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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). The weatherproof units use a patented cooling system that eliminates the inefficiencies and reliability problems associated with heat pumps. Each of the two types are offered in four enclosure sizes referred to as "1000", "2000" , "4000" and 8000 series. The 4000 series drives are capable of being paralleled to provide 8000 series capability. Drives with dual converters (identified as 12 Pulse drives) can be provided where harmonic reduction is required.

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 theElectrospeed 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.

1.3.6 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.

1.4 Multiple Converter Control Board

The Multiple Converter Control Board (MCC) has an 8097 microcontroller the same as the Digital Control Board. It mounts on top of the Digital Control Board with spacers and is connected to the DCB by 2 short ribbon cables. The MCC is only used in Drives with 2 Converters such as 12 Pulse or Paralleled Drives. It provides the 6 additional digital signals for the SCR,s in the second Converter. When used in paralleled drives it provides pass through and buffering for the 6 digital signals for the Master and Slave Inverter Control Boards. The MCC also provides fault detection from the second converter and inverter.

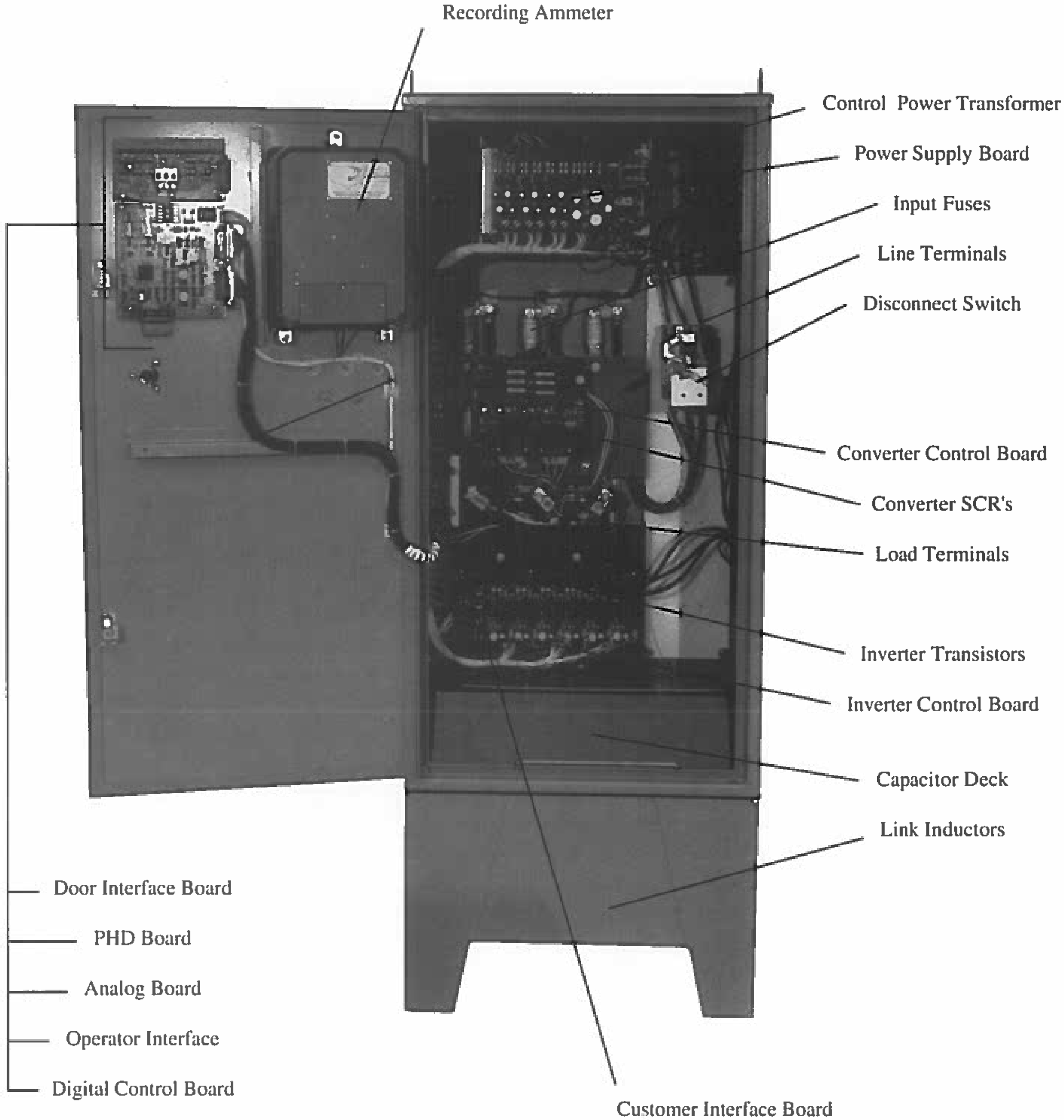


Figure 1.2 Major Components, NEMA 3, 2000 Series

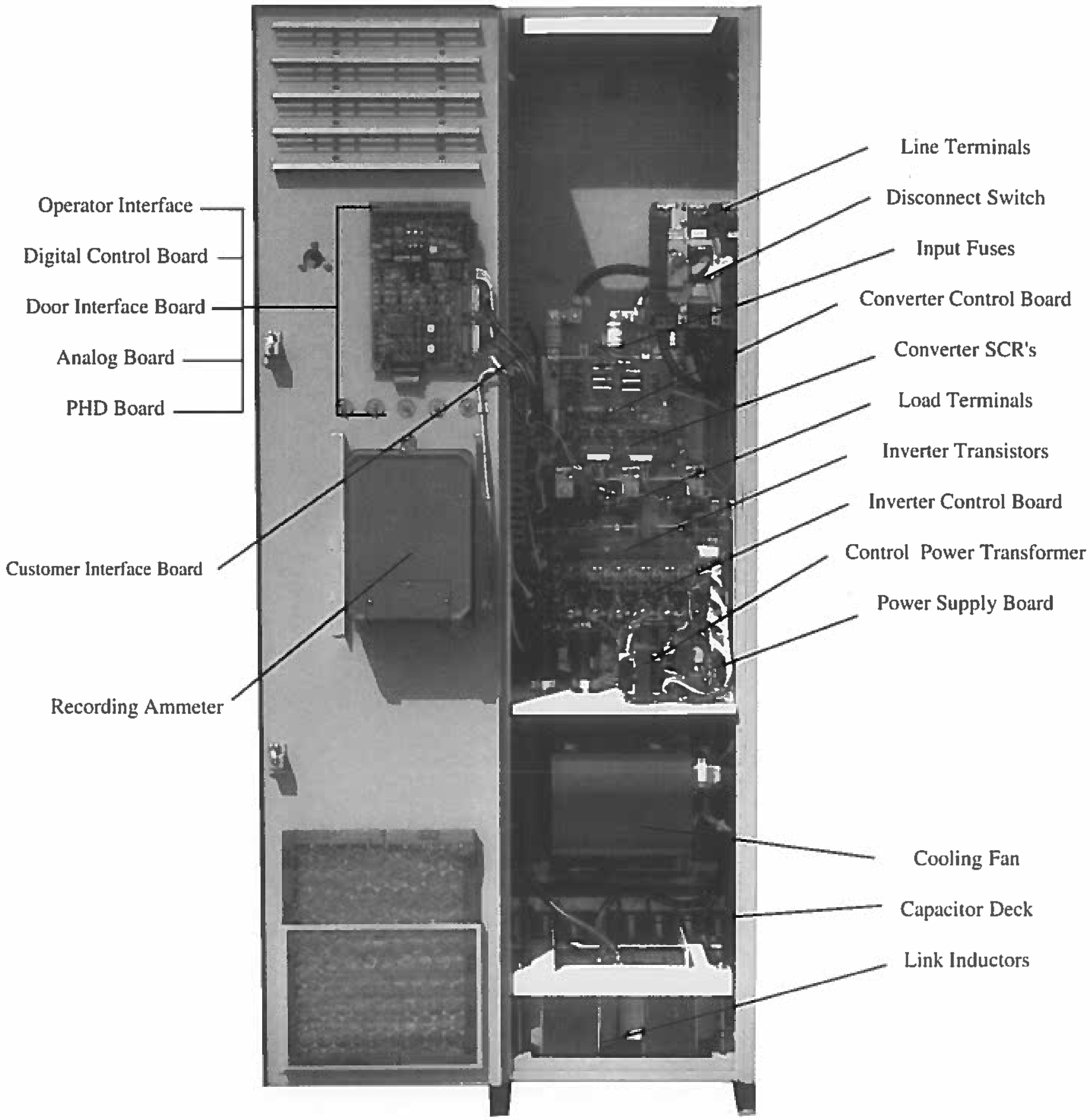


Figure 1.4 Major Components, NEMA 1, 2000 Series

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.

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

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

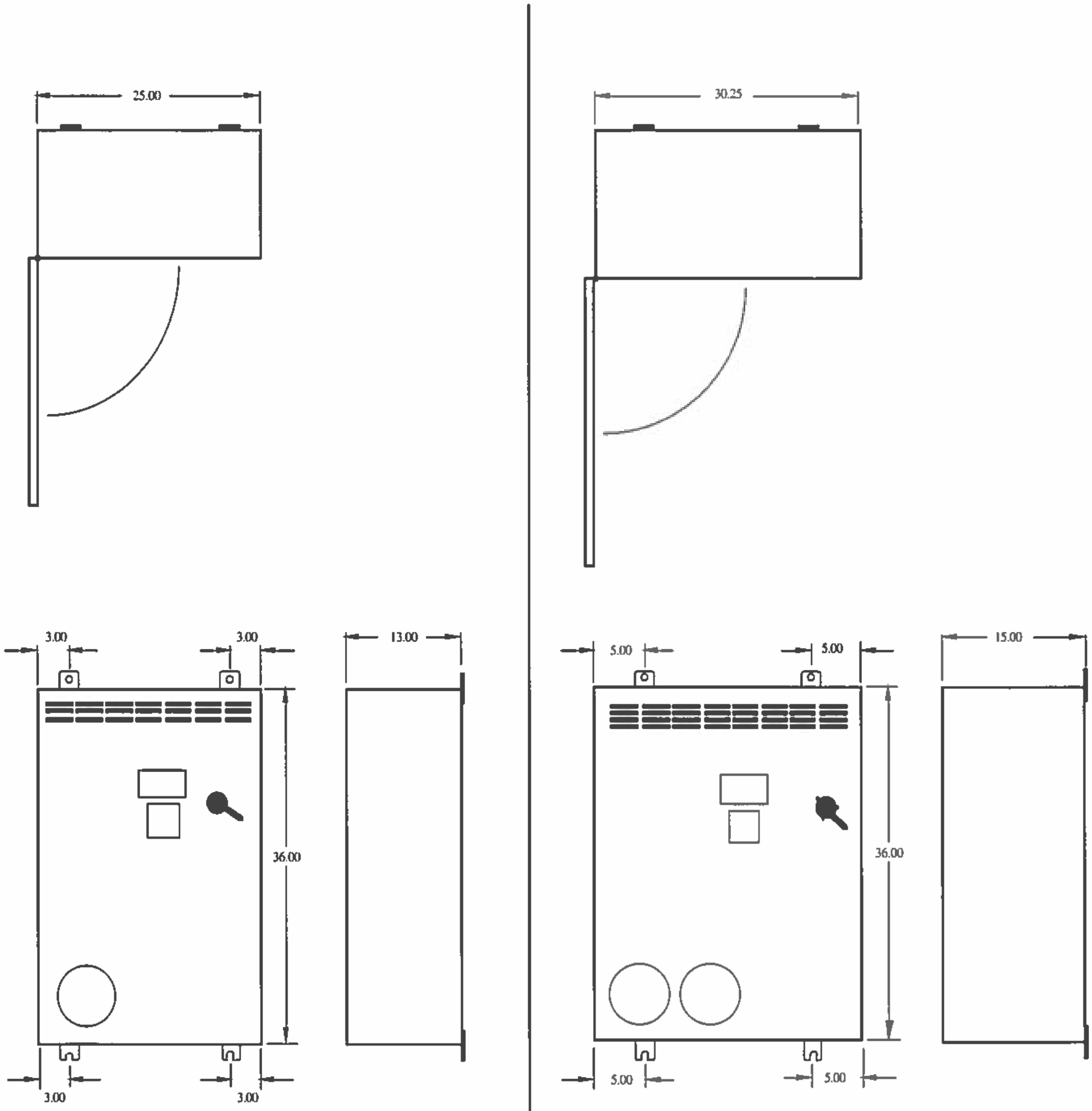
Digital Inputs (Dry contact to ground)
- Start
- Stop
- Emergency Stop/Auxiliary Stop
- Forward/Reverse
- Jog
- Analog Select

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



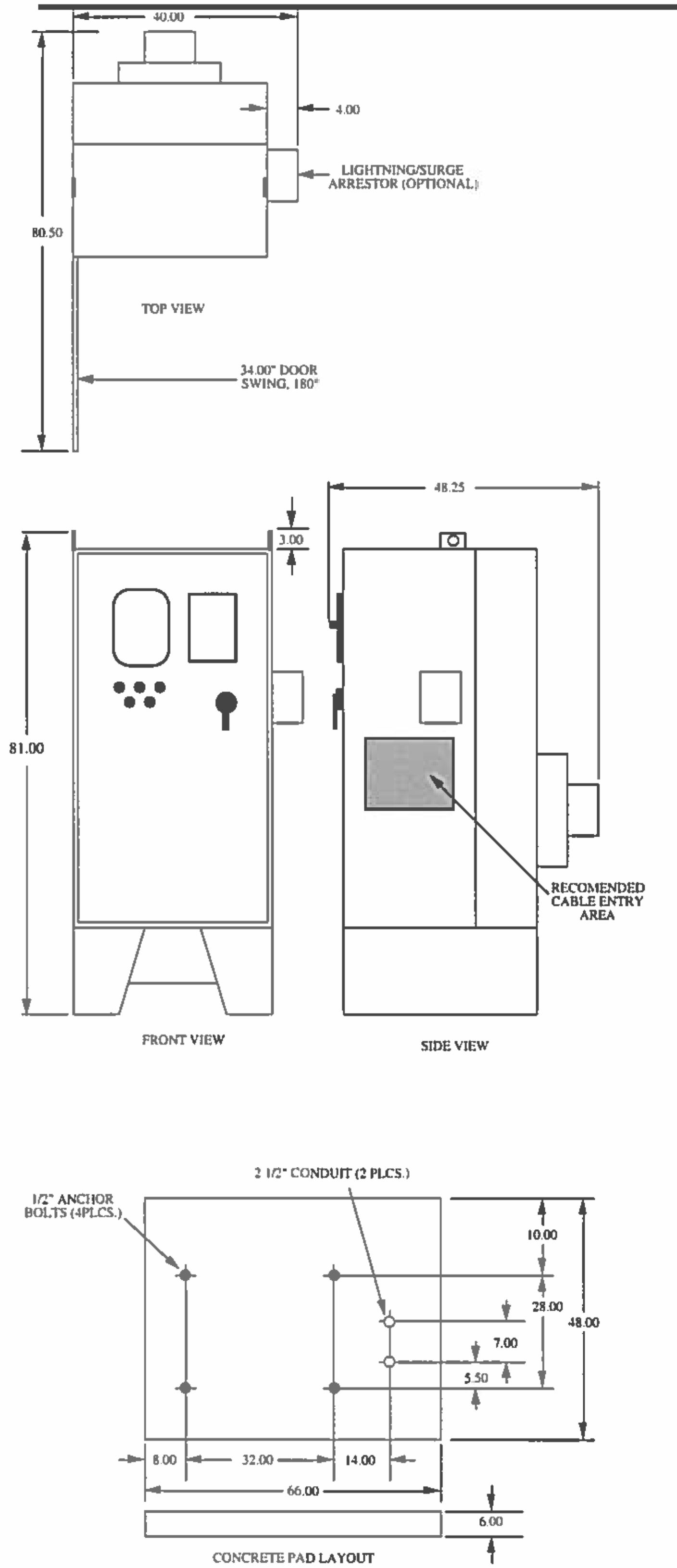
MODEL 1060

NEMA 1

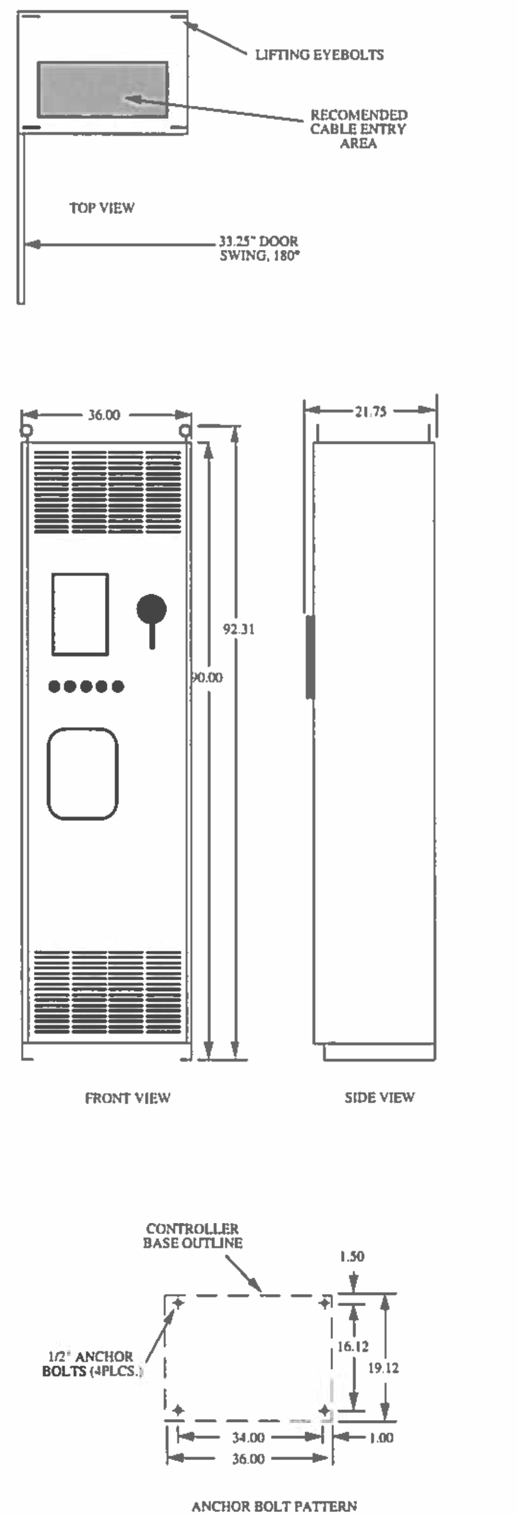
MODEL 1075
MODEL 1100
MODEL 1125

NEMA 1

Figure 2.1 Overall Dimension (inches) 1000 Series

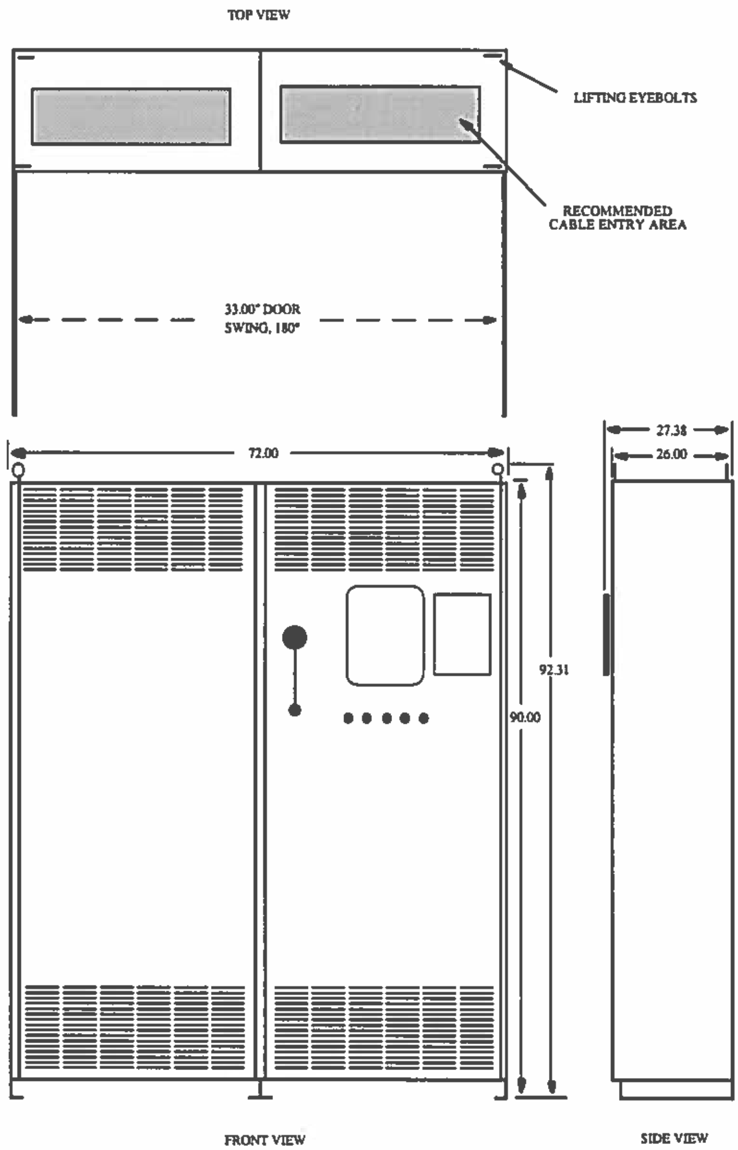


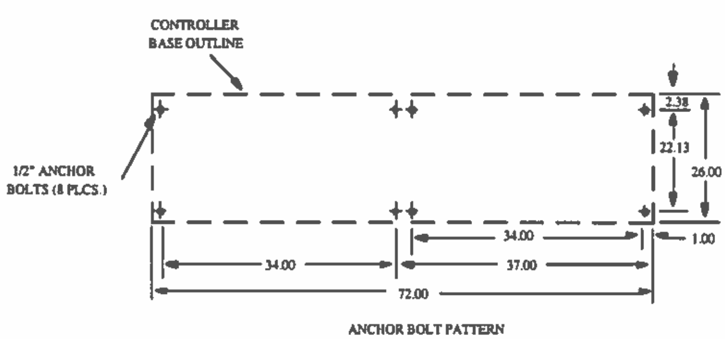
NEMA 3



NEMA 1

Figure 2.3 Overall Dimension (inches) 4000 Series





SINGLE PIECE ENCLOSURE

NEMA 1

Figure 2.5 Overall Dimensions (inches) 8000 Series

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
2 - 500	4-300 MCM	6ea. 250-600 MCM	6ea. 250-600 MCM
2 - 600	4-400 MCM	6ea. 250-600 MCM	6ea. 250-600 MCM
2 - 700	6-350 MCM	6ea. 250-600 MCM	6ea. 250-600 MCM
2 - 800	6-400 MCM	6ea. 250-600 MCM	6ea. 250-600 MCM

TABLE 3.1 CONTROLLER RECOMMENDED CABLE

Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment as recommended by the USA National Electric Code. Must meet local and other applicable codes for actual sizes.

INPUT FUSE PER PHASE (AMPS)	COPPER WIRE No	ALUMINUM or COPPER - CLAD ALUMINUM Wire No
100	# 8 AWG	# 6 AWG
200	# 6 AWG	# 4 AWG
300	# 4 AWG	# 2 AWG
400	# 3 AWG	# 1 AWG
500	# 2 AWG	# 1/0 AWG
600	# 1 AWG	# 2/0 AWG
700	# 1/0 AWG	# 3/0 AWG
800	# 1/0 AWG	# 3/0 AWG
2 - 500	# 2/0 AWG	# 4/0 AWG
2 - 600	# 3/0 AWG	# 250 kcmil
2 - 700	# 4/0 AWG	# 300 kcmil
2 - 800	# 4/0 AWG	# 350 kcmil

TABLE 3.2 CONTROLLER RECOMMENDED GROUNDING CABLE

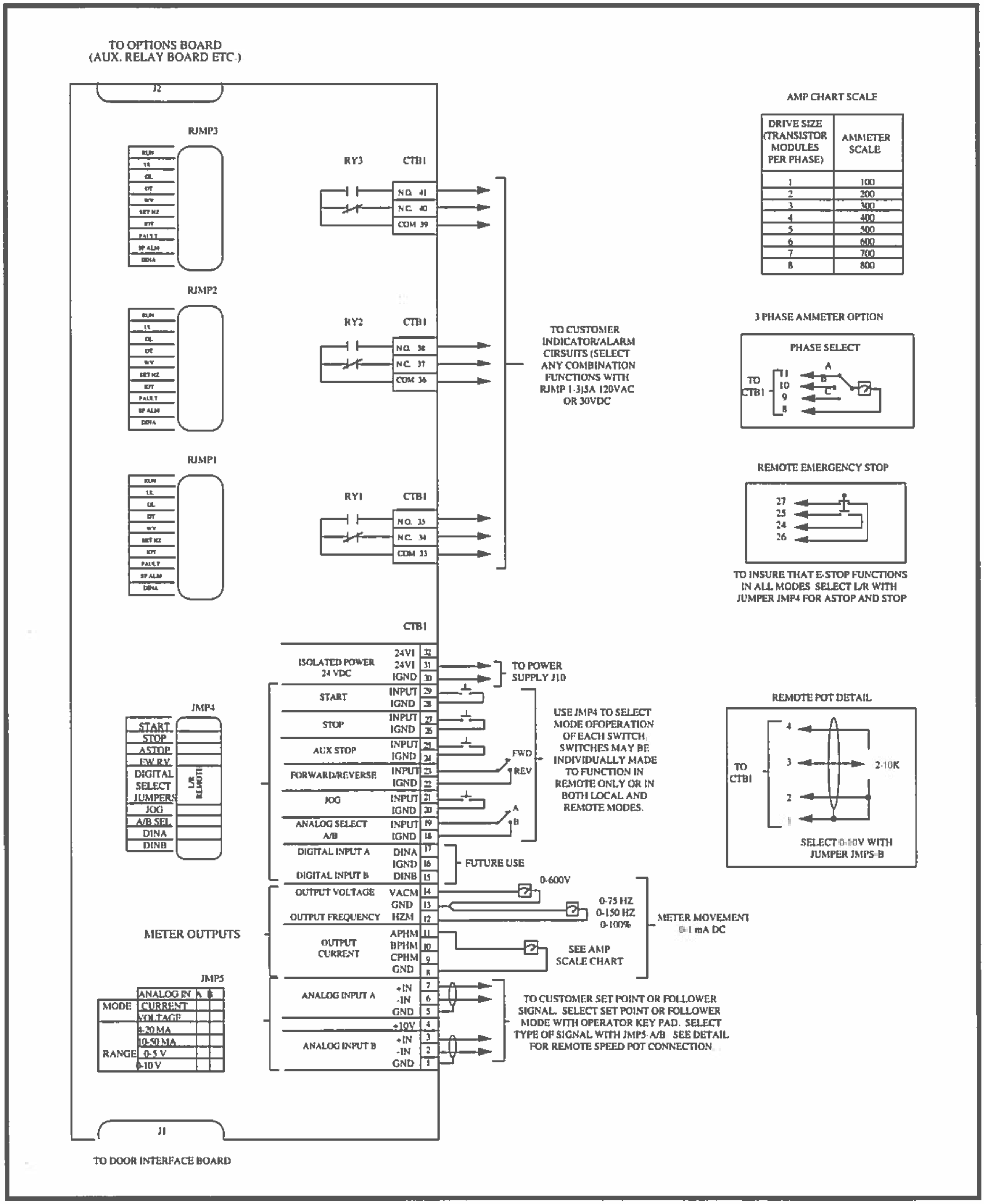


Figure 3.1 Customer Interface Board Wiring Diagram

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.

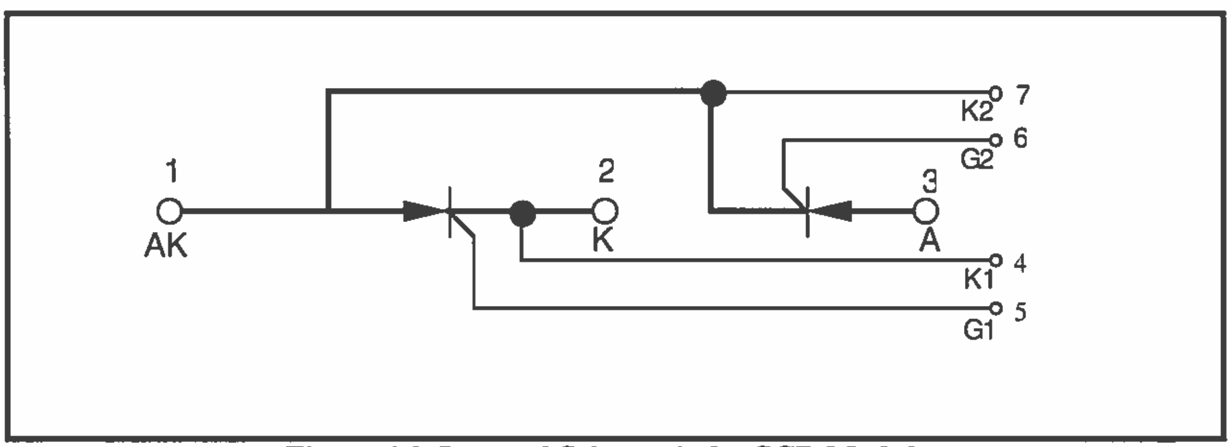


Figure 4.2 Internal Schematic for SCR Modules

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

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.

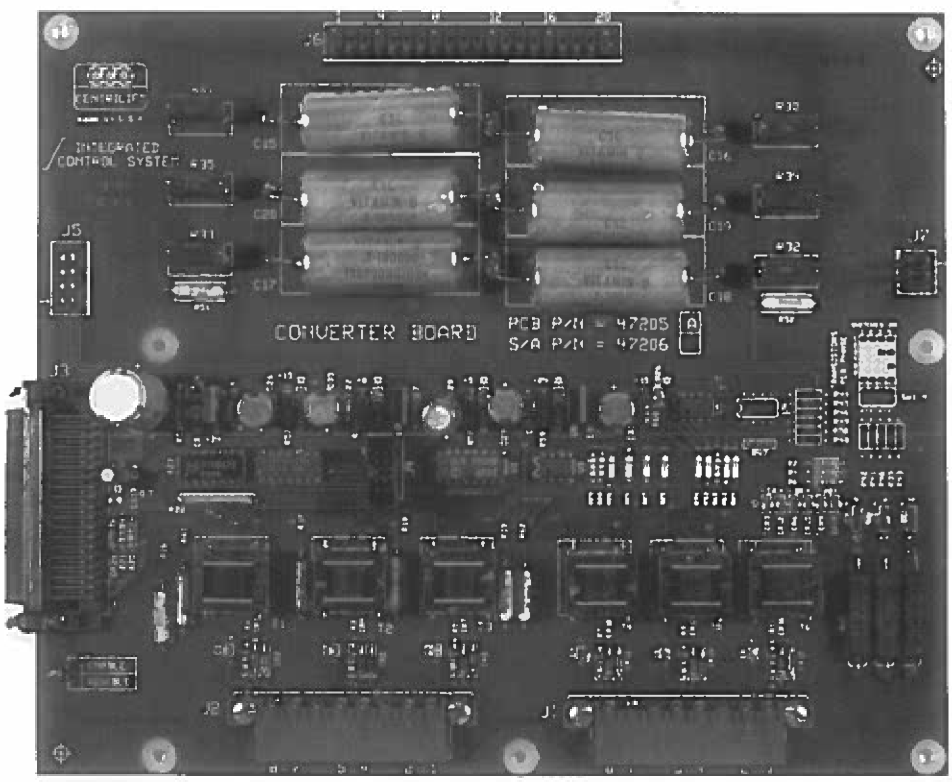


Figure 4.3 Converter Control board

4.4.4 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

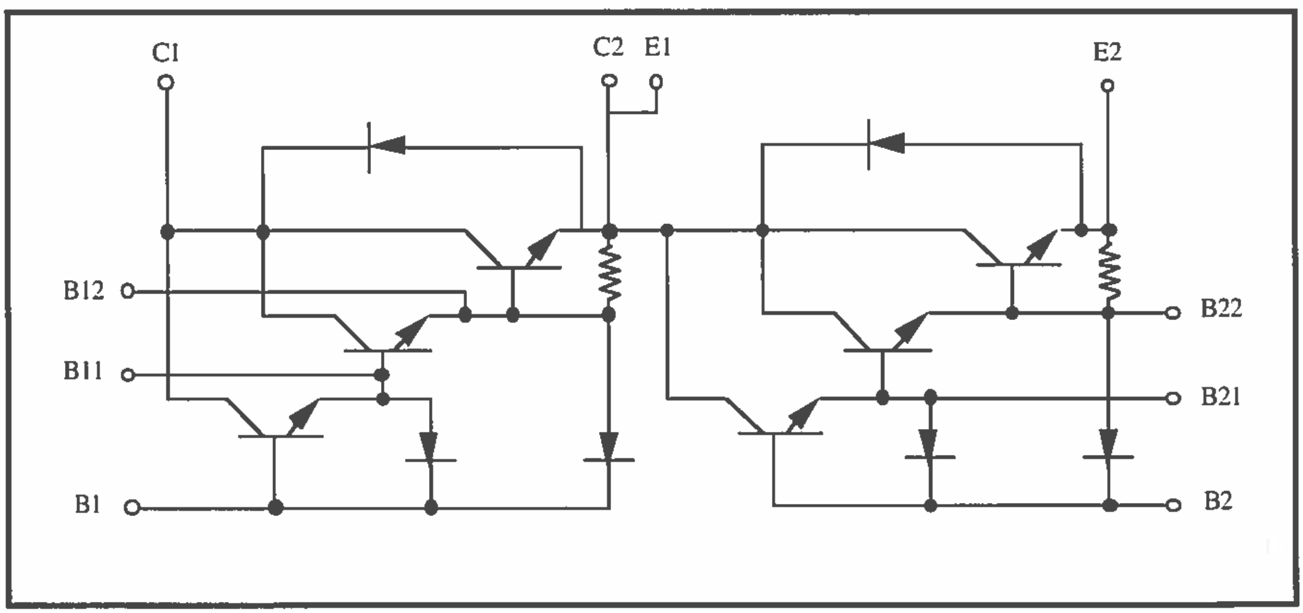


Figure 4.4 Internal Schematic for Transistor Modules

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

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.

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

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.

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.

4.8 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.

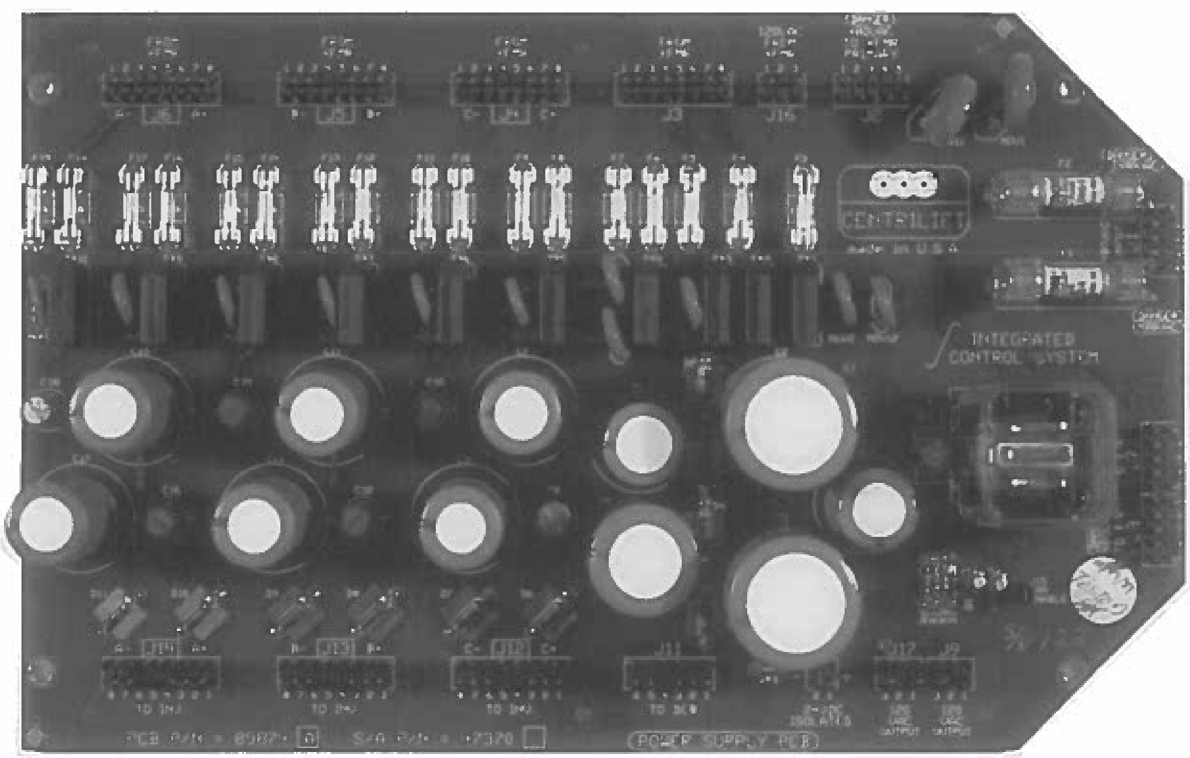


FIGURE 4.8 SYSTEM POWER SUPPLY BOARD

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.

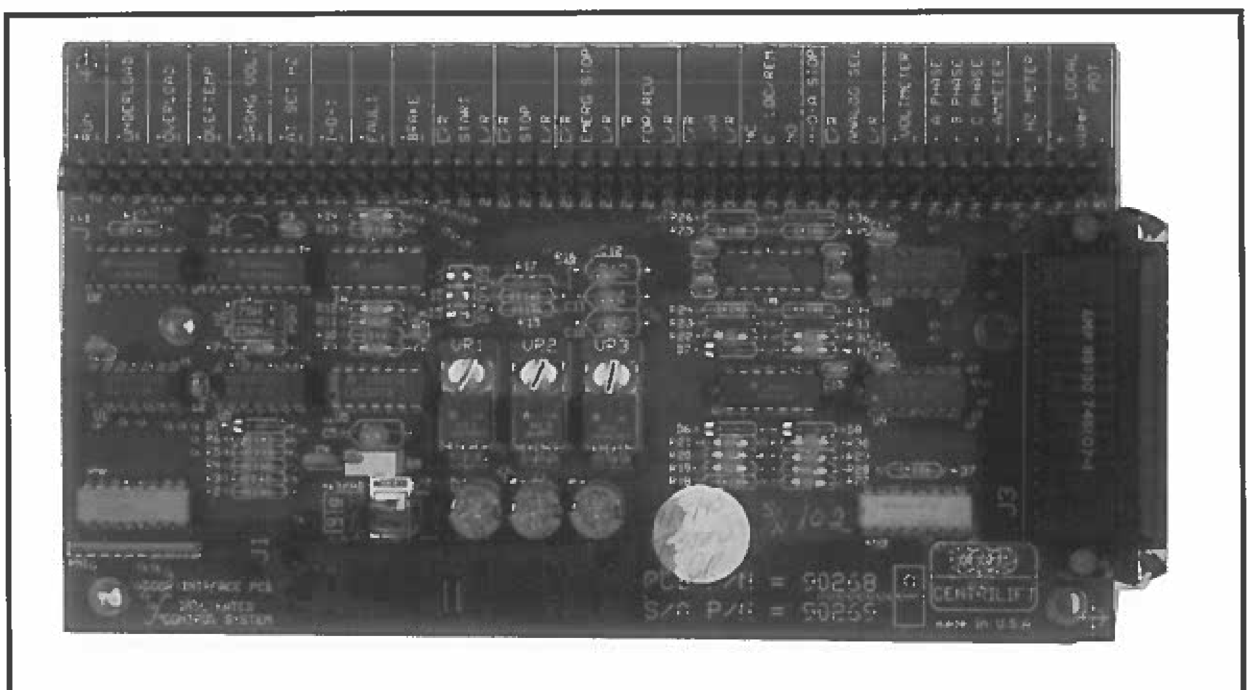


Figure 4.9 Door Interface board

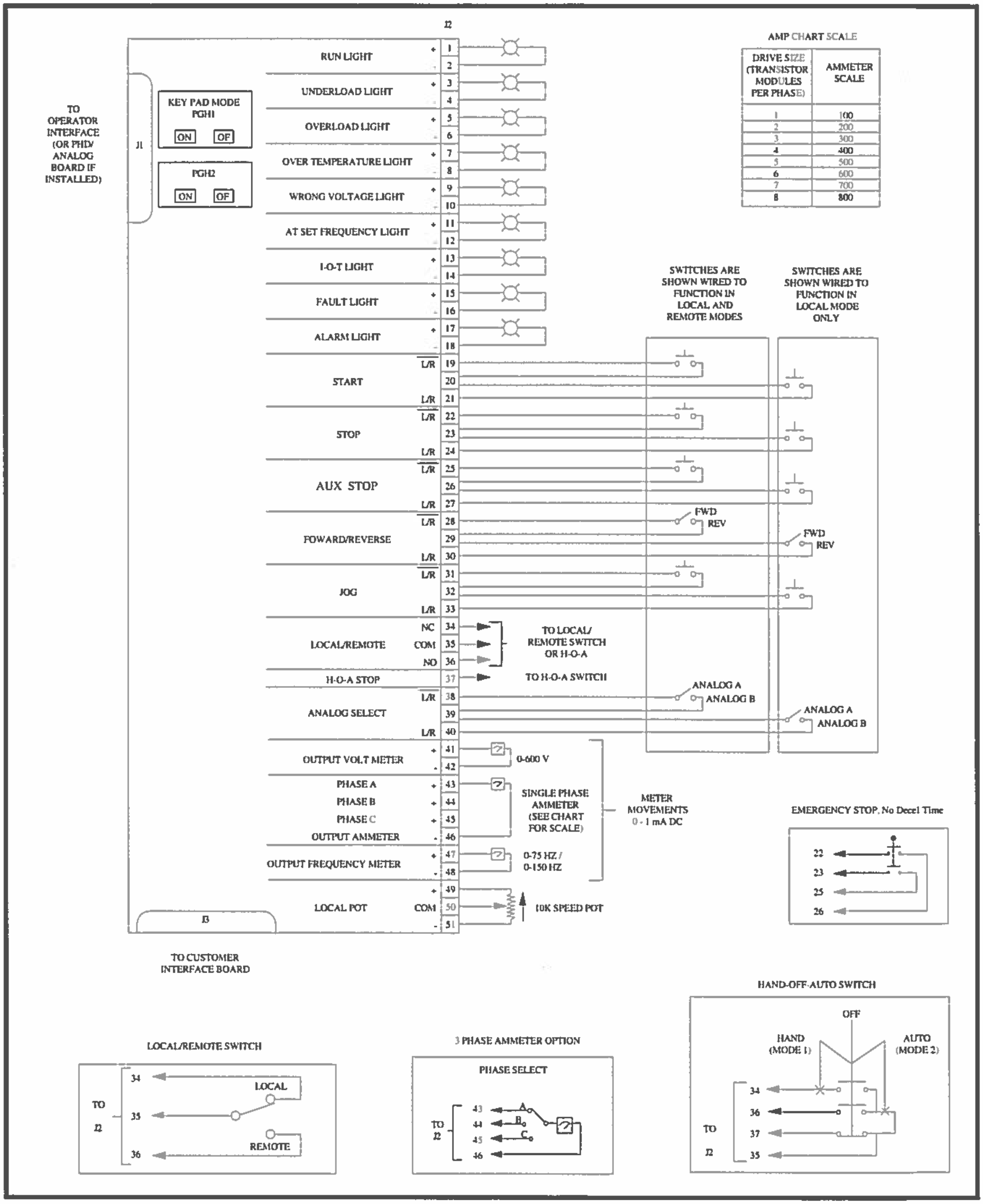


Figure 4.10 Door Interface Board Wiring Diagram

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.

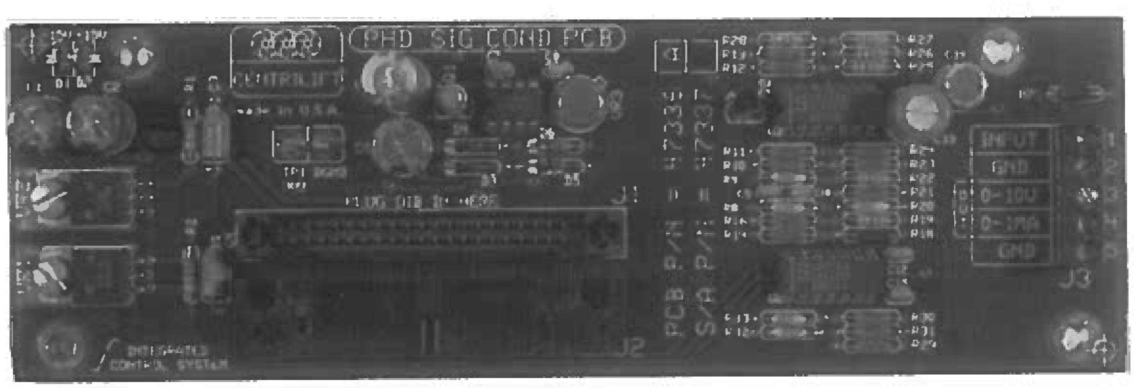


Figure 4.11 PHD Signal Conditioner

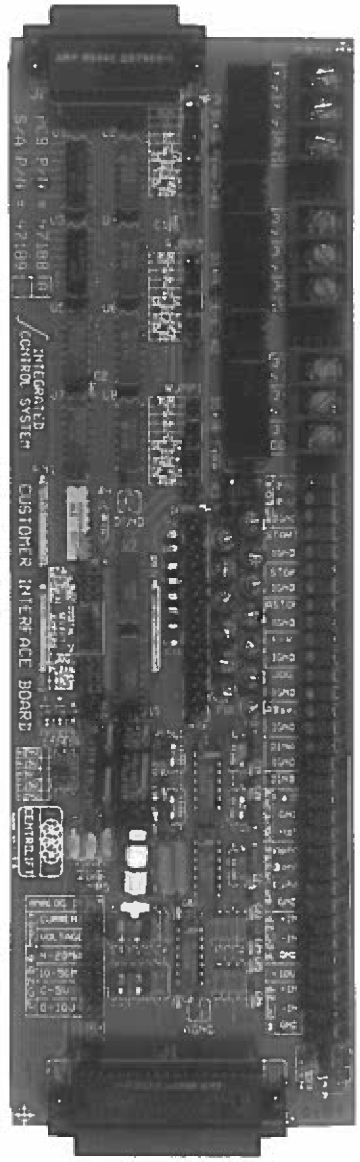


Figure 4.12 Customer Interface Board

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 OVERLAOAD TRIP, FAULT, SETPOINT ALARM, or DIGITAL INPUT ALARM on RJMP 1-3.

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.

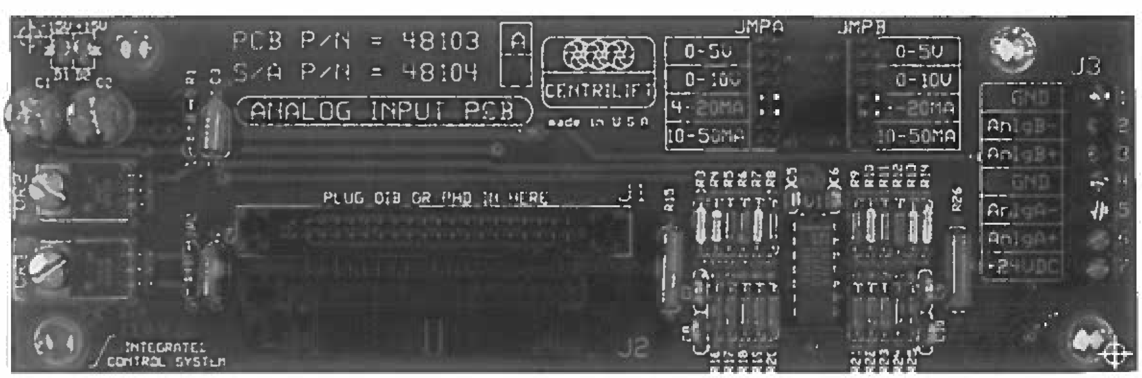


Figure 4.13 Analog Input Board

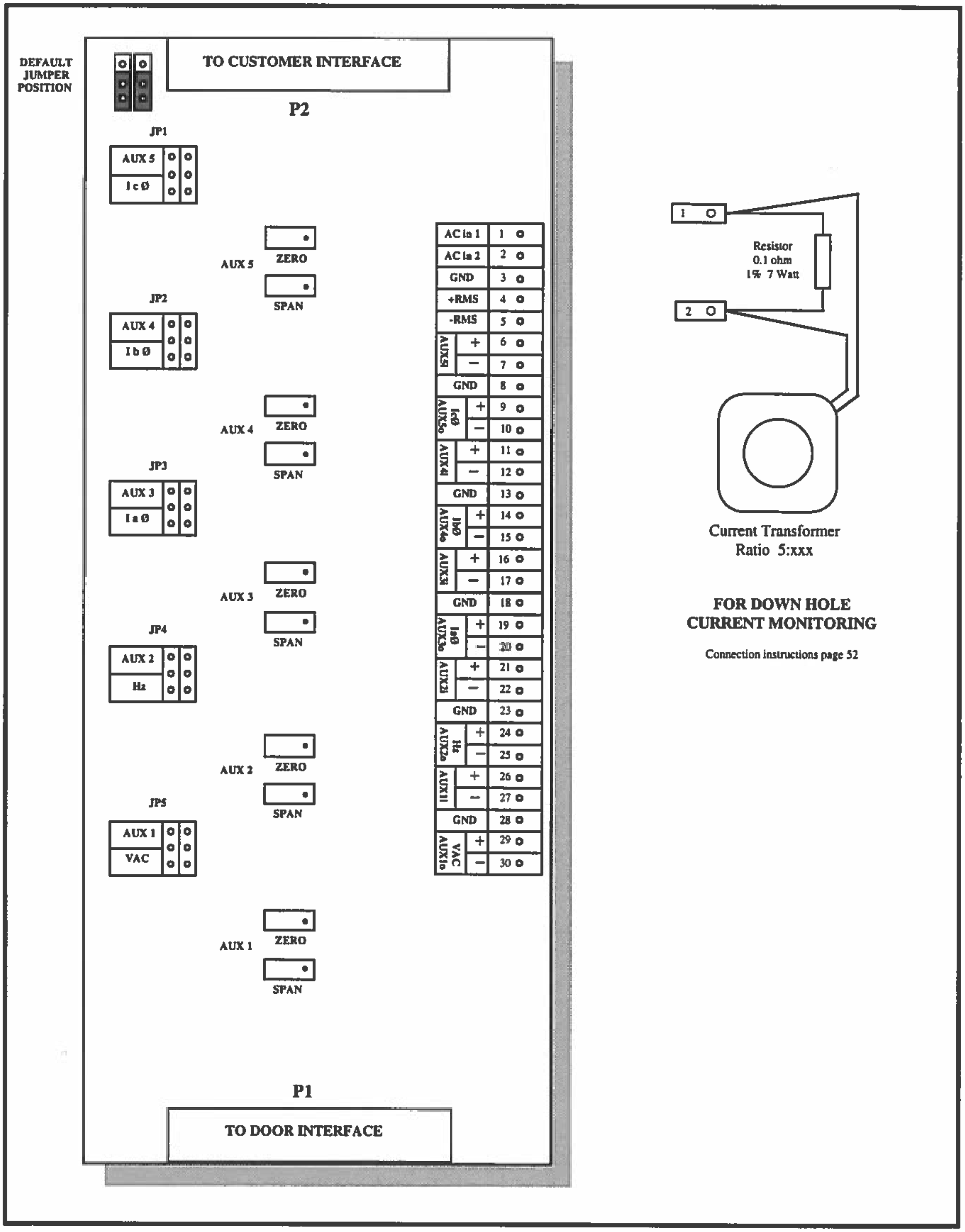
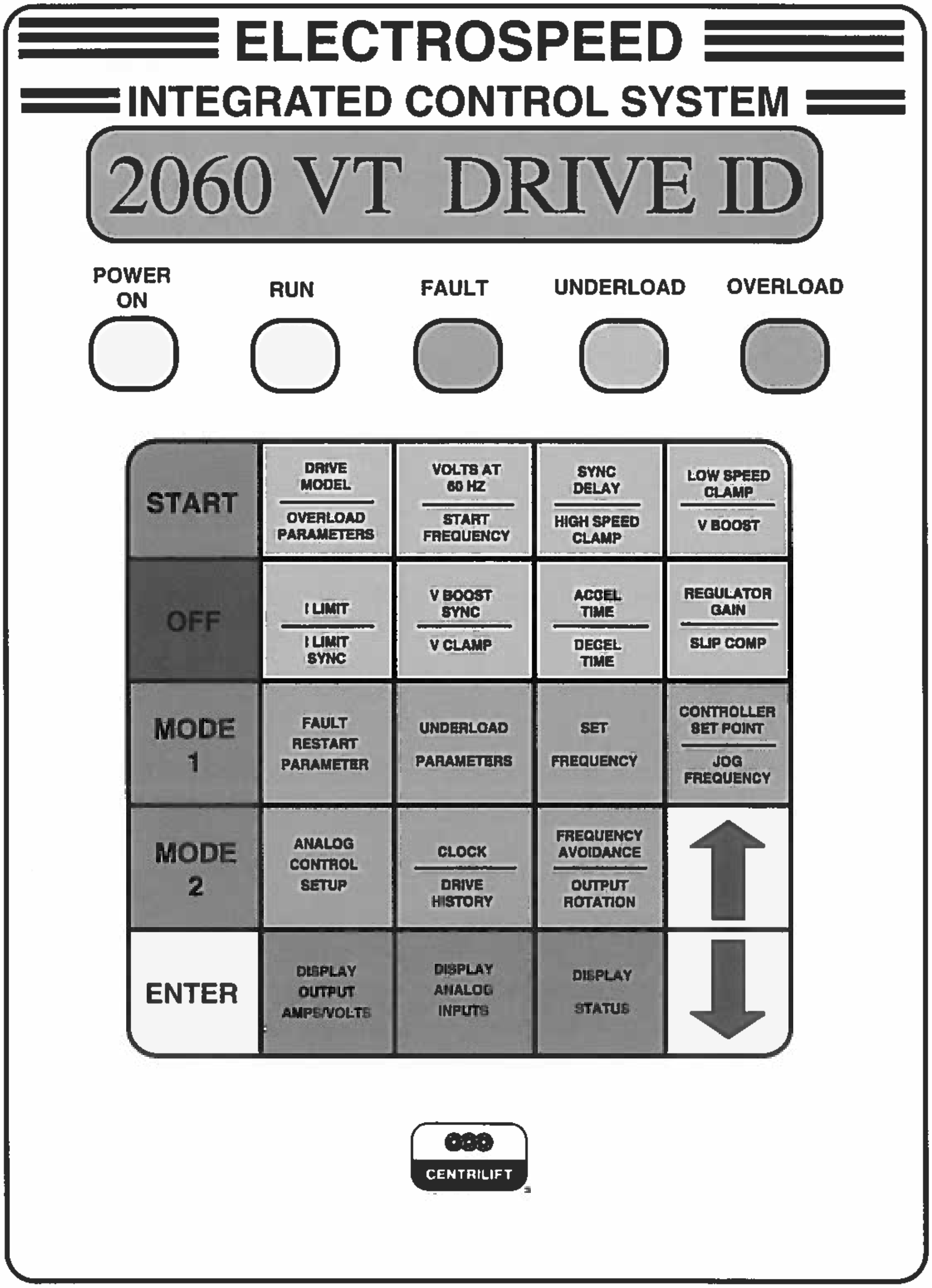


FIGURE 4.14 ANALOG OUTPUT BOARD



ICS OPERATOR INTERFACE KEYPAD

Figure 5.1

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 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).

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).

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.

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 derivitive 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 repsonse needs to be faster than practically achievable with "Integral" only. Add "Derivative Gain" to reduce overshoot.

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, refered 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 seting 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.

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 personnal 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 machnically 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.

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.

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 transformer ratio.
3. Press I LIMIT and set 5% over value set in OVERLOAD PARAMETER.
4. Set I LIMIT SYNC to motor nameplate amps X transformer ratio X 125%.
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 voltage of controller by pressing DISPLAY OUTPUT AMPS/VOLTS
5. Press SET FREQUENCY and set to maximum desired frequency per start-up sheet.

(continued next page)

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.

NOTE 2: For Short Circuit Load Tests, Set Start Frequency to 15 Hz.

5.4.5 PHD SET-UP

The Following procedure for PHD set-up is designed for operation in the automatic pressure mode, MODE 2. To operate in MODE 1, presure monitor only, ignore steps 12, 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 operate an ouput relay with a header plug programmed for SP ALM (see CIB Wiring diagram, 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.

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 commonsense 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 DISPALY 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.

6.5 Troubleshooting

The following steps decribe 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 activiated. 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 siganl 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.

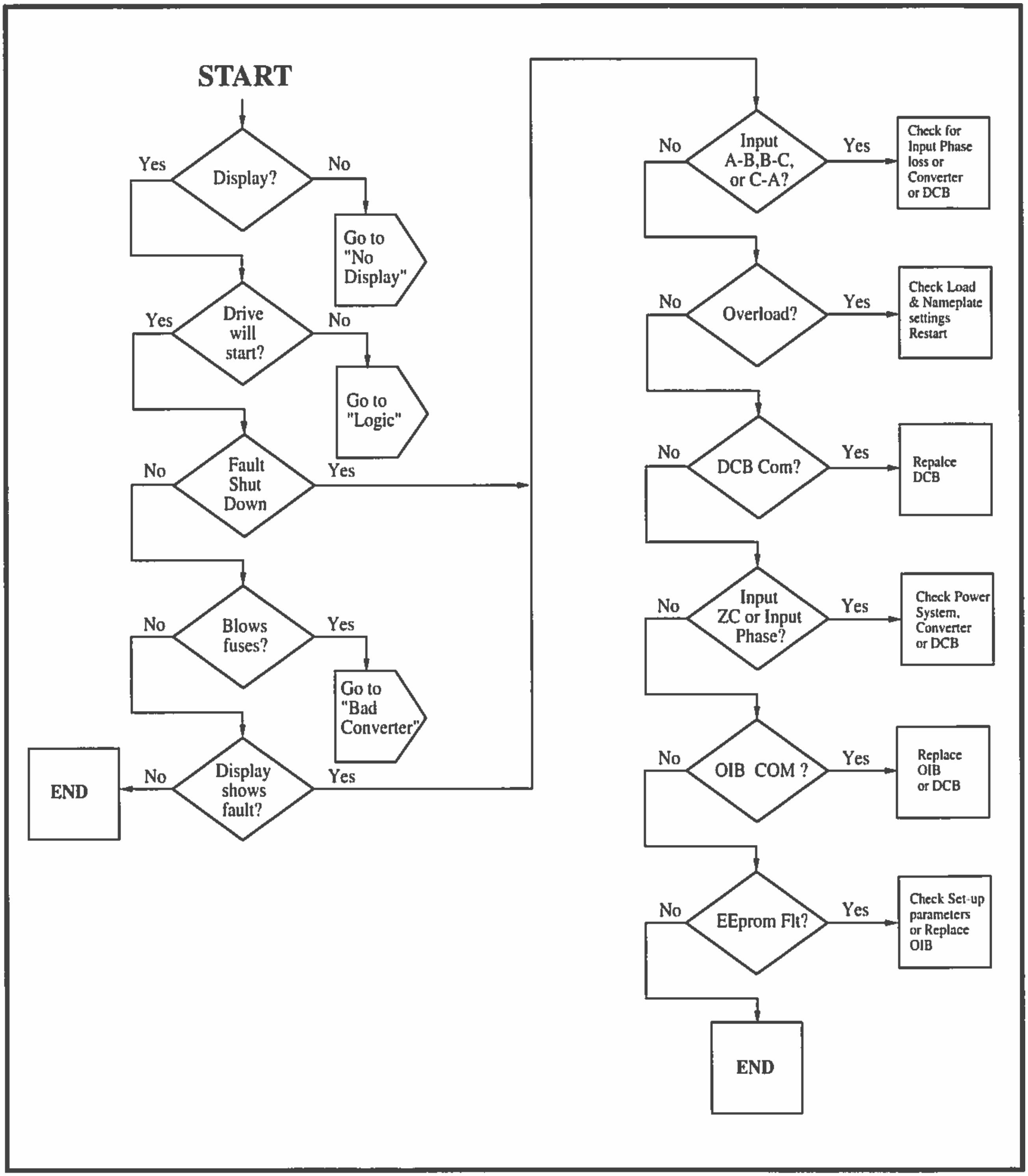


Figure 6.3 Main Troubleshooting Block

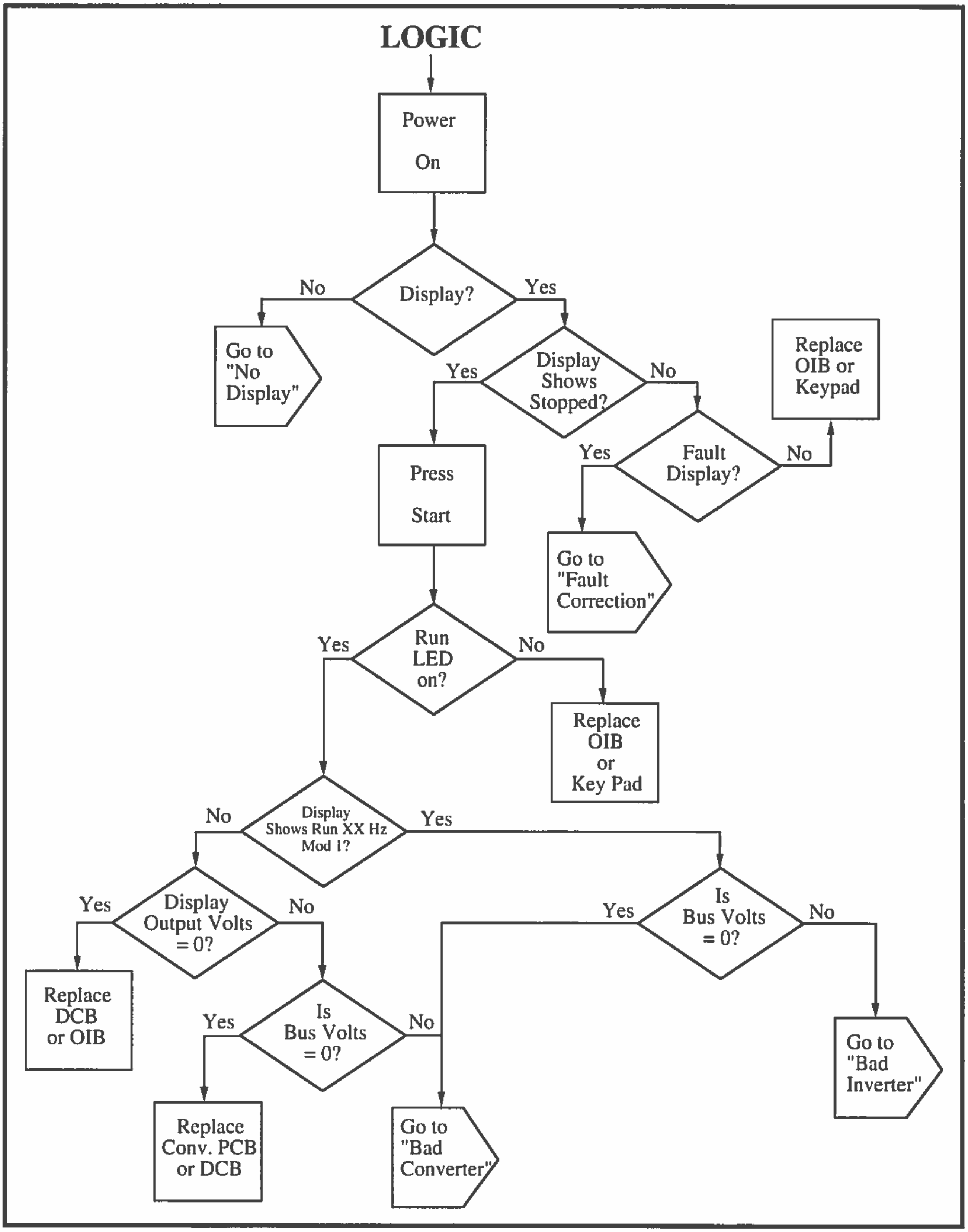


Figure 6.5 Logic Troubleshooting Block

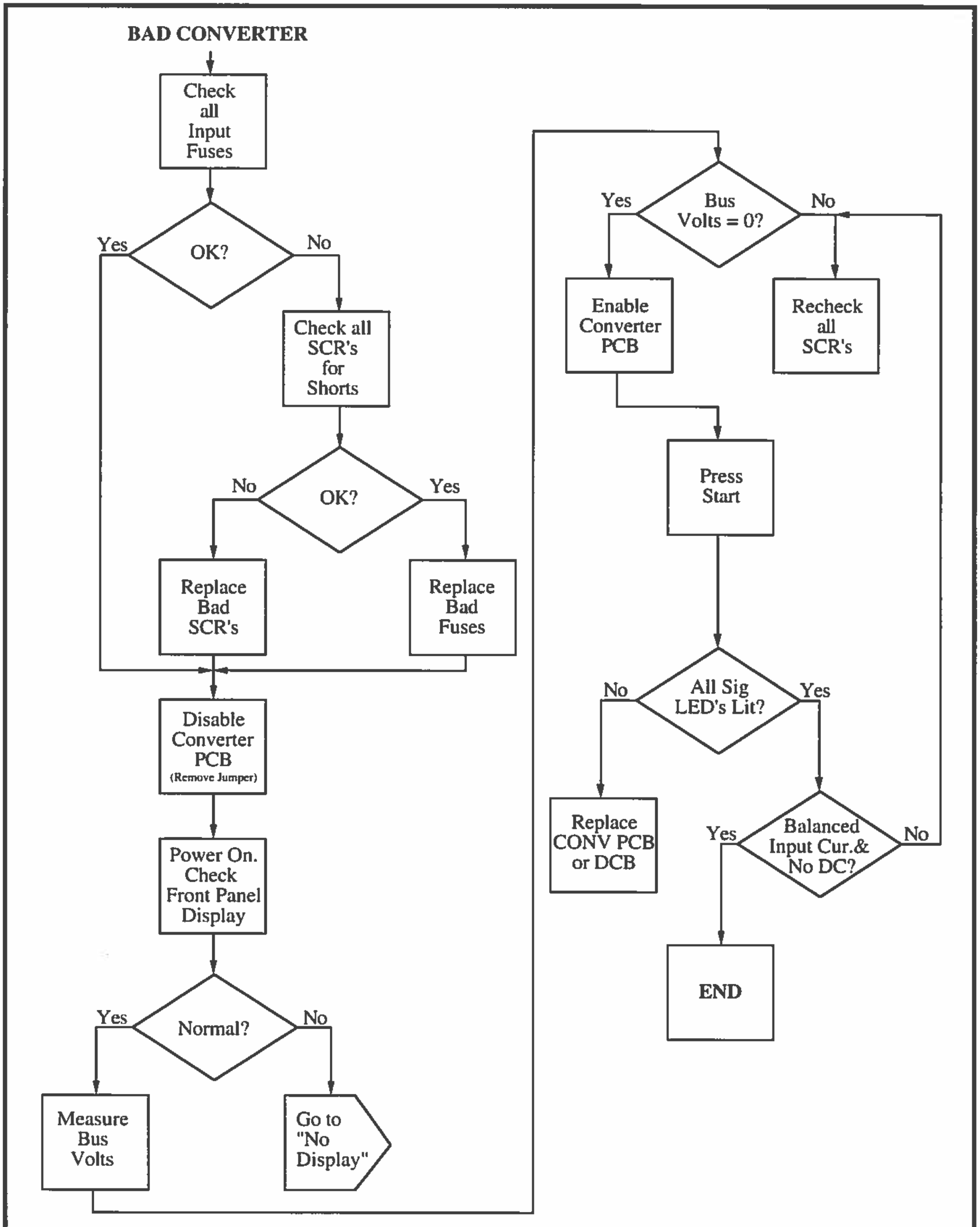


Figure 6.7 Coverter Troubleshooting Block

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. Readings taken with a Simpson 260 (analog meter) 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 using a digital meter should be approximately **.0075** to **.017** with a **Fluke 87** or **.011** to **.024** with a **Beckman 3030** and **5** to **20** ohms with a **Simpson 260.**

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.

PART No.	DESCRIPTION	PRICE	U/M
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
47792	HARNESS,S/A,TRANSISTOR MDL,2N3		EA
48122	HARNESS,S/A,TRANSISTOR MDL,4N3		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
55527	KEYPAD S/A, OPERATOR I/F		EA
50547	LAMP,GE 757,28V,.08A,T-3.25		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
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