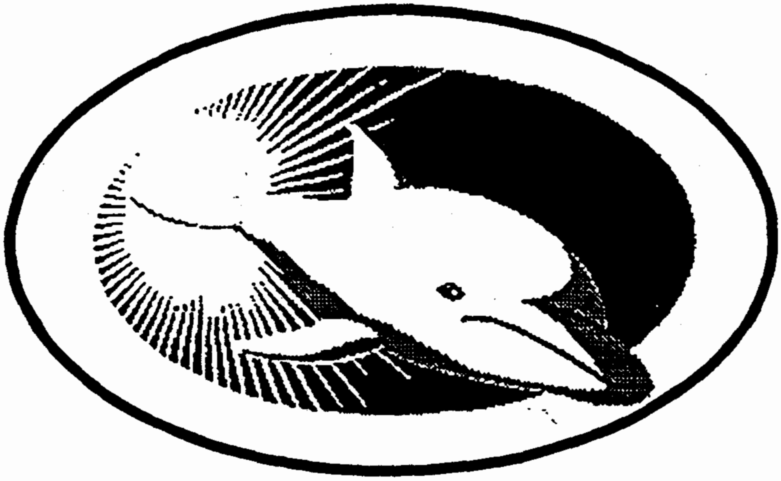
POWER CONTROL SYSTEMS	Document Number: A04500KB0
	Initial Release: 02/26/94 01/09/1995 / Last Page: 25

APPLICATION INSTRUCTIONS
FOR THE



DOLPHIN 50

ELECTRIC VEHICLE DRIVE SYSTEM

HUGHES PROPRIETARY

SYSTEMS ENGINEERING: W.W. FUREY	RELEASED PRINT
ELECTRICAL ENGINEERING: D.E. LEWIS 95-01-10	RESPONSIBLE ENGINEERING ACTIVITY: DOLPHIN 50
MECHANICAL ENGINEERING: B.H. ROBINSON	
SERVICE: J.B. MC CALLUM 10 Jan 95	REA ORG CODE
MANUFACTURING: E.J. MUNDT FOR EJM	REV / REL DATE 95-01-10 / REL BY
TEST ENGINEERING: M.M. OSUGI 95-1-10	
DOLPHIN PRODUCT LINE: A.B. MOOR FOR A.M.	

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WARNINGS

DANGER: THE DOLPHIN POWER CONTROL UNIT (PCU) IS DESIGNED FOR USE IN A LIMITED FLEET PRODUCTION OF ELECTRIC VEHICLES, HENCE THE PCU AND PERIPHERAL ELECTRONIC HARDWARE IS NOT DESIGNED TO BE SERVICED, MAINTAINED OR HANDLED IN ANY WAY BY NON-TRAINED ENGINEERING OR TEST PERSONNEL.

THE PCU COVER SHOULD NOT BE REMOVED AT ANY TIME. A 400 VOLT SHOCK HAZARD MAY BE PRESENT INSIDE THE UNIT WHEN THE COVER IS REMOVED. A 240 VOLT OR 120 VOLT AC LINE SHOCK HAZARD IS ALSO PRESENT WHEN THE COVER IS REMOVED AND THE AC CHARGING LINE REMAINS CONNECTED.

WHEN THE PCU IS COMMANDED ON (KEY ON), THE "READY" LIGHT ON THE DRIVER DISPLAY SHOULD BE ILLUMINATED WITHIN 5 SECONDS. THE READY LIGHT SHALL ILLUMINATE ONLY AFTER THE PCU INTERNAL HIGH VOLTAGE CAPACITORS ARE FULLY CHARGED, AND NO ISOLATION FAULT EXISTS. IF THE "READY" INDICATOR FAILS TO ILLUMINATE WITHIN 5 SECONDS, TURN THE KEY TO THE OFF POSITION AND CONTACT A HUGHES SERVICE REPRESENTATIVE LISTED IN THIS DOCUMENT.

WHEN THE PCU IS COMMANDED OFF (KEY OFF), HAZARDOUS VOLTAGES CAN STILL BE PRESENT WITHIN THE PCU.

WHEN THE CONDUCTIVE CHARGE CABLE (AC LINE) IS CONNECTED TO AN AC POWER SOURCE, THE PCU IS BOOTED IN CHARGE MODE AND HAZARDOUS VOLTAGES ARE PRESENT INSIDE THE PCU. EVEN IF A FAULT OCCURS AND THE PCU SHUTS ITSELF DOWN, HAZARDOUS AC VOLTAGES ARE STILL PRESENT AS LONG AS THE AC LINE REMAINS CONNECTED.

THE INSTALLER SHALL INSURE THAT THE VEHICLE CHASSIS IS GROUNDED TO THE UTILITY GROUNDING SYSTEM WHEN THE DIRECT CHARGER IS CONNECTED TO THE AC UTILITY POWER GRID. USE OF THE DIRECT CHARGER MUST BE WITH AN NEC APPROVED GROUNDED FACILITY OUTLET. A SHOCK HAZARD IS PRESENT IF THE AC OUTLET IS NOT GROUNDED TO EARTH GROUND.

IN ORDER TO ENSURE PROPER OPERATION OF THE DOLPHIN PCU, THE INSTALLER IS RESPONSIBLE TO TAKE THE PRECAUTIONS OUTLINED IN THIS APPLICATION MANUAL. FAILURE TO DO SO WILL ADVERSELY AFFECT INSTALLER/OPERATOR SAFETY, SYSTEM OPERATION, RELIABILITY, AND SERVICE LIFE.

POINT OF CONTACT

FOR QUESTIONS OR PROBLEMS,
PLEASE CONTACT THE
HUGHES POWER CONTROL SYSTEMS (HPCS)
SERVICE DEPARTMENT AT:

1-800-482-6644

SCHEMATICS

ITEM	PART NUMBER	AVAILABILITY
DOLPHIN 50 PCU (Power Control Unit) INSTALLATION DIAGRAM	A04500EE0 10-24-94	ENCLOSED
DOLPHIN 50 PCU OUTLINE AND MOUNTING (O & M) Drawing	A04600NN0	ENCLOSED
DOLPHIN 50 kW MOTOR OUTLINE AND MOUNTING DRAWING	A04730NN0	ENCLOSED

Table D-1 Drawings/Schematics

ELECTRICAL CONNECTION INTERFACES

Signal Connector J4		
Conn.	**SIGNAL NAME**	**PCU INTERFACE DESCRIPTION**
J4		12V Power Inputs (interlock & "wake-up" bias power)
pin v	P12V_BATT	Interlock & HV DC Contactor Relay Power, +12V, 3A maximum
pin A	KEY_ON_IN	Motoring "wake-up" bias power, +12V, 750mA nominal
pin K	CP_CONNECTED	Charging "wake-up" bias power, +12V, 750mA nominal
		Digital Control Inputs
pin B	PRNDLA	Digital, 0V to 12V input, 10K to ground
pin C	PRNDLB	Digital, 0V to 12V input, 10K to ground
pin D	PRNDLC	Digital, 0V to 12V input, 10K to ground
pin E	PRNDLP	Digital, 0V to 12V input, 10K to ground
pin F		NOT USED
pin G		NOT USED
pin H		NOT USED
pin J		NOT USED
pin L		NOT USED
pin M		NOT USED
pin N		NOT USED
pin P	MSTR_DIS	Digital, 0V to 12V input, 2.2K to +12V Connect To Ground
		Analog Status Outputs
pin R	BATT_SOC	Analog output, 0 to 5V, 2mA max.
pin S	TEMP	Analog output, 0 to 5V, 2mA max.
pin T		NOT USED
pin U		NOT USED
		Digital Status Outputs
pin V	READY	Open collector output, 16V, 100mA max.
pin W	CHARGE_COMPLETE	Open collector output, 16V, 100mA max.
pin X	DC/DC_SHUTDOWN	Open collector output, 16V, 100mA max.
pin Y	FAULT	Open collector output, 16V, 100mA max.
pin Z	OVERHEAT	Open collector output, 16V, 100mA max.
pin a		NOT USED
pin b	BRAKE_LIGHT	Open collector output, 16V, 100mA max.
pin c		NOT USED
pin f		NOT USED
pin g		NOT USED
pin h		NOT USED

Signal Connector J4 (continued)		
Conn.	**SIGNAL NAME**	**PCU INTERFACE DESCRIPTION**
J4		Digital & Analog Reference
pin i	AGND	*Analog or digital chassis ground reference*
pin j	AGND	Analog or digital chassis ground reference
pin k	AGND	Analog or digital chassis ground reference
pin m	AGND	Analog or digital chassis ground reference
		Digital Serial Communications
pin n	DSP_SER_OUT	RS232 serial output, 9600 BAUD
pin q	DSP_SER_IN	RS232 serial input, 9600 BAUD
pin p		NOT USED
pin s		NOT USED
pin r	no connection	-
		Analog Status Inputs
pin t		NOT USED
pin u		NOT USED
		Power & Reference for Analog Control Inputs
w	POT_+5PWR	+5V power output, 100Ω to 5V
pin x	POT_RTN	+5V power reference, 100Ω to ground
		Analog Control Inputs
pin y	ACCEL0	Analog 0 to 5 volts, 100k to ground
pin z	ACCEL1	Analog 0 to 5 volts, 100k to ground
pin AA		NOT USED
pin BB	BRAKE_PED	Analog 0 to 5 volts, 100k to ground
pin CC		NOT USED
		External Relay Analog Control Outputs
pin DD	PRECHG-	Open drain output, 16V, 1.5A max.
pin d	PUMP	Open drain output, 16V, 1.5A max.
pin e	FAN	Open drain output, 16V, 1.5A max.
		Signal Connector Interlock Pair
pin EE	INTLK_A	+12V Interlock output, 3 Amps maximum
pin FF	INTLK_B	+12V Interlock return input, 3 Amps maximum
pin GG	no connection	-
pin HH	no connection	-
pin JJ	no connection	-
pin KK	no connection	-
pin LL	no connection	-
pin MM	no connection	-
NN	no connection	-
PP	no connection	-

Battery Pack - Connector J2

J2	SIGNAL NAME	PCU INTERFACE DESCRIPTION
pin E	BATTERY+ (Positive)	Propulsion battery input, 250V to 405V max., 220 Amps max.
pin B	BATTERY- (Negative)	Propulsion battery reference return, 220 Amps max.
pin A	BAT_CON	Pre-charge power input, 250V to 405V max., 3 Amps max.
pin C	MAIN_RLY+	+12V Relay power output, 3 Amps maximum
pin D	MAIN_RLY-	Open drain output, 16V, 1.5A max.

Propulsion Motor - Connector J1

J1	SIGNAL NAME	PCU INTERFACE DESCRIPTION
pin C	PHASE_A	AC Power output, 150V RMS, 230A RMS max.
pin G	PHASE_B	AC Power output, 150V RMS, 230A RMS max.
pin B	PHASE_C	AC Power output, 150V RMS, 230A RMS max.
pin H	NEUT	AC Power output, 150V RMS, 100A RMS max.
pin J	INTLK_MOT	+12V Interlock output, 3 Amps maximum
pin D	INTLK_MOT_RTN	+12V Interlock return input, 3 Amps maximum
pin A	no connection	-
pin E	no connection	-
pin F	no connection	-

Propulsion Motor Encoder - Connector J5

J5	SIGNAL NAME	*PCU INTERFACE DESCRIPTION*
pin A	P5V	+5V power output, 100Ω to 5V
pin D	AGND	+5V power reference, 100Ω to ground
pin B	ENC1A	Digital, 0V to 12V input, 5.1K to +5V/+12V
pin C	ENC1B	Digital, 0V to 12V input, 5.1K to +5V/+12V
pin E	MOTOR_A_TEMP	Analog input, *0 to 5 volts, 10k to +5V*

12V DC Output Power - Terminal Posts E1 & E2

Post	SIGNAL NAME	PCU INTERFACE DESCRIPTION
1	12VOUT	+12V(*13.5±.4V DC) power output, 100A max.*
2	CHASSIS_RTN	Chassis Ground

120/240V AC Utility Input Power - Connector J6

J6	SIGNAL NAME	*PCU INTERFACE DESCRIPTION*
pin A	240/120VAC	80 to 250 VAC 60Hz input, 15A max.
pin B	240/120VAC	80 to 250 VAC 60Hz input, 15A max.
pin C	GROUND	Chassis Ground

High Voltage DC Power Inputs (HV Battery Connection)

See the "Main Contactor Specification" section of this document for more *information.*

BATTERY+ and BATTERY- (Primary Power Connection)

BATTERY+..425V maximum, 320V nominal PCU input
BATTERY- ....200A maximum input/return current
Isolation to chassis > 5MΩ

BAT_CON (Pre-Charge Power Connection)

Battery Connected...425V maximum, 320V nominal PCU input
3A maximum input current
Isolation to chassis > 800kΩ

High Voltage AC Power Input (AC Battery Charging)

The J6 PCU connector shall accept 120VAC or 240VAC for battery charging. The PRNDL selector must be in PARK and the starter key switch (KEY_ON_PWR inactive) in the off position. The AC input must be 60±10Hz and between 80 and 250VAC. The connections and harness wiring must be sufficient to handle a maximum of 15 amps.

Low Voltage Power Input (12V Interlock Power)

P12V_BAT (Positive 12 Volt Battery Input)
This input provides power for the unit interlock chain which in turn provides power for the high voltage connection relays and shall be connected to nominal +12V through a 3 amp fuse for overload protection. For the unit to operate properly the voltage to this input must be maintained at 12.5±3.5V at all times.

Interlock Output & Return Loop

INTLK_MOT & INTLK_MOT_RTN (Motor Interlock & Return)
If battery charging is to be done using a Hughes Power Control Systems' Inductive Charge Port this output and return pair are to be routed to the charge port as described in the charge port's application instructions. Otherwise they shall be routed to a normally open switch that closes (shorts them to each other) when the vehicle hood or access to the PCU compartment is secured (closed). Isolation from the vehicle chassis must be maintained at all times.

Mode Selection Control & "Wake-Up" Bias Power Inputs

Motoring Activation Key Switch (KEY_ON_PWR)
The KEY_ON_PWR signal input shall be used to enable/"wake-up" the Power Control Unit for motoring. To activate it shall be mechanically or electrically switched to 12.5±3.5V (auxiliary battery) indicating an active "high". This same signal shall subsequently be switched to 0.0V chassis ground or disconnected to shut down the PCU. This input provides power to a dynamic power supply load and shall require a minimum of 700mA (8.4 Watts) at the rated voltage.

Charging Activation Switch (CP_CONNECTED)
The CP_CONNECTED signal input shall be used only in conjunction with a HUGHES POWER CONTROL SYSTEMS Inductive Charge Port to enable the PCU for charging. Although the electrical requirements for this signal are identical to those of the KEY_ON_PWR input, these requirements shall be satisfied by the Inductive Charge Port controller unit upon connection to it as described in its supplied documentation. Without an Inductive Charge Port this signal pin is required to be connected to chassis ground. Note that any time the CP_CONNECTED signal goes active, the unit shall transition to charging mode, overriding motoring mode if the vehicle is in PARK or in NEUTRAL and not in motion.

Digital Control Inputs to PCU

Drive Mode Selector (PRNDL) Control Inputs
PRNDL_A, PRNDL_B, PRNDL_C, and PRNDL_P (parity) inputs are decoded to select the desired motoring mode. *They shall be electrically switched to 12V* nominal (auxiliary battery) to indicate a "1" or active "high". They shall be switched to chassis ground or left unconnected to indicate a "0" or inactive "low". The following table defines the encoding strategy and characteristics of each selectable motoring sub-mode.

PRNDL mode	PRNDL input logic A	B	C	P	REGEN TORQUE COAST DOWN DRAG	BRAKING	ACCEL TORQUE	RPM LIMIT
PARK	1	1	1	1	none	disabled	disabled	none
REVERSE	*0*	*1*	*1*	*0*	50% of max.	yes	yes	1000±100
NEUTRAL	0	0	1	1	none	yes	ramp to disable	none
DRIVE	1	0	1	0	50% of max.	yes	yes	9000±100
2	1	0	0	1	75% of max.	yes	yes	TBD
[illegible]W	1	1	0	0	maximum	yes	yes	TBD

The PRNDLX interfaces are characterized as follows:

PRNDP (parity) PRNDA PRNDB PRNDC	*Voltage 0 to 16V maximum* 10V minimum input high, 2V max. input low 6.9kΩ±1kΩ input resistance to ground (chassis) 5 milliamps max. input current requirement

MSTR_DIS (Master Disconnect)
The master disconnect is intended to disable the power control unit's output propulsion power in the event of a major fault or accident. Under normal operating conditions this input shall be at 0.0±2 volts, chassis ground. An event that requires an immediate shut down of the unit shall switch this input to 12V. If this emergency feature is not desired then this input shall be connected to chassis ground.

Analog Control Inputs to PCU

ACCEL_0 ACCEL_1 BRAKE_PED

The accelerator pedal and brake pedal interface characteristics shall be implemented as follows and as shown in diagram figure AB-1.

ACCEL_0	»	Voltage 0 to 4.2V maximum w.r.t. POT_RTN
ACCEL_1	»	Voltage ACCEL_0 = ACCEL_1 ±0.2V
BRAKE_PED	»	10kΩ input resistance to ground (chassis)

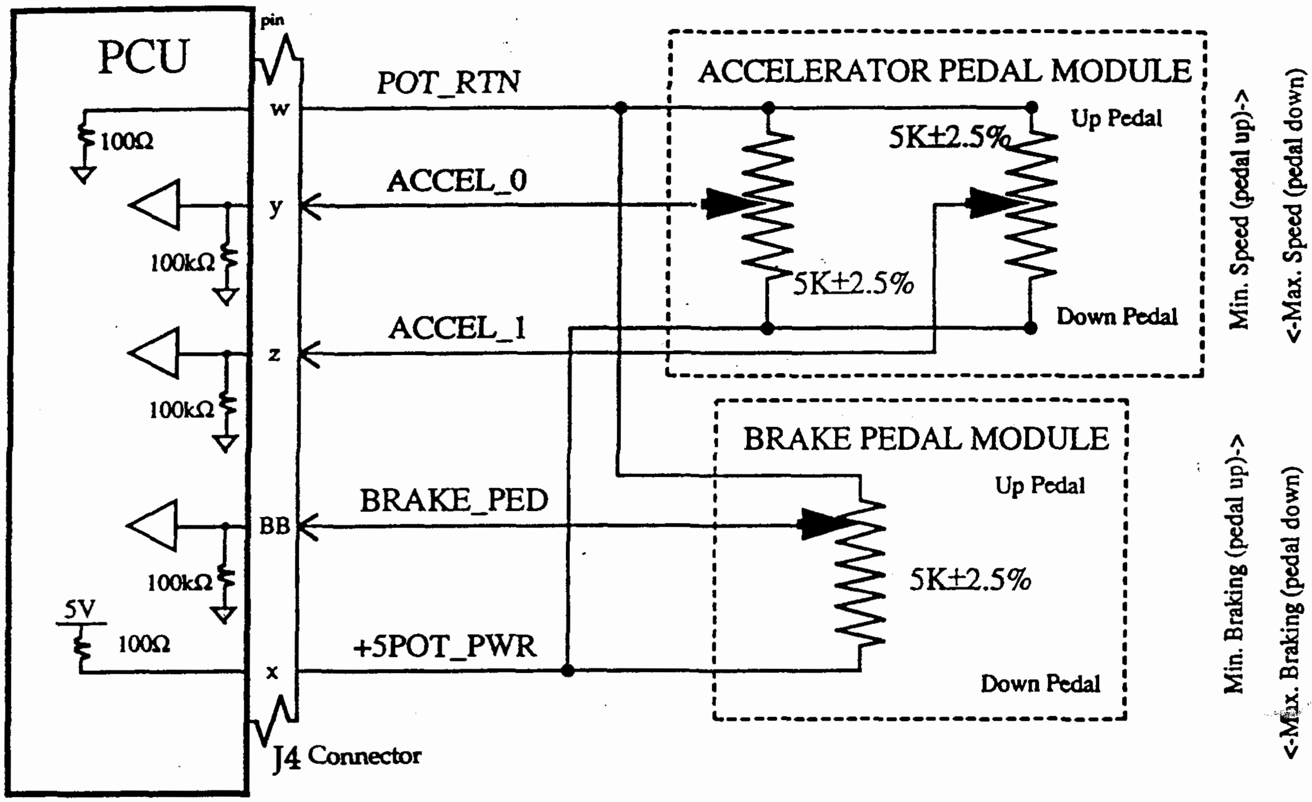


Figure AB-1 Accelerator Pedal & Brake Pedal to PCU Interface

Output Power and Reference For Analog Control Inputs

5V_POT_PWR Accelerator & Brake Pedal Potentiometer Power

The accelerator pedal module and the brake pedal module shall each receive +5 volt power from the 5V_POT_PWR output of the PCU. The required PCU connector is specified in the MECHANICAL section of this document. The required pedal modules/potentiometers are TBD. See drawing for the proper connection.

POT_RTN Accelerator & Brake Pedal Potentiometer Reference

The accelerator pedal module and the brake pedal module must each also receive a reference signal designated POT_RTN. The required PCU connector is specified in the MECHANICAL section of this document. The required pedal modules/potentiometers are TBD. See drawing for the proper connection.

Digital Status Outputs

The following outputs shall be used to indicate various data/status to the vehicle operator/driver.

READY

CHARGE_COMPLETE

DC/DC_SHUTDOWN

FAULT

BRAKE_LIGHT

The above listed driver indication lights are open collector outputs that shall be connected ("pulled-up") to the auxiliary battery through a minimum of 320Ω resistance and an indicator LED. When the PCU activates an output, the output will go "low" (0.0±0.3 volts) pulling current from the cathode (negative side) of the LED, illuminating the LED, thereby signaling the driver of the vehicle. The installer must ensure that no more than a maximum 100 mA of continuous open collector current is input to each signal line when the output is "active". If this output is to drive a small PC board type relay, a 1 second 200mA transient is allowed. The maximum pull-up voltage for these outputs is 30V DC.

Analog Status Outputs

BATT_SOC Battery State of Charge

0 to 5 volt analog output
10mA maximum allowable output current draw

TEMP Temperature

0 to 5 volt analog output
10mA maximum allowable output current draw

Note that the *PCU shall shutdown when its* cold plate temperature reaches 70°C or the motor temperature reaches 85°. The following diagram illustrates the output of the TEMP (PCU temperature signal) signal interface over the indicated range of PCU temperatures.

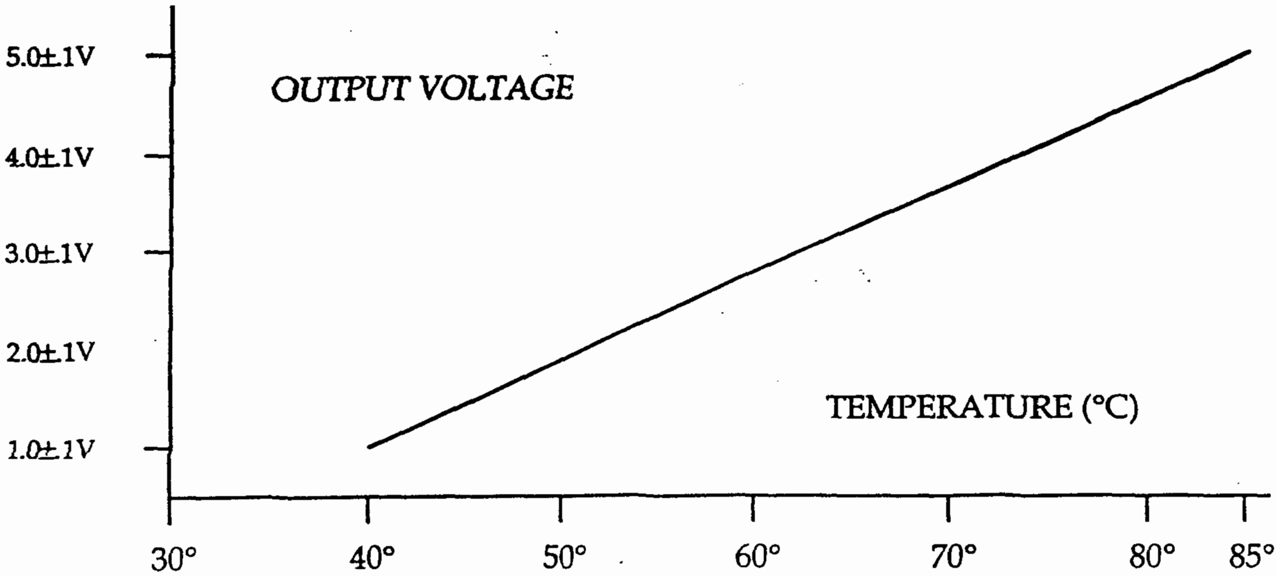


Figure T-1 PCU Temperature Output

High Power Outputs

Propulsion Drive Motor Power Connection
PHASE_A, PHASE_B, PHASE_C;
This harness is included with the Dolphin System. Connection to PCU requires no modification.

Motor Speed Encoder with Temperature Sensor Connection
This harness is included with the Dolphin System. Connection to PCU requires no modification.

13.5 Volt Accessory Power Connection
12VOUT and CHASSIS_RTN;
This is the DC accessory and auxiliary 12 Volt battery power supply. Connect 12VOUT to the positive auxiliary battery terminal. CHASSIS_RTN shall be connected to the negative *auxiliary* battery terminal. Do not connect to negative side of high voltage propulsion battery pack.

Power Output

MAIN_RLY+
The MAIN_RLY+ output is intended to provide a maximum total current output of 3 Amperes to power the coils of the two high voltage connection control relays. The two *relays described* are controlled by the outputs MAIN_RLY- and PRECHG- that are detailed in the next section. This output receives its power from the P12V_BAT input described earlier in this document, and therefore will output voltage of the same specification. The implementation of the high voltage connection is further detailed in the Main Contactor Specification section of this document.

External Relay Control Outputs

The following outputs are open drain and are each intended to control an external 12V relay by connecting one side of the relay's excitation coil to chassis ground when activation of the relay is desired. This requires the installer to connect the positive side of the relay's activation coil to a voltage source (16V maximum continuous, 30V max. peak) and the negative (opposite) side directly to the controlling PCU output. Note that the connection to ground described is made <u>internal</u> to the PCU. Do <u>not</u> connect either side of the relay's coil to chassis ground. The installer shall verify that the coil resistance is at least 11Ω so as not to exceed the maximum continuous input current rating of 1.5A (10A peak for < 10 msecs).

High Voltage Connection Control Relays

The 12V relays controlled by the following two outputs shall be powered from the MAIN_RLY+ output detailed in the previous section.

PRECHG-;

The 12V relay controlled by this output shall be powered from the MAIN_RLY+ output detailed in the previous section. See the Main Contactor Specification section.

MAIN_RLY-;

The 12V relay controlled by this output shall be powered from the MAIN_RLY+ output detailed in the previous section. See the Main Contactor Specification section.

Thermal Subsystem Control Relays (Radiator Fan & Coolant Pump)

The 12V relays controlled by the following two outputs shall be powered from an external)ltage source (16V max. continuous, 30V max. peak).

PUMP;

The 12V relay controlled by the PUMP output should be selected to switch the rated current of a 12V DC coolant pump. Do not connect a pump motor directly to the PCU or permanent damage to the PCU will result. See figure TS-1.

FAN;

The 12V relay controlled by the FAN output should be selected to switch the rated current of a 12V DC cooling fan. Do not connect a blower or fan motor directly to the PCU or permanent damage to the PCU will result. See figure TS-1.

The following modes of activation apply for the cooling pump and cooling fan:

<table>
<tr><th colspan="3">MOTORING</th><th rowspan="3"></th><th colspan="7">CHARGING</th></tr>
<tr><th rowspan="2">PUMP</th><th colspan="2">FAN</th><th colspan="3">normal</th><th colspan="4">trickle</th></tr>
<tr><th>ON</th><th>OFF</th><th>PUMP</th><th>FAN ON</th><th>FAN OFF</th><th>PUMP ON</th><th>PUMP OFF</th><th>FAN ON</th><th>FAN OFF</th></tr>
<tr><td rowspan="2">latched on* during motoring</td><td>50°</td><td>45°</td><td><- PCU Cold Plate temperature °C -></td><td>latched on</td><td>45°</td><td>40°</td><td>45°</td><td>40°</td><td>45°</td><td>40°</td></tr>
<tr><td>55°</td><td>50°</td><td><- Motor <- temperature °C</td><td colspan="7">pump and fan operation not dependent on motor temperature during charging</td></tr>
</table>

*after the first time acceleration is requested.

Main Contactor Specification (HV Battery Connection)

Component Description:

The installer shall provide a contactor capable of completely disconnecting both sides of the battery bus from the PCU. The contactor shall allow each side of the battery bus to be disconnected independently or simultaneously. The contactor shall be completely controlled by the PCU. The contactor shall be rated for interrupting a minimum of 200% (400Amps) of the rated DC Current of 200 Amps at the maximum battery pack voltage of 400 Volts.

Function:

To pre-charge the high voltage bus capacitors and to locate the high voltage connection function outside of the PCU and as close to the high voltage battery pack as possible so that when the system is off, no high voltage potential from the high voltage battery main DC input lines exists inside the PCU box or elsewhere outside of the battery pack and main contactor box. These connections are controlled by commands from the PCU software and the high voltage interlock loop mechanism.

Operation:

The PCU shall enable the pre-charge controlling relay, AUXILIARY RELAY 1, by pulling the pre-charge- (PRECHG-) line "low". This shall energize the coil of the PRE-CHARGE RELAY and the coil of the MAIN RETURN RELAY allowing the high voltage bus capacitors to charge. AUXILIARY RELAY 1 must be selected b[illegible] the user to handle the worst case relay coil currents of the MAIN RETURN RELAY and PRE-CHARGE [illegible]AY coils at their rated voltage.

The PCU shall then enable the main power controlling relay, AUXILIARY RELAY 2, by pulling the main relay- (MAIN_RLY-) line "low". AUXILIARY RELAY 2 shall then energize the coil of MAIN RELAY 1, connecting high voltage to the PCU. AUXILIARY RELAY 2 must be selected by the user to handle the worst case coil current of the MAIN RELAY 1 coil at the relay's rated voltage.

NOTE: The main contactor does not disconnect the AC-Line from the PCU. If the vehicle is connected to the AC-Line, high voltage AC exists inside the PCU.

Contents:

The contactor shall be between the main vehicle high voltage battery pack and the PCU and be packaged in a grounded or double insulated case. This case shall contain one relay each for the BATTERY+ ,the BATTERY-, the battery connected (BAT_CON) or pre-charge line, and additionally, the two controlling auxiliary relays. See Figure MC-1, which shows wiring arrangement, contactor box contents, and device connections. Additional parallel battery strings may be added if AUXILIARY RELAY 2 is properly specified to handle the additional coil current for each parallel battery string's main relay (MAIN RELAY 2, 3, etc.).

Interface Specifications:

Application of operational power shall be regulated via the PCU, using the main contactor box scheme outlined herein. Failure to meet this requirement will result in permanent unit damage.

Suggested Relay Requirements:

All relays shall have a typical coil energize voltage of 12.0±4.0 Volts, with typical coil pickup voltages of 8.0±2.0 Volts and typical coil drop-out voltages of 2.5±2.0 Volts.

AUXILIARY RELAY 1 , AUXILIARY RELAY 2,
12V nominal, 16V maximum external relays
500mA maximum coil current
32Ω minimum coil resistance
maximum switch able current to be determined by contactor configuration

PRE-CHARGE RELAY
320V nominal, 425V maximum external relay
3A minimum current switching capability
maximum coil current not to exceed capabilities of controlling relay
minimum coil resistance(see max. coil current)

MAIN RELAY 1 , MAIN RETURN RELAY,
320V nominal, 425V maximum external relay
400A minimum current switching capability
maximum coil current not to exceed capabilities of controlling relay
minimum coil resistance(see max. coil current)

Additional Requirements:

Contactor box shall contain a reverse inductance clamping diode for each relay coil as shown in diagram. Note that MAIN RETURN RELAY will have to be rated for currents much greater than MAIN RELAY 1 if multiple battery strings are utilized.

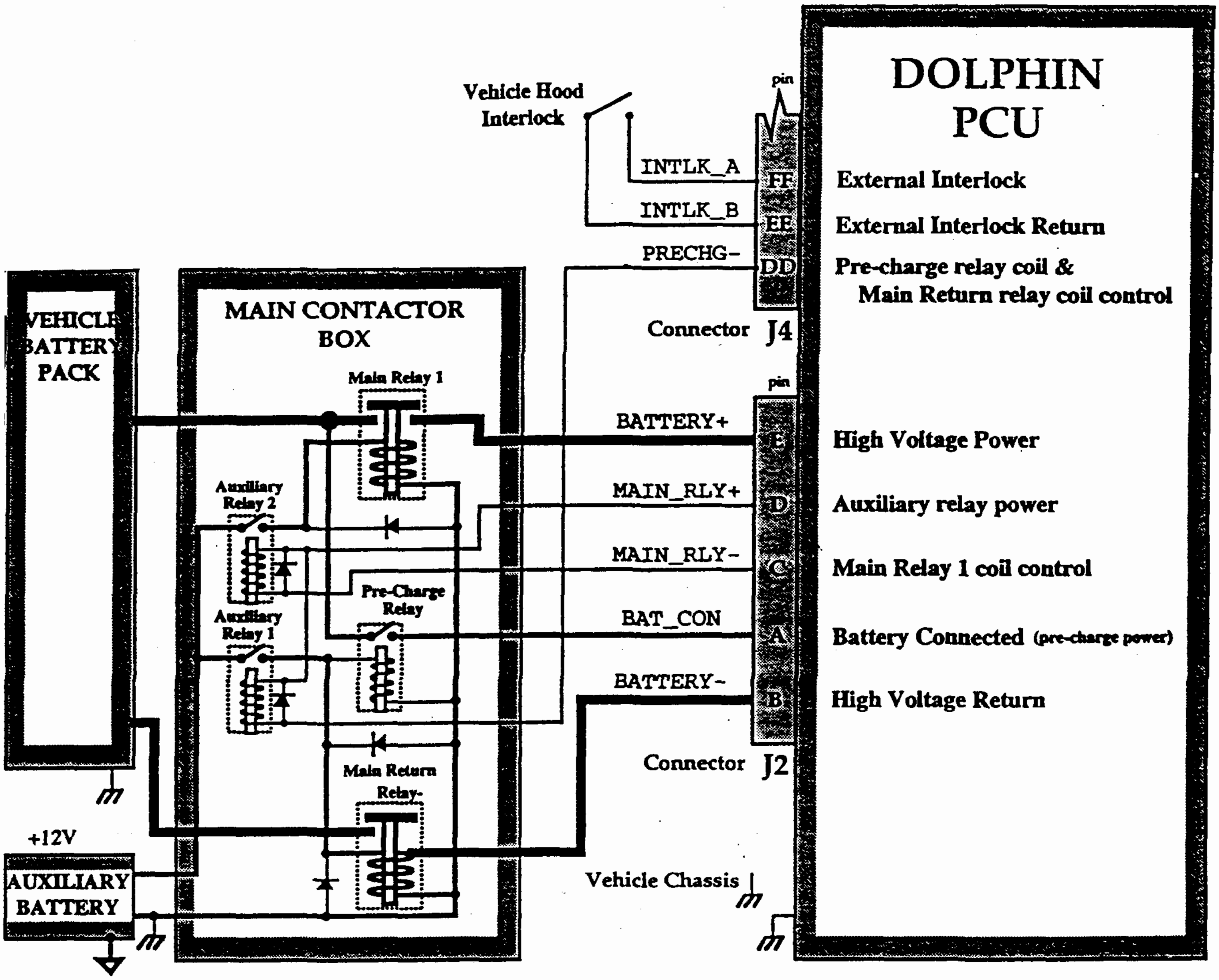


Figure MC-1 Main Battery Contactor to PCU Interface

MECHANICAL INTERFACES (MOUNTING)

PCU & Propulsion Motor

Thermal/Cooling Strategy and Mounting Location

Coolant Requirement:
The Dolphin System is required to use a 50% distilled water and 50% commercial antifreeze (with corrosion inhibitors) solution in its cooling system.

System Cooling Requirements:
The motor and PCU contain heat exchangers which dissipate 7550 Watts average at 50kW. A conventional coolant loop must be provided to reject this thermal load.

PCU
The PCU must have a water inlet temperature no greater than 65°C and a flow rate of 2 GPM minimum This insures that the maximum component temperatures are not exceeded at the full load heat dissipation.

Motor
The motor must have a coolant inlet temperature no greater than 75°C and a flow rate no ›wer than 2 GPM to insure that internal temperatures during the maximum allowable power cycle will not damage the motor.

Loop Configuration
The recommended coolant circuit should be arranged such that the PCU is directly after the radiator since PCU temperature control is the most critical. The pump discharge outlet should be connected directly into the motor to expose the PCU to the lowest pressure in the system, see Figure TS-1. The pressure to the PCU and Motor shall not exceed 10 psig at any time. Hoses should have an inside diameter of no less than 5/8" so that pressure drop will be negligible.

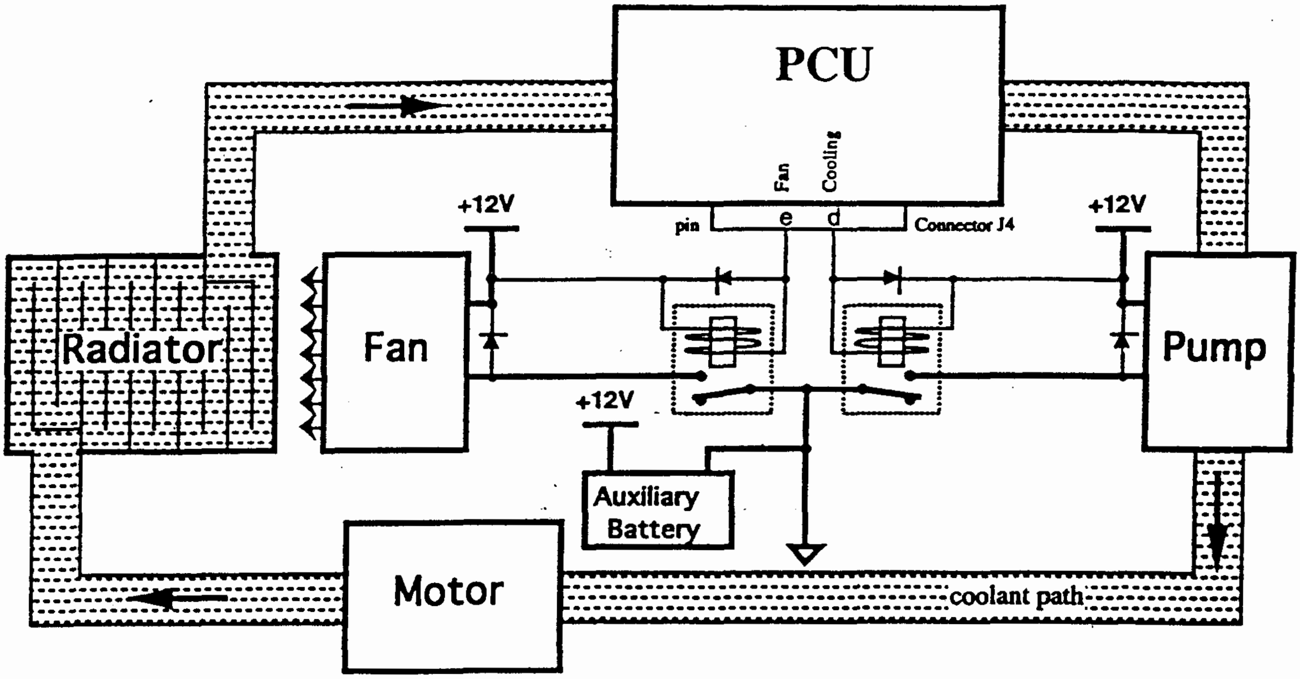


Figure TS-1 Thermal Subsystem Coolant Circuit

Radiator and Cooling Fan Requirement
The radiator and radiator fan must reject a heat dissipation of 7550 Watts (the entire system heat load). This corresponds to reducing the temperature of the coolant by approximately 15°C at the minimum 2 GPM flow rate.

The worst case condition is 45°C entering air. To meet the 65°C PCU entering temperature, the radiator must be able to reject the 7550 Watts with an average temperature difference of 27.5°C between the air and coolant.

Pump Requirement
The installer shall provide a coolant pump that maintains a minimum 2 GPM circulation rate through the PCU heat exchangers, and a typical radiator and hoses over the allowable range of temperatures and coolant mixtures.

Mechanical Installation

PCU Mounting

The installer shall provide mechanical attachments for the PCU in accordance with its O&M drawing.

The PCU shall be isolation mounted in six locations to the vehicle structure or other vehicle bracketry. The isolation mounts shall be designed to restrict dynamic input in accordance with the shock and vibration requirements outlined this section. The isolation mounts should accommodate M8 threaded studs or bolts. The M8 bolts shall be torqued to a minimum of 32 Nm, and locking hardware (i.e. lock washers) must be used.

The spectra in Figure M-1 represents the limits that the PCU can withstand in operating or non-operating conditions. Environments which subject the PCU to vibration in excess of Figure M-1 will result in PCU mechanical damage.

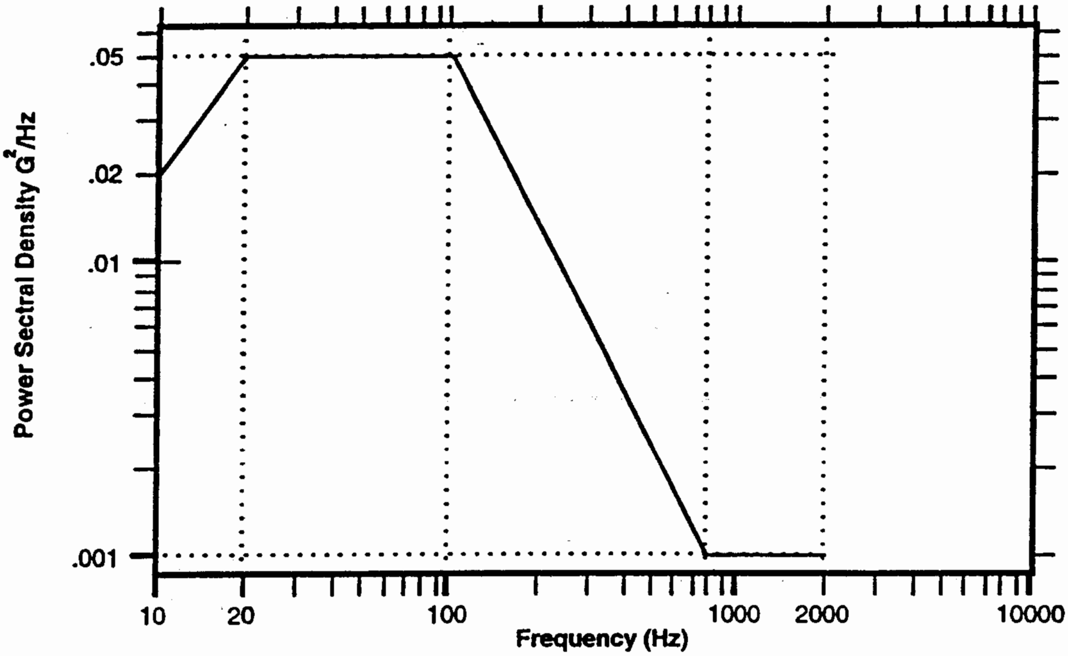


Figure M-1 Operational Vibration, Tri-Axial

Propulsion Motor Mounting

The installer shall provide mechanical attachments for the motor in accordance with its O&M drawing.

The Dolphin Motor should be mounted to the transmission adapter plate using the O-ring seal alignment feature on the motor. Failure to mount the motor using this alignment ring will result in excessive motor bearing and spline side loads and will result in motor damage.

Connectors

The installer shall provide mating connectors to the PCU from the external vehicle subsystems in accordance with the outline and mounting drawing enclosed with this document. The PCU connectors are summarized in Table C-1. The connector pin assignments are given in the signal table of this document.

Table C-1 PCU Connectors--Part Nos.

J1 (9 pin female)	Main Propulsion Drive Motor Connector	
Unit Chassis Mount Connector	configuration	Harness Mating Connector
CA02COM-E 28A16 S-B-01 (female) pin sockets: 031-8560-000/031-8556-110	4 x 4 AWG / 5 x 16 AWG	CA08COM-E 28A16P-B-01-44(male) pins: 330-0168-016/330-0168-004

J2 (5 pin male)	High Voltage DC Input Connector	
Unit Chassis Mount Connector	configuration	Harness Mating Connector
CA02COM-E 32-1 P-B-01 (male) s: 030-8588-000/031-8555-110	2 x 0 AWG / 3 x 12 AWG	CA08COM-E 32-1S-B-01-44 (female) pin sockets: 031-8557-000/330-0168-004

J3 (Terminal Posts A & B)	12V DC Output & 12V Chassis Return Posts	
Unit Chassis Mount Connector	configuration	Harness Mating Connector
C1938 (two 3/8 inch threaded studs)	2 x 3/8" studs	3/8" lug, lock washer & nut

J4 (61 pin male)	Main Control Signal Connector	
Unit Chassis Mount Connector	configuration	Harness Mating Connector
KPSEO2E24-61P-07 (male) pins: 030-9036-000	61 x 16 AWG	KPSEO6FF24-61S-07 (female) pin sockets: 031-9074-030

J5 (5 pin male)	Propulsion Motor Encoder Connector	
Unit Chassis Mount Connector	configuration	Harness Mating Connector
CA02COM-E 14S-5 P-B-01 (male) pins: 030-8586-000	5 x 16 AWG	CA08COM-E 14S-5 S-B-01-44(female) pin sockets:031-8555-110

J6 (3 pin male)	110/220 High Voltage AC Input Connector	
Unit Chassis Mount Connector	configuration	Harness Mating Connector
CA02COM E 16-10-P-B-01 (male) pins: 030-8588-000	3 x 12 AWG	CA08COM-E 16-10-S-B-01-44(female) pin sockets: 031-8557-000

GROUNDING AND ISOLATION

A) Installer shall ensure isolation of battery pack and charging cable from vehicle chassis. Resistance to chassis ground greater than minimum 1 MΩ (each side). Resistance imbalance less than TBD MΩ.

B) The installer shall ensure that the 12 Volt return line which is referenced to the PCU chassis is tied to the motor chassis.

FUSING

The installer shall not replace any fuse internal to the PCU. If a broken internal fuse is suspected, the PCU shall be shipped-back to HPCS. There are two (2) externally replaceable AC-line fuses on the PCU. They are located adjacent to the input AC power connection. They are 250 Volt, 20 Amp, J-Type, fast blow fuses. Refer to PCU Mechanical Isometric Drawing enclosed.

These fuses are designed to protect the PCU inverter and internal 12 AWG gauge cables.

GFI/GFCI

The PCU contains a ground fault interrupt (GFI) circuit that will trip when a current differential of 8 milliamps or greater is detected. This GFI protects humans against ground faults within the PCU enclosure. *This GFI is for industrial applications.*

The installer shall provide or assure that a ground fault current interrupt (GFCI) is between the PCU and the AC power outlet to protect against ground faults from the PCU to the AC outlet during vehicle charging. The GFCI is for consumer applications and the following GFCIs are recommended:

Table G-1 125 Volt AC, 15 Amp Rated GFCIs

Company	Part No.	Company Location
1. Pass & Seymour	1591-SW	Pass & Seymour Inc. Syracuse, NY
2. Eagle	646-2V	Eagle Electric Manufacturing Co. Inc. Long Island City, NY
3. Arrowhart	GF52421	Arrow Hart Wiring Devices Division of Cooper Industries Inc. Syracuse, NY
4. Leviton	6899I, and/or 6898-HGI	Leviton Manufacturing Co. Inc. Little Neck, NY

These are the recommended GFCIs (125V, 15A Rated) for use with the Dolphin Direct Charger. Other brands of GFCIs may be used, however, the user may experience increased occurrences of nuisance tripping.

TEST

The installer need not perform any tests to isolate faults within the PCU or motor.
The supplier, HPCS, shall perform testing on the PCU and/or motor to diagnose failures.

In the event of any suspected internal PCU failure, contact and return the unit to PCS.

MAINTENANCE

PCU

The PCU and motor do not require any routine or preventative maintenance other than ensuring proper coolant level.

The cooling system should be maintained to ensure reliable operation of the PCU and motor. See the Thermal/Cooling Section of this document.

FIELD REPLACEABLE UNITS (FRU)

The Dolphin system FRUs are repairable with re-manufactured exchange units or new units by HPCS only. The FRUs are identified as either re-manufacturable, recyclable, or throw away. The Dolphin system FRUs are defined in Table F-1 below, Dolphin FRUs.

FRU	Part Number	Disposition
PCU	A04600AA0	re-manufacturable
Wire Harness, Encoder	A04706AA0	re-manufacturable
Optical Encoder Module (Hewlett Packard)	QEDS-5922	throw away
DOLPHIN MOTOR	A04731AA0	re-manufacturable

Table F-1 Dolphin System FRUs

PCU FUNCTIONS - INVERTER AND CONTROLLER ;

GENERATE 3-PHASE 50KW OUTPUT POWER
MOTOR CONTROL
REGENERATIVE BRAKING

BUS PRE-CHARGE & DISCHARGE
DC FILTERING (NOISE REDUCTION)
AC FILTERING (NOISE REDUCTION)
IN RUSH SENSING
EMI FILTERING (RADIATED NOISE FILTERING)
INPUT & OUTPUT CURRENT SENSING

MOTOR TEMPERATURE SENSING
INVERTER TEMPERATURE SENSING
UNDER/OVER VOLTAGE PROTECTION (INVERTER) (OPENS CONTACTORS)
CONTROL OF BATTERY DISCONNECT (CONTACTORS CONTROL)

BATTERY STATE OF CHARGE REPORTING
COOLING PUMP AND FAN CONTROL
DISABLE MOTORING WHILE INTEGRAL LINE OR INDUCTIVE CHARGER CONNECTED (PARK CONDITION)
PRNDL FUNCTIONS
FAULT MONITORING - DEFINITION OF FAULTS AND RESPONSES
REDUCED PERFORMANCE DUE TO LOW BATTERY VOLTAGE
MOTOR & VEHICLE SPEED LIMITING
SPEED LIMIT TO ALLOW DIRECTION CHANGE FROM D TO R, AND R TO D (3 MPH)

MOTOR/BATTERY PACK/CHARGE PORT & INVERTER LID INTERLOCKS
REGEN VOLTAGE LIMITING

PCU FUNCTIONS - DC/DC CONVERTER;

FIXED 13.5±2% VOLTAGE OUTPUT (REGULATED)
100 A MAX. OUTPUT, 80A CONTINUOUS
12 V AUXILIARY BATTERY CHARGING (UP TO 85% SOC)
OVER TEMPERATURE PROTECTION
JUMP START (> 9.0 V ONLY)
85% MIN. EFFICIENCY TO ACHIEVE MAX. OUTPUT POWER=1.35 KW
(1588 KW INPUT POWER) (312 V @ 5 AMPS)
MINIMUM 0.5 MΩ CHASSIS ISOLATION TO EITHER SIDE OF BATT TERMINALS
OUTPUT TO DRIVER WHEN SHUTDOWN (ALT LIGHT)
REVERSE VOLTAGE PROTECTION

PCU FUNCTIONS - PROPULSION BATTERY CHARGING;

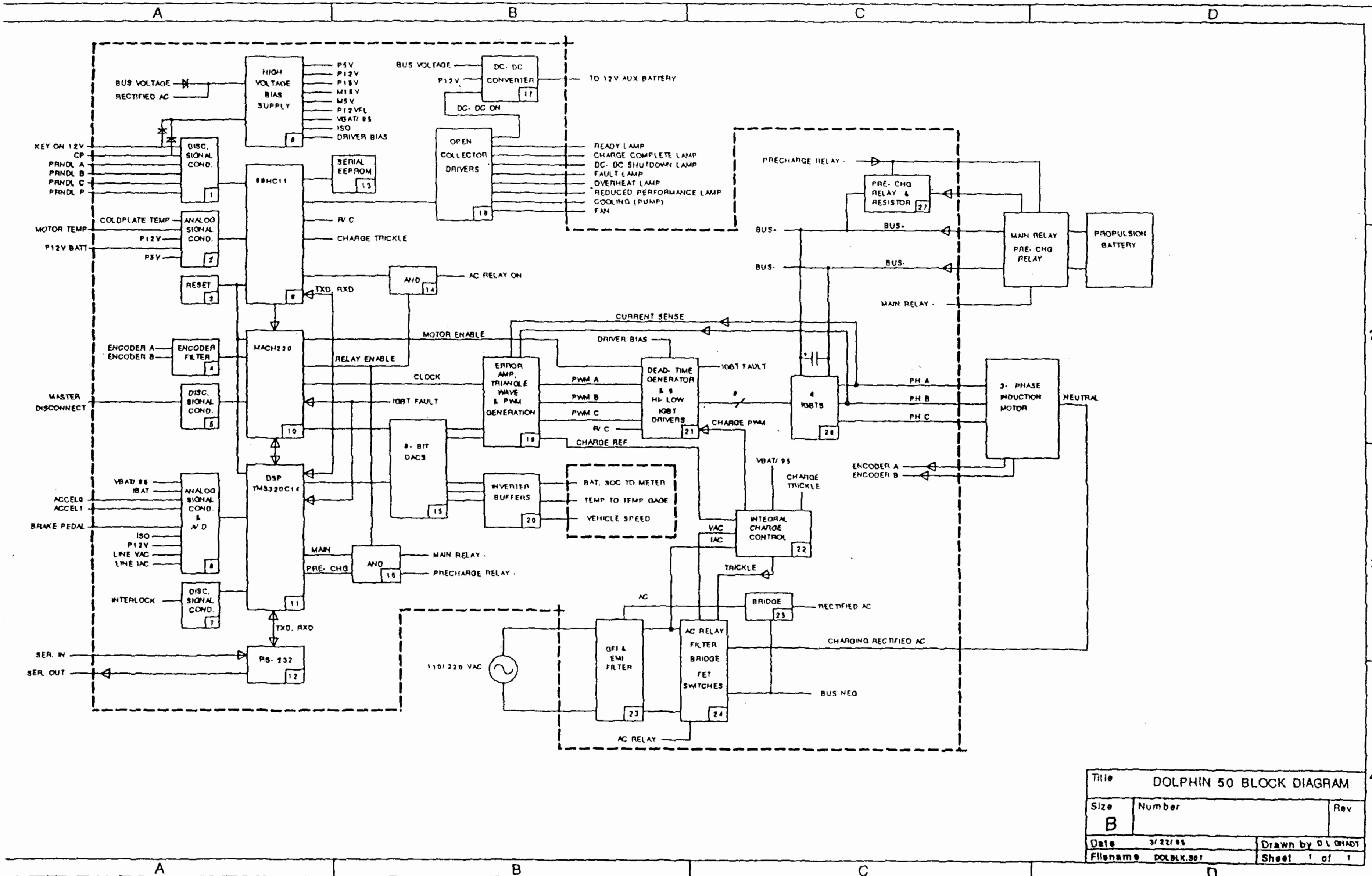
SIMULTANEOUS INTEGRAL AND INDUCTIVE CHARGING
INTEGRAL 110/220 VOLTS AC, 60/50 HZ CONVERTER TO DC POWER
- 1.5/3.0 KW OUTPUT POWER
- 85% MINIMUM EFFICIENCY AT RATED POWER
- BUILT-IN GFI, FUSE AND DISCONNECT CONTACTOR
- OVER-VOLTAGE PROTECTION
- INPUT POWER LIMITING
- WAKEUP TO AC-LINE VOLTAGE
- AUTO SHUTDOWN
- CONSTANT VOLTAGE CHARGE CONTROL

DOLPHIN MOTOR;

50KW THREE PHASE, FOUR-POLE AC INDUCTION MATCHED TO INVERTER
COMPATIBLE WITH STANDARD OR AUTOMATIC TRANSMISSION
STANDARD SPLINED SHAFT
LOW NOISE ENVIRONMENTALLY SEALED HOUSING

ACRONYMS/ABBREVIATIONS

AC	Alternating Current
AUX	Auxiliary (Battery)
BATT	Battery
DC	Direct Current
DSP	Digital Signal Processor
FRU	Field Replaceable Unit
GFI	Ground Fault Interrupt
GFCI	Ground Fault Current Interrupt
ICD	Interface Control Drawing
kW	Kilowatts
LED	Light Emitting Diode
O.C.	Open Collector
O&M	Outline and Mounting
PRNDL	denotes the gear selector (Park, Reverse, Neutral, Drive, 2, Low)
PCU	Power Control Unit
PCS	Power Control Systems
SER	Serial
SOC	State of Charge
TEMP	Temperature
UL	Underwriter's Laboratories
V	Voltage
w.r.t	with respect to



HIGH VOLTAGE BIAS SUPPLY
BUS VOLTAGE
RECTIFIED AC
P5V
P12V
P15V
M15V
M5V
P12VFL
VBAT/95
ISO
DRIVER BIAS
DC-DC CONVERTER
P12V
DC-DC ON
TO 12V AUX BATTERY
OPEN COLLECTOR DRIVERS
READY LAMP
CHARGE COMPLETE LAMP
DC-DC SHUTDOWN LAMP
FAULT LAMP
OVERHEAT LAMP
REDUCED PERFORMANCE LAMP
COOLING (PUMP)
FAN
KEY ON 12V
CP
PRNDL A
PRNDL B
PRNDL C
PRNDL P
DISC. SIGNAL COND.
68HC11
SERIAL EEPROM
R/C
CHARGE TRICKLE
COLDPLATE TEMP
MOTOR TEMP
P12V BATT
ANALOG SIGNAL COND.
RESET
AND
AC RELAY ON
TXD, RXD
MACH220
ENCODER A
ENCODER B
ENCODER FILTER
MOTOR ENABLE
RELAY ENABLE
CLOCK
MASTER DISCONNECT
IGBT FAULT
8-BIT DACS
ERROR AMP, TRIANGLE WAVE & PWM GENERATION
PWM A
PWM B
PWM C
CHARGE REF
DRIVER BIAS
DEAD-TIME GENERATOR & 6 HI-LOW IGBT DRIVERS
CHARGE PWM
CURRENT SENSE
6 IGBTS
PH A
PH B
PH C
3-PHASE INDUCTION MOTOR
NEUTRAL
PRECHARGE RELAY
PRE-CHG RELAY & RESISTOR
BUS+
BUS-
MAIN RELAY PRE-CHG RELAY
PROPULSION BATTERY
MAIN RELAY
VBAT/95
IBAT
ACCEL0
ACCEL1
BRAKE PEDAL
ISO
LINE VAC
LINE IAC
ANALOG SIGNAL COND. & A/D
DSP TMS320C14
INVERTER BUFFERS
BAT. SOC TO METER
TEMP TO TEMP GAGE
VEHICLE SPEED
CHARGE TRICKLE
INTEGRAL CHARGE CONTROL
VAC
IAC
TRICKLE
MAIN
PRE-CHG
MAIN RELAY
PRECHARGE RELAY
INTERLOCK
AC
BRIDGE
RECTIFIED AC
CHARGING RECTIFIED AC
SER. IN
SER. OUT
RS-232
110/220 VAC
GFI & EMI FILTER
AC RELAY FILTER BRIDGE FET SWITCHES
BUS NEG
AC RELAY
Title DOLPHIN 50 BLOCK DIAGRAM
Size B
Number
Rev
Date
Filename DOLBLK.SC1
Drawn by
Sheet 1 of 1

DOLPHIN 50 BLOCK DIAGRAM DESCRIPTION

The Dolphin 50 system is a processor controlled dc to three phase inverter with the purpose of driving a three-phase induction motor capable of 50 kWatts input. The system is intended for use in light duty vehicles with a propulsion battery system outputting a nominal 320 VDc. The system accepts driver control inputs which in turn command the motor direction and torque to propel the vehicle in the same manner as a normal internal combustion engine.

The following description for the block diagram is a simplified general explanation of each of the functional blocks shown. No detailed descriptions will be given. Each of the blocks are numbered for quick reference.

At Key On, (when the driver turns the ignition key) 12 volts is applied to a 5 volt regulator in the high voltage bias supply (block 8) to provide power to the 5 volt logic. This allows the processors to power up the system in a controlled manner. Both processors and the MACH (blocks 9, 10 & 11) first turn on the Precharge relays (block 27 & 28) to limit the inrush current to the capacitors on the high voltage bus of the inverter. When the bus voltage rises to a set voltage, the main relay is then energized to provide full current capability to the inverter. The bus voltage is then applied to the high voltage bias supply (block 8) to provide power to the remainder of the inverter. The READY lamp will then light and the vehicle is ready to go when a drive mode is selected by the PRNDL.

The 68HC11 processor (block 9) does the basic "housekeeping" for the inverter. It determines whether run or charge mode is selected from the "key on 12v" or "CP" inputs. CP is high when an inductive charger is connected. If neither input is high and the system turns on, it determines that direct ac power is connected for integral charging. The PRNDL inputs are used to determine the commanded direction and amount of regenerative braking when the accelerator pedal is released while driving as in a normal vehicle. When a lower gear is selected, more braking is provided by the motor. The PRNDL does not select different gear ratios as in an IC engine vehicle so there is no difference in the acceleration. The 68HC11 also monitors the inverter cold plate and motor temperatures, the bias supply 12 volt and 5 volt outputs and the aux. battery 12 volts for fault conditions. The temperature is also monitored to control the cooling fan and if it gets too high, reduced performance is commanded to limit power dissipation. The aux. battery voltage is monitored to determine whether the DC-DC converter (block 17) is operating. P12V from the bias supply (block 8) is monitored to be sure there is enough power to drive the IGBTs. If not, the inverter will fault and not allow motoring in order to prevent damage to the IGBTs.

The 68HC11 outputs telltale and control signals via open collector drivers (block 18) to show status and faults to the driver and control the dc-dc converter and the cooling pump and fan. It outputs clocks and *device control to the MACH220 for device selection and data communication.* It selects run or charging mode (trickle or normal) and controls turn on of the ac relay for integral charging. It communicates with the DSP (block 11), sending motor control commands and receiving operating status. It stores operating constants in Serial EEPROM (block 13). These operating constants are written to the EEPROM with an external computer via the RS-232 interface (block 12) and the DSP (block 11). Communication with the 68HC11 is only done via the DSP.

The Discrete Signal Conditioning block (no. 1) level shifts 12 volt input signals to 5 volt signals for use by the 68HC11. The Analog Signal Conditioning block (no. 2) scales its inputs to 0 to 5 volt analog inputs to the HC11.

Block no. 3 (RESET) delays operation of the HC11, MACH220 and DSP at power up to ensure that the 5 volt power is stable before operation is permitted.

The MACH220 (block 10) is basically several function blocks and state machines in one device. It has counters, logic gates, combination logic for device selection and data flow control and motor enabling. It receives filtered motor encoder signals (block 4) to provide motor direction, speed and fault data to the DSP (block 11). It monitors for IGBT faults (block 21) to shut down IGBT drive in a fault condition. It provides clock signals for motoring and charging PWM generation. The Master

Disconnect signal via block no. 5 must be grounded at all times for the inverter to function. Its purpose is to provide an emergency shutdown by pressing a normally closed switch to open the line.

The DSP (block 11) is a processor specifically designed for motor control. It generates 8-bit code for the DACs (block 15) to output two reference sine waves 120 degrees apart for use by block 19 to generate 3-phase PWM motor drive. The amplitude of the sine waves are determined from the accelerator inputs and the battery voltage input via block 6. The command direction of rotation comes from the 68HC11 and actual motor direction from the MACH220. The frequency of rotation is then determined from the actual speed plus added slip frequency during acceleration or subtracted slip frequency during deceleration. The DSP also monitors the battery voltage and current and ac line voltage and current for display via the RS-232 link. The line ac voltage is also used during charging to synchronize a charge reference current command waveform with the incoming ac current for unity power factor control. The Isolation voltage (ISO) from block 8 is used to determine if there is any high voltage leakage to the vehicle chassis. In the event of an isolation fault, the system is disabled. The DSP also monitors the P12V which is used for the IGBT drivers such that if the 12 volts droops too low, the IGBTs are disabled to prevent them from damage. The interlock 12 volts is also monitored through block 7 to cause immediate shutdown if the interlock line is opened at some point. This is for safety to prevent someone from getting a shock if they remove a connector or cover. The DSP controls the energizing and de-energizing of the Precharge and Main relays during power up and power down. These signals are ANDed with a relay enable signal from the MACH220 to prevent inadvertent energizing of the relays.

The Analog Signal Conditioning and A to D block (no. 6) translates the inputs to 0 to 5 volt signals and converts them to digital data for the DSP. Block 7, Discrete Signal Conditioning. translates the 12 volt interlock signal into a 5 volt logic signal for the DSP to cause immediate shutdown.

The DC-DC CONVERTER (block 17) is a 100 amp output supply at 13.6 volts. It is a hard switching H-bridge configuration is current limited to 100 amps. It provides all the power for the 12 volt systems in the vehicle and maintains the auxiliary battery charge.

The Error Amp., Triangle Wave & PWM Generation block (no. 19) produces the third sine wave signal 120 degrees from the two sine waves from block 15. The 3-phase sine waves are then compared with a triangle wave to produce 3-phase PWM signals to drive the IGBTs. Two phase current sense signals are fed back from the motor drive lines and summed with the sine wave references to control the PWM duty cycles via current feedback regulation. The clock input from the MACH220 is used to generate the triangle wave. One of the sine wave outputs is used in charging mode to control the charging current (block 22).

Block 21 contains the dead time generation circuits and IGBT drivers. The 3-phase PWM inputs are gated to each provide high and low side IGBT drive signals with a dead-time inserted to prevent both high and low side IGBTs from turning on at the same time. The Driver Bias provides isolated power for each of the six IGBT drivers. The motor enable signal from the MACH220 enables drive when torque or regen are commanded. The R/C (run/charge) switches between PWM from either block 19 in run mode or block 22 in integral charging mode. De-sat circuitry detects an overcurrent condition in an IGBT to immediately shut down the local IGBT drive signal and also signal the MACH220 and the DSP to shutdown all the drive signals.

Block 26 is the six IGBTs which form a 3-phase bridge for driving the propulsion motor.

Block 22 is the Integral Charge Control function which generates PWM to drive the lower IGBTs in a boost configuration using the motor as the boost inductor. The Chg. Ref. input provides the current command which is summed with the ac input current feedback to provide closed loop current control. The ac input voltage and propulsion battery voltage are compared to provide trickle charging when the ac peak voltage exceeds the battery voltage. During the time the ac voltage cycle is higher than the battery voltage the FET switches in block 24 are turned off to prevent uncontrolled current flow into the batteries. The DSP also measures battery and line Vac to determine whether trickle charging is to be enabled via the "charge trickle" signal. When the peak ac voltage no longer exceeds the battery voltage, then trickle charging is disabled by turning the FET switches in block 24 on continuously.

Block 23 represents a standard GFI circuit built into the system and the EMI filter reduces the switching noise going out the ac input line.

Block 24 contains the ac relay, full wave bridge rectifier and FET switches required to provide integral charging. The ac relay is controlled by the 68HC11 to close after the system is fully powered up and ready to charge. The bridge full wave rectifies the incoming ac power and the FET switches connect the power to the motor neutral for boost mode conversion.

The bridge rectifier (block 25) supplies the power for the high voltage bias supply (block 8) during power up when plugging into an ac outlet for charging. As soon as the contactors have closed, then the dc power bus supplies the power for the bias supply.

The 8-bit DACs (block 15) besides supplying the sine waves for motoring also provide analog outputs through inverter buffers (block 20) of battery state of charge (SOC), Temperature output to the instrument panel temperature gage and vehicle speed. Vehicle speed is a 0 to 5 volt dc output that tracks motor rpm.

The pre-charge relay and resistor of block 27 limit the inrush current to the bus capacitors at power up and discharge the capacitors during power down.