, 346 4000 N3		EA
48304	BREAKER, 500A, 600VAC, 345 4000 N3		EA
47512	CAP, 3 MFD, 660 VAC, 90 DEG		EA
47556	CAP, 7.5 MFD, MOTOR, 2000/4000 N3		EA
86413	CAP, 1400 MFD, 350 VDC		EA
88916	CAP, PUSHBUTTON		EA
47790	CBL, LOGIC S/A, DCB TO INVERTER, 5'		EA
47791	CBL, ROUND S/A, CUSTOMER I/F TO DIB		EA
47793	CBL, RIBBON S/A, PHD TO DIB, 2"		EA
47794	CBL, RIBBON S/A, ANALOG TO DIB, 14"		EA
48133	CBL, LOGIC S/A, DCB TO CONVERTER		EA
48309	CBL, AUX CONV, S/A		EA
31415	CHT, AMTR, 7 DAY, 321 2000 N3		BX
47655	CHT, AMTR, 7 DAY, 322 2000 N3		BX
34757	CHT, AMTR, 7 DAY, 323 2000 N3		BX
89061	CHT, AMTR, 7 DAY, 324 2000 N3		BX
31412	CHT, AMTR, 24 HR, 321 2000 N3		BX
47656	CHT, AMTR, 24 HR, 322 2000 N3		BX
34756	CHT, AMTR, 24 HR, 323 2000 N3		BX
89062	CHT, AMTR, 24 HR, 324 2000 N3		BX
86749	CHT, AMTR, 7 DAY, 347/348 4000 N3		BX
89061	CHT, AMTR, 7 DAY, 345 4000 N3		BX
89063	CHT, AMTR, 7 DAY, 346 4000 N3		BX
86431	CHT, AMTR, 24 HR, 347/348 4000 N3		BX
89062	CHT, AMTR, 24 HR, 345 4000 N3		BX
89064	CHT, AMTR, 24 HR, 346 4000 N3		BX
88126	CMPD, THERMAL COND		OZ
47741	CONN, PIN, CONN HSG		EA
47740	CONN, HSG, 2 CKT		EA
47957	CONN, HSG, 3 CKT		EA
47742	CONN, HSG, 5 CKT		EA
47959	CONN, HSG, 6 CKT		EA
47743	CONN, HSG, 8 CKT		EA
47803	CONN, HSG, 20 CKT		EA

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PART No.	DESCRIPTION	PRICE	U/M
86124	CONN, STUD, GRD		EA
47958	CONN, KEY, PLZN		EA
86752	CTG, OXIBAN, CTB		OZ
47422	TRACK, MOUNTING, 1 FT, DIN		EA
89052	DIODE MDL, 95A, 1600V, 2000, N1/N3		EA
88523	DIODE MDL, 260A, 1600V, 4000, N1/N3		EA
47565	DISCONNECT, #23N3666		EA
90261	DOOR, ENCL, OPERATOR INTERFACE		EA
89843	ENCL, OPERATOR INTERFACE		EA
47433	FAN, 16" NEMA 3		EA
88424	FAN, MUFFIN		EA
48111	FUSE, 50MA, 125V, CUSTOMER I/F		EA
48109	FUSE, 4A, 250V, INVERTER PS		EA
48108	FUSE,1.6A, 250V, MUFFIN FAN		EA
48107	FUSE,1A, 250V, ISOLATED 24VDC		EA
48106	FUSE, 5A, 500V, FAN/XFMR		EA
85572	FUSE, IMPUT POWER, 321 2000 N3		EA
86808	FUSE, INPUT, 600 AMP, 346 4000 N3		EA
86809	FUSE, INPUT, 800 AMP, 348 4000 N3		EA
88895	FUSE, INPUT, 200 AMP, 322 2000 N3		EA
88896	FUSE, INPUT, 300 AMP, 323 2000 N3		EA
88897	FUSE, INPUT, 400 AMP, 324 2000 N3		EA
88898	FUSE, INPUT, 500 AMP, 345 4000 N3		EA
88899	FUSE, INPUT, 700 AMP, 347 4000 N3		EA
86887	GSKT, 1/4X1, ADH BACKED		FT
87043	GSKT, 1/8X1, ADH BACKED		FT
89713	GSKT, BASE, 4000		EA
88919	HDL, OPERATING, ASH-GY		EA
47564	HINGE, ENCL, OPERATOR INTERFACE		EA
86387	HTR, SPACE		EA
85297	ISOLATOR, 4-20 MA		EA
47511	INDUCTOR, FILTER, DUAL WINDING		EA
48137	KEYPAD S/A, OPERATOR I/F		EA
90212	LATCH,ADJ GRIP, SOUTHCO		EA
47574	LATCH, SLAM, SOUTHCO		EA
89684	LEGEND, OVERLOAD		EA
48097	LEGEND, MODE 1-OFF-MODE 2		EA
48098	LEGEND, UNDERLOAD		EA
48099	LEGEND, RUN		EA
48101	LEGEND, START		EA
47547	LIGHT, PILOT, RED, (OPT)		EA
47548	LIGHT, PILOT, GREEN, (OPT)		EA
47549	LIGHT, PILOT, AMBER, (OPT)		EA
47517	LUG, OUTPUT, 324/324 2000 N3		EA
87516	LUG, OUTPUT, 321/322 2000 N3		EA
88673	LUG, 4/0 AWG, 323/324 2000 N3		EA
88160	LUG, 2/0 AWG, 322 2000 N3		EA
88758	LUG, #6 AWG, 321 2000 N3		EA
86237	LUG, 500 MCM, 3/8 STUD		EA
86238	LUG, #3/0 AWG, 3/8, STUD		EA
86331	LUG, OUTPUT, 3/0 TO 400 MCM, 4000 N3		EA
88824	MOV, 420VDC		EA
88826	MOV, SURGE ARSTR, S/A, (OPT)		EA

PART No.	DESCRIPTION	PRICE	U/M
88967	MOTOR, 1/3 HP,1075 RPM, 1PH, 2000/4000 N1		EA
47420	MOTOR, 1/2 HP, 1625 RPM, 1PH ,2000/4000 N3		EA
88622	OIL, UNIVOLT 61, 5 GAL CAN, 2000/4000 N3		EA
47746	OPR, 3 POS		EA
88915	OPR, PUSHBUTTON		EA
48104	PCB, ANALOG, S/A		EA
47462	PCB, AUX RELAY, S/A		EA
47210	PCB, AUX CONVERTER, S/A		EA
89744	PCB, BLDR RES, S/A, 2000/4000 N3		EA
89745	PCB, BLDR RES, S/A, 2000/4000 N3		EA
89782	PCB, CAP DECK, S/A 4000		EA
89781	PCB, CAP DECK, S/A 2000/4000		EA
47206	PCB, CONVERTER CONTROL, S/A		EA
47189	PCB, CUSTOMER INTERFACE, S/A		EA
47371	PCB, DIGITAL CONTROL, S/A		EA
90269	PCB, DOOR INTERFACE, S/A		EA
89856	PCB, INVERTER CONTROL, S/A		EA
47323	PCB, OPERATOR INTERFACE, S/A		EA
47337	PCB, PHD, S/A		EA
47370	PCB, PWR SPLY, S/A		EA
87052	PLUG, HSG, 8 CKT		EA
47710	REACTOR, LINK, 2000/4000 N3		EA
85236	REACTOR, LINK, 2000/4000 N3		EA
31408	RECORDER, AMP CHART		EA
87857	RESISTOR, BLEEDER, S/A, 2000/4000, N1		EA
48110	RELAY, FAN, 24VDC		EA
88565	SCR, MODULE, 2000/4000 N3		EA
88465	SCR, MODULE, 2000/4000 N3		EA
89808	SKT, CONTACT, 350689-2 OR 7		EA
47423	SNAP TRACK, 4" X 2'		EA
48168	STEM, SHAFT, VARIDEPTH		EA
88767	STRIP, COPPER		EA
47998	SWITCH, MTR CIRCUIT, 323/324 2000 N3		EA
47999	SWITCH, MTR CIRCUIT, 321 2000 N3		EA
48000	SWITCH, MTR CIRCUIT, 322 2000 N3		EA
48306	SWITCH, MTR CIRCUIT, ALL 4000 N3		EA
47557	SW, THERM, CONV, OVR TEMP,90C, NC		EA
86388	SW, THERM, SPACE HTR		EA
86390	SW, THERM, SPACE HTR, CLS @ 80 DEG, OPN @ 30 DEG		EA
48298	TERM, RED FEM DISC 3/16X.020		EA
89457	TERM, RED, PUSH-ON		EA
88747	TERM, PUSH ON, SCR GATE		EA
86346	TERM, RED, FEM DISC		EA
85332	TRANSISTOR, MODULE, 2OOO/4000 N3		EA
47650	XFMR, CURRENT, CT, 321 2000 N3		EA
47651	XFMR, CURRENT, CT, 322 2000 N3		EA
86141	XFMR, CURRENT, CT, 323 2000 N3		EA
47649	XFMR, CURRENT, CT, 324 2000 N3		EA
89734	XFMR, CURRENT, CT, 345/346 4000 N3		EA
86330	XFMR, CURRENT, CT, 347/348 4000 N3		EA
47800	XFMR, INV SPLY, 50 HZ, ICS, 2000/4000 N3		EA
47801	XFMR, LGC SPLY, 50 HZ, ICS 2000/4000 N3		EA
47407	XFMR, INV SPLY, 60 HZ, ICS 2000/4000 N3		EA
47802	XFMR, LGC SPLY, 60 HZ, ICS 2000/4000 N3		EA
47419	XFMR, CURRENT, CT 2500:1, 2000/4000 N3		EA