UQM TECHNOLOGIES, INC.

User and Installation Manual For

PowerPhase® 150 Traction System
PowerPhase® 125 Traction System
PowerPhase® 100 Traction System
PowerPhase® 75 Traction System
HiTor Traction System

with

DD45-400L Inverter/Controller
DD45-500L Inverter/Controller

(With firmware version 4.05 and above)

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12/16/2008

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1 Introduction

Thank you for your purchase of a UQM™ Motor and Inverter/Controller package. Please notify UQM Technologies immediately if any damage has occurred during shipment. **PLEASE READ THIS ENTIRE MANUAL BEFORE APPLYING VOLTAGE TO THE SYSTEM.**

This system is a state-of-art, standard package that is specifically designed for high performance drive applications. Depending on the system that was ordered, the package consists of a high performance 50 kW, 75 kW, 100 kW, 125 kW or a 150 kW Brushless DC motor, a 425 VDC (max) high-power liquid-cooled inverter, and a full-featured digital signal processor (DSP) controller. This manual covers installation and operation of all HiTor, PowerPhase® 75, PowerPhase® 100, PowerPhase® 125 and PowerPhase® 150 systems. All systems are a ready to use, powerful, lightweight, rugged, and reliable system based upon years of developing and manufacturing motors and controllers for electric drive systems.

The system provides many easily incorporated features required to develop a customized, high performance drive application. The system is capable of fully a regenerative, four-quadrant, bi-directional, and torque controlled operation. The DSP controller is user programmable to allow for flexibility. The system also maximizes reliability by minimizing hazardous conditions.

This manual gives a broad description of this package. It is highly recommended that you read through these instructions to familiarize yourself with the operation and installation of the package. Please feel free to contact the Applications Department at UQM Technologies, Inc., if you have any questions regarding installation, application, or service.

WARNING: DANGEROUS VOLTAGES, CURRENTS, AND ENERGY LEVELS EXIST IN THIS PRODUCT. EXTREME CAUTION SHOULD BE EXERCISED IN THE APPLICATION OF THIS EQUIPMENT. ONLY QUALIFIED INDIVIDUALS SHOULD ATTEMPT TO INSTALL, SET-UP, AND OPERATE THIS EQUIPMENT.

WARNING: INCORRECT MOTOR AND CONTROLLER WIRING CAN CAUSE CATASTROPHIC FAILURE. PROPER CONNECTION OF MOTOR CABLES, HALL-EFFECT CABLES, AND TEMPERATURE CABLES IS NECESSARY FOR SAFE OPERATION. DO NOT SWAP MOTOR WINDINGS TO REVERSE DIRECTION.

1.1 Packing List

Quantity	Item	Part Number
1	HPM150 brushless PM liquid-cooled motor; HPM125 brushless PM liquid-cooled motor; SR286 brushless PM liquid-cooled motor; SR218 brushless PM liquid-cooled motor; SR218 high-torque brushless PM liquid-cooled motor	27580 27800 23350 25935 24427
1	DD45-500LWB liquid-cooled inverter/controller; DD45-400L liquid-cooled inverter/controller	27565 27270
1	Rotor position signal cable (6 ft length with 15-pin and 10-pin connectors)	66024
1	Hand Control and cable with 19-pin Amphenol connector	85963200 / 66013
1	User and Installation Manual	N/A
1	508 mm (20 in) long copper tape (25.4 mm) wide	N/A
1	Spare 19-pin Amphenol connector for customer use	36400029
1	3/8-24 Lifting Eye	N/A

1.2 Overview of Manual

This manual provides installation and basic operating instructions for the following systems:

- HiTor Traction System
- PowerPhase® 75 Traction System
- PowerPhase® 100 Traction System
- PowerPhase® 125 Traction System
- PowerPhase® 150 Traction System

If instruction pertains directly to a specific system, it will be referenced directly. Please contact UQM Technologies, Inc. with any questions.

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Sections 1-4 cover the installation of your specific drive system in a vehicle, or on a dynamometer. Section 5-6 covers basic and system operation. Section 7 describes the UQM Motor Diagnostic Software, and Section 8 covers troubleshooting procedures.

1.3 System Features

HiTor Traction System	**PowerPhase® 75 Traction System**
440 N·m Peak Torque	240 N·m Peak Torque
50 kW peak, 30 kW continuous power	75 kW peak, 45 kW continuous Motor power
Regenerative braking	Regenerative Braking
Full power @ 250-425 VDC input	Full power @ 250-425 VDC Input
CAN bus compatible	CAN bus compatible
DSP-controlled inverter with sine wave drive	DSP-controlled inverter with sine wave drive
Light weight/Compact	Light weight/Compact
Maximum speed 5000 RPM	Maximum speed 8000 RPM

PowerPhase® 100 Traction System	**PowerPhase® 150 Traction System**
550 N·m Peak Torque	650 N·m Peak Torque
100 kW peak, 55 kW continuous power	150 kW peak, 100 kW continuous Motor power
Regenerative braking	Regenerative Braking
Full power @ 250-425 VDC input	Full power @ 300-425 VDC Input
Custom Shaft Output Options	Custom Shaft Output Options
DSP-controlled inverter with sine wave drive	DSP-controlled inverter with sine wave drive
Maximum speed 5000 RPM	Maximum speed 5000 RPM

PowerPhase® 125 Traction System
300 N·m Peak Torque
125 kW peak, 45 kW continuous Motor power
Regenerative Braking
Full power @ 250-425 VDC Input
CAN bus compatible
DSP-controlled inverter with sine wave drive
Light weight/Compact
Maximum speed 8000 RPM

2 Installation

The installation of the drive system in a vehicle or dynamometer is fairly straightforward, but the user should be cautious when installing.

2.1 Possible Catastrophic Installation Problems

Any of the following errors will void the warranty:

- Reversal of the input voltage to inverter
- Rotor position cable wrapped around motor leads
- Lack of liquid cooling
- Shorted motor leads
- Obstruction of the motor shaft during acceleration
- Opening the inverter or motor cases

2.2 Inverter Installation

Mounting dimensions of the liquid-cooled inverter/controller are shown in Appendix F. The inverter may be mounted in any orientation. The inverter should be secured using the four mounting studs on the corners of the case. Securely fasten all connections with locking hardware to assure that they cannot vibrate loose. Cables should be routed to avoid unnecessary binding and premature wear. Do not locate connections in close proximity with any surface or connector that could short the motor leads, inadvertently.

2.3 Motor Installation

Mounting dimensions of the PowerPhase®150 and the PowerPhase®100 are shown in Appendix I. There are several options for mounting the motor to the vehicle. The primary mount for the motor is the 8 - M10 X 1.5 tapped mounting holes located on the shaft side of the motor. There are also 7 - M10 X 1.5 tapped holes in the lead exit end of the motor that are provided to add an additional mounting bracket for stability of the motor in the application. However, do not use only the lead exit mounting points without first using the shaft end mounting points. Make sure that the motor is securely mounted to a rigid surface when used in any drive system.

The mounting dimensions of the Hi-Tor, PowerPhase®75, and PowerPhase®125 systems are shown in Appendix G and Appendix H. The primary mount for the motor is the 0.500 inch holes that are tapped for 1/2 - 13 UNC bolts holes located on side opposite of the end with the power cables. However care must be taken that the mounting bolts do not protrude through the housing and contact the rotor. **The actual bolt lengths are dependent on the mounting surface used in the application, and the maximum bolt-hole depth in the motor housing is 0.750 inches.** Make sure that the motor is securely mounted to a rigid surface when used in any drive system. - all bolt holes on the front mounting plate (output side) must be used.

NOTE: The motor case is not a structural member, and will not bear structural loads. Exercise care when mounting the motor to assure that all moving parts are not constrained and proper clearances are observed. All pulleys, gears, and drive mechanisms mounted to the motor shaft should be properly secured. UQM systems are not designed to accept any thrust loading. Please contact UQM if there are any questions regarding shaft loading.

NOTE: A separate 6 AWG (minimum) ground wire (not included) should connect the motor case to the inverter case. Bus ground must not be tied to the chassis, or the motor and inverter cases. Please see Section 3.6 for more information on grounding requirements.

The hose connections for the motor should be located on the topside of the motor, or within 45 degrees from the top.

See Section 4.0 and Figure 4.1-1 for more information on the recommended coolant system setup.

WARNING: HIGH VOLTAGE AND TEMPERATURE MAY BE PRESENT ON THE INVERTER, MOTOR, OR BATTERY. MOUNT THESE UNITS AND THEIR CONNECTION TERMINALS IN SAFE LOCATIONS TO PREVENT DAMAGE OR INJURY.

2.4 EMI/EMC of UQM Technologies Brushless PM Motor Drives

It should be understood that the drive systems manufactured by UQM Technologies, Inc., are prototype drives designed and manufactured for the purpose of evaluating the feasibility of electric drive vehicle applications. UQM Technologies, Inc., does not imply that these drives have been tested or pass EMI/EMC standards, as set forth by any of the regulatory agencies. It should be understood that EMI and EMC from UQM Technologies, Inc., drives could interfere with radio transmissions and/or reception. Application-specific designs for EMI reduction must be discussed with UQM Engineering.

2.5 EMI/EMC Installation Precautions

Some precautions can be taken to reduce the level of electromagnetic emissions and compatibility issues from the drive system, when installed into a vehicle. They include, but are not limited to, the following suggestions:

1. Keep the motor controller and the drive motor as close as possible to one another in the installation. This reduces the power connector length, thus reducing the length of the radiating antenna.
2. Keep all of the high power motor leads as close together as possible in the routing from the controller to the motor. This will reduce the open loop area of the radiating element.
3. When routing the high power conductors, take care to run them side-by-side. This will reduce the loop area and length, and thus reduce emissions.
4. Adding tined copper braded shielding around the motor leads can help, however this task is difficult due to the fact that the controller and motor connections are not designed to accept the shielding.
5. Above all, remember that the high power DC and motor phase leads, to and from the controller, are moving several hundred amperes. Routing of any of these wires next to other control or signal wires will provide a coupling path for the emissions from these drives. Great care should be taken to insure that proper grounding and shielding techniques are used when building a prototype vehicle.

CAN and serial shielding

1. For the CAN connection on the user interface connector use a good quality insulated shielded twisted pair and terminate the shield on the user interface connector ground pins H or K. Do not allow the shield to touch the motor or controller housing.
2. For the Serial cable you can also use this same type of shielded twisted pair cable as used on the CAN and use the shield for the ground connection.
3. When using CAN make sure that you have a ground connection on the user interface connector to the same source as the CAN signal. This can be done with the CAN shield or a separate ground connection.

3 Electrical Connections

The motor and controller electrical connections are shown in Figure 3.0-1. Power cables connected to the motor are factory-installed. The following sections describe the motor and controller connections. Ensure that the input voltage is not connected before making any connections.

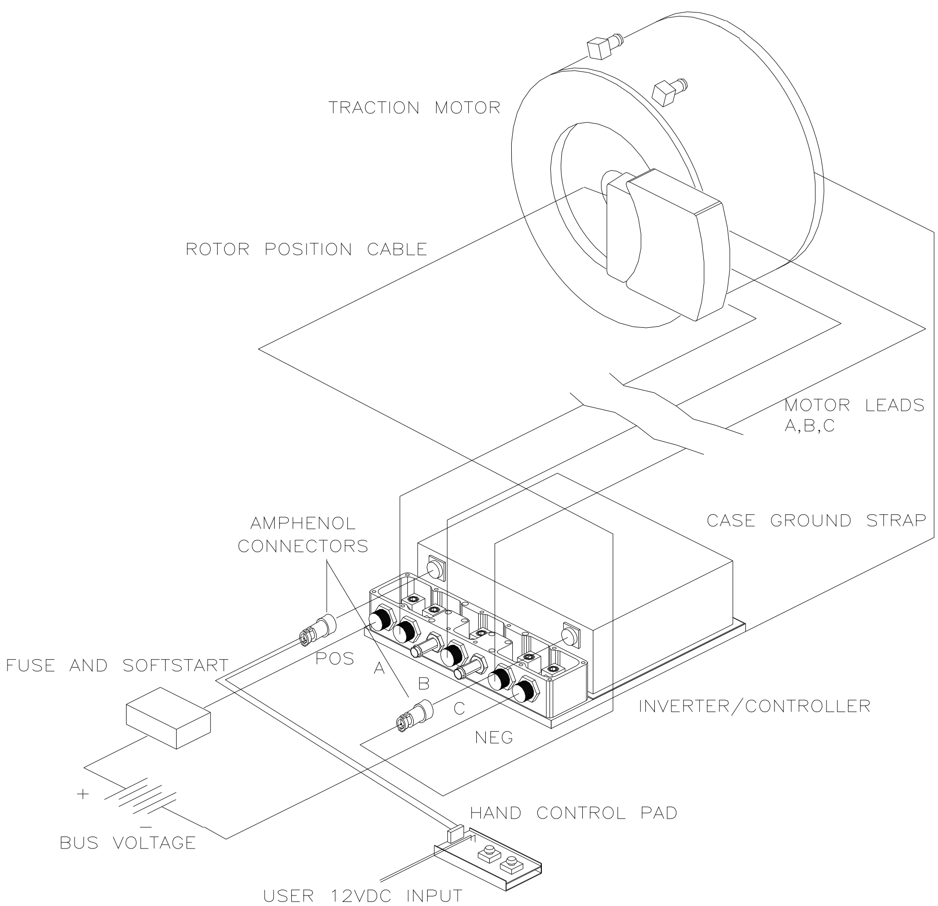
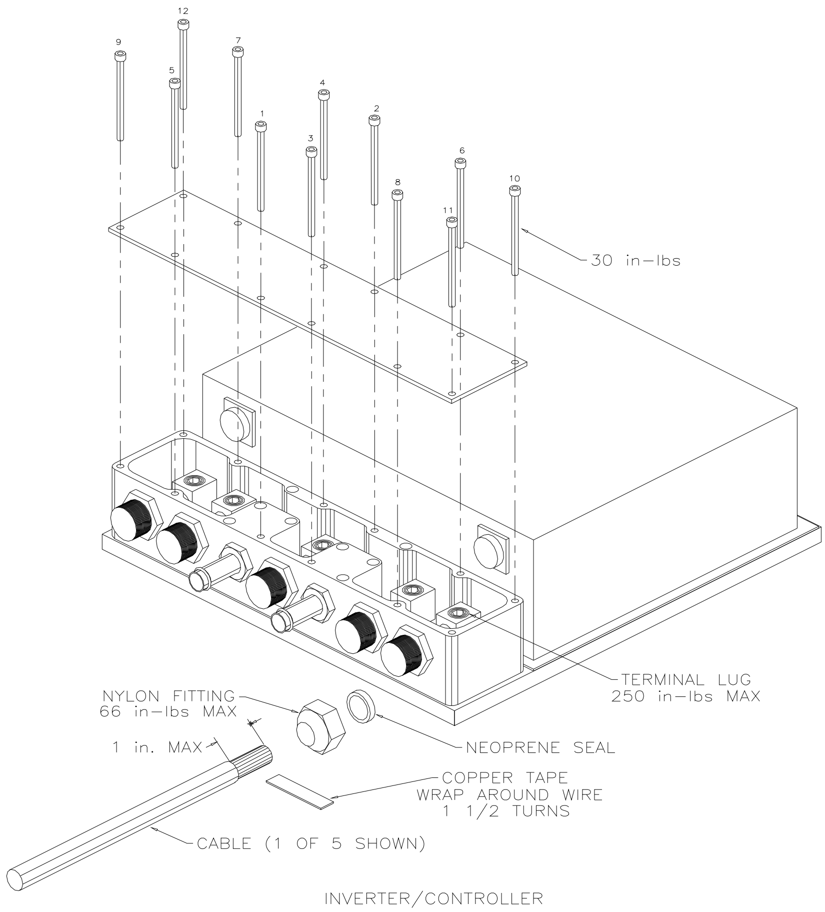


Figure 3.0-1: System Electrical Connections

3.1 Controller Power Cable Connections

Figure 3.1-1 shows an exploded view of the inverter/controller connections. Before connecting any cable to the inverter, the terminal cover must be removed. Also, the ends of the five power cables (POS, NEG, A, B, C) must be stripped back (1 in maximum), and have a layer of copper tape wrapped over the wire strands to prevent fraying. See Figure 3.1-1.



<u>Figure 3.1-1: Power Cable Connections</u>

Motor cables A, B, and C should be connected to their respectively labeled motor lead terminals in the inverter. The Battery cables POS and NEG should be connected to their respective inverter terminals. Install all the cables with the watertight fittings and seal, as shown in Figure 3.1-1. <u>Caution</u>: Do not over tighten the terminal lugs or watertight fittings. The connection hardware recommended tightening torques, is shown in Figure 3.1-1. Tighten the cap screws in sequence, which will secure the cover, as shown in Figure 3.1-1. This will ensure that the gasket is pressed evenly, to guarantee water sealing of the cover.

3.2 Motor Connections

There are three motor leads on the motor labeled A, B, and C. These motor leads connect to the inverter via their respectively labeled terminals. If any lead is connected to the wrong terminal, the motor will not run and damage may occur.

> **WARNING**: DO NOT ATTEMPT TO SWAP MOTOR WINDINGS TO REVERSE DIRECTION. DO NOT CONNECT OR DISCONNECT MOTOR LEADS, OR ROTOR POSITION CABLE, IF INPUT VOLTAGE IS APPLIED.

3.3 Controller Connections User Interface 19-pin Amphenol Connector

A user interface 19-pin Amphenol connector is available for remote operation of the system. For test purposes, the User Interface Hand Control Pad is provided with the system.

NOTE: some systems are configured for CANbus control by default. These systems will not respond to the User Interface Hand Control Pad. See section 7.4 of this manual to disable CANbus control in order to use the user interface hand control pad for set-up purposes. See the UQM Technologies, Inc., CAN manual for details on CANbus control

The hand control pad consists of a DIRECTION switch, an ENABLE switch, an ACCELERATOR potentiometer, and a BRAKE potentiometer. These signals simulate common control signals on a vehicle, and they are fully described below.

Before connecting the user interface control pad, ensure that the direction switch is at the FORWARD position, and the ENABLE switch is at the DISABLE position. Both acceleration and brake potentiometers should be fully counterclockwise (minimum value). The user interface control pad attaches to the 19-pin Amphenol connector on the inverter/controller, through a ribbon cable that is provided.

> **WARNING**: THE USER INTERFACE CONTROL PAD IS FOR TESTING PURPOSES ONLY. DO NOT USE THE CONTROL PAD IN A VEHICLE.

3.4 User Interface I/O Signals

Please note that all user interface control signals are isolated from the high voltage DC bus, and should not be referenced in any way to the high voltage DC bus supply.

The user interface connector is a 19-pin bayonet Amphenol connector. The input/output signal descriptions are listed below for the pins that are used on the 19-pin connector.

Vcc_user (+5 V): (Output, Pin A)

This voltage supply is intended to provide the user with the necessary voltage level used on the accelerator, brake, enable, direction, and key start signals. This supply can source 50 mA of current. This line is referenced to the "GND_user" pin.

GND_user: (Output, Pin B)

This is the internal logic control card and ground reference point associated with all pins that are used in the "User Interface Connector".

Reserved: (Output, Pin C)

Enable: (Input, Pin D)

This is an alternative way to zero the desired torque command. This pin has a pull-up resistor (10 kΩ), therefore it is not necessary to switch this pin to Vcc_user to enable the system. If this pin is open or tied to the Vcc_user the system is enabled, and the Accelerator and Brake signals are used to determine the desired torque command. If the pin is shorted to GND_user, the desired torque command is 0 N·m. The maximum signal input current shall not exceed 0.5 ma.

Direction: (Input, Pin E)

The desired motor direction is defined with this pin. This pin has an internal pull-up resistor (10 kΩ) and therefore it is not necessary to switch this pin to Vcc_user to change to a forward rotation. Open or switched to Vcc_user is a forward rotation and shorted to GND_user is a reverse rotation. The maximum current through the short is 0.5 ma.

Drive_ready: (Output, Pin F)

This is used to drive an LED, which will indicate when the software has been initialized correctly without any errors. This signal is powered by the external 12 V supply. The maximum signal output shall not exceed 5 ma.

ACCEL_2: (Input, Pin G)

GND_user (GND): (Pin H) Same as Pin B

GND_serial (GND): (Pin J) Serial GND (same reference point as GND_user)

GND_user (GND): (Pin K) Same as Pin B

Brake: (Input, Pin L)

The Brake is a 0.5 to 4.5 V input signal, referenced to GND_user. 0.5 V implies a 0% torque command, and 4.5 V implies a -100% torque command. If this signal is less then 0.25 V, or greater then 4.75 V, the system will error and generate a zero torque command.

Accelerator: (Input, Pin M)

The Accelerator is a 0.5 to 4.5 V input signal, referenced to GND_user. 0.5 V implies a 0% torque command, and 4.5 V implies a 100% torque command. If this signal is less then 0.25 V, or greater then 4.75 V, the system will error and generate a zero torque command.

+12 VDC: (User Input, Pin N)

External User 12VDC input. This voltage can power up the Microprocessor and allow system configuration through the serial port, when high voltage is not present. In addition, the Microprocessor recognizes this input as "key on" or "key off". If no voltage is present on this pin and the Microprocessor is powered up through high voltage, then "key off" is assumed, and the system will not operate beyond zero torque.

Note: if normal operation is desired without delivering an external 12VDC input on this pin, check the "Key Always On" in the system configuration. See section 7.4 for details.

Spare (Output, Pin P)

Ctrl_link: (Input, Pin R) RESERVED

CAN_L: (Pin S) Low (CAN Optional)
CAN_H: (Pin T) High (CAN Optional)

When the CAN option is present, these two pins deliver the CANbus signal. See the UQM CAN manual for details.

Serial: (Pin U) User RxD serial receive
Serial: (Pin V) User TxD serial transmit

These two pins, along with GND_serial, deliver the serial interface connection for serial port communications (see Chapter 6 "Serial Port Communications and System Status" for details.)

A User Interface Hand Control Panel is provided with the system for testing purposes only. DO NOT USE THE USER INTERFACE PANEL IN A VEHICLE, except to troubleshoot your system wiring. This panel utilizes all of the signals described above, and may be used as a sample guide for the wiring of your system.

Two drawings relating to the User Interface are included in Appendix K and L. The first shows the schematic of the hand control panel. The second is the schematic of the output circuits inside the microprocessor, and the first stage input of the user interface pins. Remember, The hand control panel is provided for test purposes only and should not be used in a vehicle.

Table 3.4-1: List of User Interface Control Signals

Name	Signal	I/O port	Pin # of 40-Pin Hand Control connector	Pin # of 19-Pin Amphenol bayonet connector
Vcc_user	+5 VDC		1	A
GND_user	GND		2	B
Reserved	Reserved		3	C
Enable	5 V = Enable command 0 V = Disable command	USER-PE0	4	D
Direction	5 V = Forward 0 V = Reverse	USER-PE1	5	E
Drive Ready	LED Indicator	USER-POUT0	12	F
ACCEL_2	2nd Accelerator input	AD1	13	G
GND_user	GND		14	H
GND_serial	GND		15	J
GND_user	GND		21	K
Brake	0.5 to 4.5 V = 0 to -100 % of torque profile	USER-AD0	22	L
Accelerator	0.5 to 4.5 V = 0 to 100% of torque profile	USER-AD1	23	M
+12 VDC	USER_12V INPUT	INPUT	24	N
Reserved	Reserved	USER-PE2		P
CTRL_LINK	Reserved	CTRL-LINK	26	R
CAN_L	Low (CAN optional)	CAN_L	28	S
CAN_H	High (CAN optional)	CAN_H	29	T
Serial	Receive	USER-RxD	30	U
Serial	Transmit	USER-TxD	31	V

3.4 Rotor Position and Motor Temperature Cable

The rotor position and motor temperature cable is the gray-shielded cable with a 15-pin bayonet Amphenol connector. Five of the wires are used for the Hall Effect signals. Three wires are used to send motor thermal information to the microprocessor controller. Connect the rotor position cable to the motor with the 10-pin connector, and to the controller with the 15-pin Amphenol connector.

WARNING: DO NOT ATTEMPT TO LENGTHEN OR SHORTEN THE CABLE IN ANYWAY. CONTACT UQM TECHNOLOGIES, INC., IF THE CABLE IS TOO SHORT OR TOO LONG FOR THE APPLICATION.

WARNING: DO NOT ROUTE THE ROTOR POSITION CABLE WITH THE MOTOR POWER LEADS. THIS MAY CAUSE A CATASTROPHIC FAILURE.

3.5 Traction Battery Power Connection

WARNING: YOUR SYSTEM MAY BE CONFIGURED FOR ROTATION WHEN INPUT VOLTAGE IS APPLIED. BEFORE APPLYING INPUT VOLTAGE, ENSURE THAT THE SHAFT AND/OR ANYTHING CONNECTED TO THE SHAFT HAS SUFFICIENT AREA FOR ROTATION. ALWAYS DISCONNECT INPUT VOLTAGE BEFORE MAKING OR REMOVING ANY OTHER CONNECTIONS.

The battery or power supply, is connected to the inverter terminals marked POSITIVE and NEGATIVE. Connections should be made observing the correct polarity.

The DD45-500L and DD45-400L inverters are designed to have an operating voltage range of 250 to 420 VDC. DO NOT APPLY MORE THAN SPECIFIED INPUT VOLTAGE RANGE TO THE INVERTER OR DAMAGE WILL OCCUR.

The system can provide the rated peak power when the input voltage is in the range of the specified normal operation voltage. The output power de-rates below the normal operation voltage.

WARNING: DO NOT CONNECT EITHER THE POSITIVE OR NEGATIVE BUS TO THE CHASSIS OR CASES OF THE MOTOR OR INVERTER. CATASTROPHIC DAMAGE MAY OCCUR. PROVIDE SUFFICIENT INSULATION ON ALL POWER TERMINALS FOR SAFETY.

WARNING: DO NOT CONNECT EITHER THE POSITIVE OR NEGATIVE BUS TO THE CHASSIS, MOTOR CASES, OR INVERTER. CATASTROPHIC DAMAGE MAY OCCUR. PROVIDE SUFFICIENT INSULATION ON ALL POWER TERMINALS FOR SAFETY.

If the system is being tested on a dynamometer, the power supply must be capable of delivering and accepting energy. If the power supply cannot accept regenerated energy, the voltage will quickly exceed the maximum rated input voltage limit.

The ripple voltage on the power supply should be less than 10 V peak-to-peak at all current levels.

Before applying input voltage ensure that the shaft, and/or anything connected to the shaft, has sufficient area for rotation. Always disconnect input voltage before making or removing any connections.

The DC bus POS supply line must pass through an in-line fuse and power disconnect switch or breaker, prior to connection to the inverter. Proper sizing of the fuse (See Appendix J "Soft Start Guidelines") and power disconnect switch or breaker is necessary. In the interest of safety, the power disconnect switch or breaker control should be located where it is accessible to the operator of the vehicle. All electrical conductors must be covered and insulated.

When the bus is energized and the power disconnect switch is closed, a rush of current can be expected due to the charging of the capacitors within the inverter. This can be avoided by using a soft start circuit to slowly charge this capacitor before closing the power disconnect switch. A SOFT START CIRCUIT IS RECOMMENDED FOR INPUT VOLTAGES ABOVE 100V DC. Soft start guidelines are provided in Appendix J.

3.6 Grounding Requirements

The cases of the inverter and motor must be wired together with 6AWG copper wire and may or may not be tied to chassis. THE BUS POSITIVE OR NEGATIVE MUST NOT BE TIED TO THE CHASSIS, THE CASES OF THE INVERTER, OR MOTOR. The User Interface Reference Ground must be isolated from the DC bus.

If your system has an auxiliary battery, the negative of the auxiliary battery may or may not be connected to chassis. The User Interface Reference Ground may be connected to an auxiliary battery negative. Do not connect the DC bus POS or NEG, to the auxiliary battery or the user interface reference ground.

4 Liquid Cooling System

4.1 Liquid-Cooled System Setup

The Electric Vehicle Driveline package requires a liquid-cooling system. The recommended liquid-cooling setup is shown in Figure 4.1-1.

The coolant ports in the motor and controller are o-ring sealed, so that they can be changed by the customer to fit their various applications. From the SAE 1926 port there are several options that can be supplied from the factory, or purchased and changed by the customer.

For proper performance and to achieve rated power the coolant loop must meet the following requirements:

PowerPhase®150 and PowerPhase®100

Minimum coolant flow rate:	7.5 l/min (2 gpm) to 15 l/min (4 gal/min)
Maximum coolant loop pressure:	10 psi
Coolant temperature range:	-20˚C to 50˚C
Maximum coolant temperature:	55˚C

A coolant flow rate of 7.5 l/min (2 gal/min) will have a pressure drop of approximately 3.2 psi, due to the controller and motor. This does not include additional fittings, valves, or plumbing.

PowerPhase®75, PowerPhase®125, and Hi-Tor

Coolant flow rate:	7.5 l/min (2 gal/min) to 19 l/min (5 gal/min)
Maximum coolant loop pressure:	13 psi
Coolant temperature range:	-20˚C to 50˚C
Maximum coolant temperature:	55˚C

A coolant flow rate of 7.5 l/min (2 gal/min) will have a pressure drop of approximately 1.8 psi due to the controller and motor. This does not include additional fittings, valves or plumbing.

It should be noted in Figure 4.1-1 that the coolant should go from the radiator, through the pump, and on to the controller. Then it should move from the controller, to the motor, and back to the radiator. Try as hard as we might, the electronics are still more heat sensitive than the wires in the motor, and as such need the coolant as cool as possible. While the system can operate at maximum rated coolant temperatures, the operating life of the controller will be longer if the coolant is kept below that temperature.

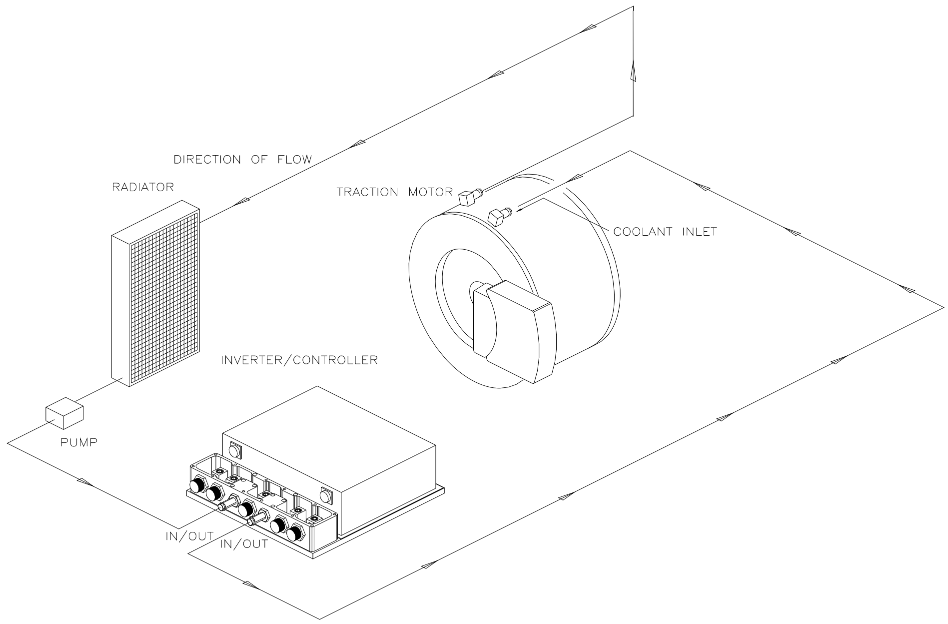


Figure 4.1-1: Suggested Cooling System Connection Scheme

4.2 Liquid Cooling System Installation

Make sure the radiator fill port is higher than the motor and controller. The hose connections for the motor are located on the topside of the motor, or within 45º from the top. (See Section 2.3 "Motor Installation.") For the inverter, either hose connection can be used as coolant in or out. For the coolant connection to the motor, coolant "IN" must be connected to the motor coolant fitting marked as "INLET." The "INLET" fitting is the taller of the two coolant fittings, and is located nearest to the termination housing.

4.3 Flow Rate vs. Pressure Drop

Table 4.3-1: Flow Rate vs. Pressure Drop

PP150 and PP100 LIQUID COOLED SYSTEM

FLOW RATE gal/min	MOTOR psi	INVERTER psi	TOTAL psi
1	**0.6**	**0.5**	**1.1**
2	1.4	1.8	**3.2**
3	2.4	3.5	**5.9**
4	3.8	6.2	**10**

PP75, PP125, and Hi-Tor LIQUID COOLED SYSTEM

FLOW RATE gal/min	MOTOR psi	INVERTER psi	TOTAL psi
1	**0.0**	**0.5**	**0.5**
2	0.2	1.8	**2**
3	0.5	3.5	**4**
4	1.1	6.2	**7.3**
5	1.7	9.3	**11**

5 Basic Operating Instructions for Drive System

The drive system can either be operated on a dynamometer or in a vehicle. Instructions are given for both. Prior to applying power ensure that the drive system is properly secured, nothing is in the way of the rotating shaft, and that all connections are made to the motor and controller. Also, be sure that there is coolant in the system, and that it is flowing through both the motor and controller.

NOTE: Some systems are configured for CANbus control by default. These systems will not respond to the User Interface Hand Control Pad that is referred to in this manual. See section 7.4 to disable CANbus control in order to use the User Interface Hand Control Pad for set-up purposes. See the UQM Technologies, Inc. CAN manual for details on CANbus control.

NOTE: The instructions in this chapter assume that the system is in Torque Control, which is the factory default. The system can be set into other control mods via CANbus or serial port. The instructions in this chapter will NOT apply for control modes other than Torque Control. Refer to Chapter 7, "System Operation," for other control modes. Refer to Chapter 6, "Serial Port Communications and System Status," for changing control mode via serial port.

5.1 Hand Control Functions and Operation

Appendix K contains a circuit diagram of the hand control. Some of the functions of the other pins on the hand control will be explained in more detail. For an explanation of each pin, see Section 3.3 on User Interface signals.

User_xxV Input: (Optional) (Refer to Appendix A-D for rated voltage.) The external User_xxVDC input can be used as a "key on" and "key off" signal. If the User_xxV voltage supply is not present, then "key off" is assumed and the system will not operate. If the key on signal is not used with the hand control, the key on/off parameter must be checked in the system configuration, or the system will not operate. See section 7.4, System Configuration, for information on configuring the key signal.

NOTE: the Drive ready LED will not function without the external User_xxVDC input.

The external user (User_xxVDC) supply input signal can be applied to the hand control P2 header, Pins 4 and 17. See Section 3.3 on user interface and Appendix K for more information.

WARNING: Do not connect the high voltage DC bus POS or NEG to the user voltage interface reference ground. The user interface Pins are reference to the 12 volts and should remain isolated from the high voltage DC bus for safety. See Section 3.6 for more information on grounding requirements.

Enable Switch

Once the power is up, the control pad can be used to control the motor. Turn the enable switch to the ENABLE position. If the enable switch stays at the DISABLE position, the desired torque level will be forced to zero by the controller. This switch simulates the Neutral drive mode in the vehicle.

Direction Switch

The DIRECTION switch simulates the DRIVE and REVERSE signals on an automatic transmission vehicle. It sets the direction of motor shaft rotation. The Electric Vehicle Drive system performance is optimized for motor rotation in both directions.

5.1.1 Accelerator Potentiometer

The Accelerator Potentiometer simulates the Accelerator signal. It generates an analog signal ranging from 0 to 5V. Based on the preset acceptable voltage range for accelerator signal, this voltage is converted into the desired percentage of full scale accelerate torque, which can be read in the Diagnostic Software (Refer to section 7.4, System Configuration, for more details on setting the voltage range.)

5.1.2 Brake Potentiometer

The Brake Potentiometer simulates the Brake signal. It generates an analog signal ranging from 0 to 5V. Based on the preset acceptable voltage range for accelerator signal, this voltage is converted into the desired percentage of full-scale brake torque, which can be read in the Diagnostic Software (Refer to section 7.4, System Configuration, for more details on setting the voltage range.)

5.2 Basic Dynamometer Operating Instructions

WARNING: OPERATE MOTOR SLOWLY DURING FIRST TIME STARTUP.

If the system is being tested on a dynamometer, the power supply must be capable of delivering and accepting energy. If the power supply cannot accept regenerated energy, the voltage will quickly exceed the maximum voltage limit rating of the control, and may cause damage to the controller or power supply.

The system should be connected as shown in Figure 3.0-1. Turn the accelerator and brake potentiometers fully counterclockwise, to 0. Flip the Enable/Disable switch to the DISABLE position. Turn up the DC input bus voltage source to the desired operating voltage. This must be greater than the Minimum Bus Voltage (set for each customer’s specific battery.) The hand control “drive ready” LED, should be on (if User_xxV is connected, see Section 5.1.)

The system should be fully operational. Turn the Enable/Disable switch to the ENABLE position. Slowly turn the accelerator potentiometer clockwise. The motor should begin to rotate. If the motor does not rotate when the potentiometer has been turned 30º, then there is a problem. (See Chapter 7, “Troubleshooting,” in this manual.) Be careful if the motor is unloaded, because the torque command will drive the motor to the maximum rated rpm very quickly. Turn the accelerator potentiometer fully counterclockwise to stop the motor. Turn the brake potentiometer clockwise to add in brake, if necessary.

5.3 Basic Electric Vehicle Operating Instructions

We are assuming that the electric vehicle is equipped with batteries, and a soft start circuit. These instructions are written assuming the user is debugging the vehicle system with the hand held control pad. Do not use the control pad for vehicle operation. If the drive motor is connected to the drive wheels, then jack the drive wheels off the ground. The system should be connected as shown in Figure 3.0-1. Turn the accelerator and brake potentiometer fully counterclockwise, to 0. Flip the Enable/Disable switch to the DISABLE position.

Normal Operation

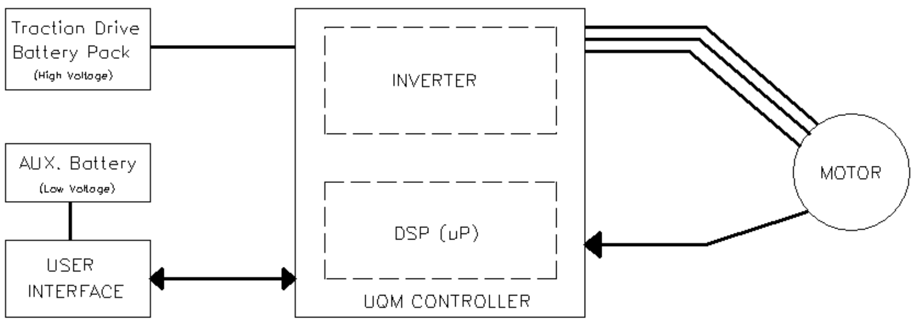
Turn the Enable/Disable switch to the ENABLE position. The system should be fully operational. The drive ready LED on the control pad should be illuminated (if User_xxV is connected, see Section 5.1.) Slowly turn the accelerator potentiometer clockwise. The motor should begin to rotate. If the motor does not rotate when the potentiometer has been turned 30º, then there is a problem. (See Chapter 7, "Troubleshooting," in this manual.) Be careful if the motor is unloaded, because the torque command will drive the motor to the maximum rated rpm limit very quickly. Turn the accelerator potentiometer counter clockwise, and the brake potentiometer clockwise, to stop the motor.

6 System Operation

6.1 System Overview

The UQM Electric Drive System consists of a Brushless PM motor, a high-power liquid-cooled inverter, and an internal DSP controller. Figure 6.1-1 shows the block diagram of the system.

Figure 6.1-1: Block Diagram of Electric Vehicle Drive System



6.2 Control Modes

There are four Control Modes in the UQM Motor System:

CANbus Control	Control commands are issues to the controller/inverter via the CANbus. Torque, speed, and voltage control are possible.
Analog Torque Control	Control commands are issued to the controller/inverter via the two analog signals. Only torque control is possible.
Analog Speed Control	Control commands are issued to the controller/inverter via the two analog signals. Only speed control is possible.
Generator	An autonomous control mode where no control commands are expected. Control values are delivered via the System Configuration.

As noted above, these four control modes provide methods to access the three types of control possible in the UQM Motor System: torque, speed, or voltage control. You have the choice of commanding through a digital path (CANbus) or an analog path.

6.2.1 Torque Control

This is the most common operational mode for the motor. When in analog Torque Control, torque is commanded as a percentage of full scale through the analog controls, via the “ACCEL” (positive torque request,) and “BRAKE” (negative torque request) signals. The two command input signals offset each other. Motor control tries to deliver the requested torque level.

Alternatively, if in CANbus Control, then torque is commanded as a requested torque value through the Universal Command. See the UQM CANbus Manual for details.

6.2.2 Speed Control

In the operational mode of speed control, the motor controller tries to keep its spinning rate and direction matching the requested speed level. When in Analog Speed Control, speed is commanded as the absolute desired value through the analog controls, via both the ACCEL and BRAKE signals. However, the ACCEL signal is the requested speed and BRAKE is the percentage of full-scale torque allowed, to achieve that speed. In other words, the BRAKE signal MUST be greater than 0% if you want the motor to move at all.

Alternatively, if in CANbus control then the speed is commanded as a requested speed value through the Universal Command, and the torque limitation is passed in the same command. See the UQM CANbus Manual for details.

6.2.3 Voltage Control

> **WARNING**: UQM Motors in Voltage Control require that the controller's voltage bus have a separate UQM capacitor box attached to it for safe control. Not all controllers are enabled to allow voltage control.

In the operational mode of voltage control, the motor controller tries to maintain a requested voltage level. When in Generator Mode, the voltage is maintained to the desired voltage that is stored in the System Configuration (see section 7.3.) There are no analog signals that affect this mode; even the hardware enable signal is ignored.

Alternatively, if in CANbus Control then the voltage is commanded as a requested voltage value through the Universal Command. See the UQM CANbus Manual for details.

6.3 Torque and Power Profiles

When operating in analog signal control, the system computes the desired command torque based on the accelerator and the brake signals. In essence, the accelerator and brake signals simply cancel each other, if they are equal in magnitude.

Both accelerator and brake signals represent desired percentage torque, with respect to the full torque profile shown in Figure 6.3-1. The accelerator signal is treated as positive command torque, and the brake is treated as negative command torque. The resultant command torque is the sum of these two signals as follows:

Command torque = Accelerator + Brake

Where Accelerator ≥ 0 %, and Brake ≤ 0 %

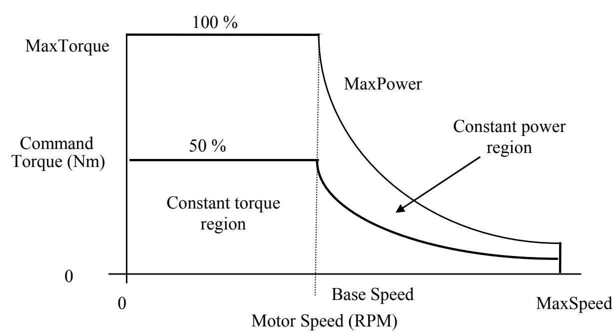


Figure 6.3-1: The Torque Profile for 100% Input Command Level

Figure 6.3-1 shows the torque curve used to calculate the desired output torque, based on the given input command percentage. The profile shows the command torque profile running at 100% and 50% command level. It displays the relationship between the command torque and the motor speed. The base speed determines the line between the constant torque region and the constant power region. Note: If the calculated percentage torque is less than 100%, the profile is scaled down proportionally based on the percentage command input.

Please note, that the figure does not imply that the torque is the determining factor for the motor speed, as the system load is required to determine the motor speed. The figure, however, does suggest that the output torque may vary based on the motor speed during the constant power region. In the constant torque region, there is no direct correlation between the output torque and the motor speed. The output torque is determined only by the input command.

6.4 Limit Features

Limits

The system provides built-in limit features to minimize hazardous conditions. Limits regulate the command torque when a system condition is close to its limit such as over motor current, over/under battery voltage, or over motor speed. The UQM Motor Diagnostic Software (see section 7) shows you the limitations acting on the torque whenever they are below 100%. Take, for example, the locked rotor (stall) case. If the rotor does not move when high torque is commanded, the current can exceed safe limits. The lock rotor limit protects the power devices in the inverter, and safely gives the user as much current as possible.

Potential Motoring Limitations

Cause	Max. Limitation
Over temperature (Inverter/Stator/Rotor)	25%
Motor Leg current over current	27%
Bus current over positive current	24%
Motor velocity over speed	0% to full regen.
CTL_LINK analog signal set	50%
CAN control, no CAN communication	0%
Bad controller calibration	13%
Bad driver safety	40%
Stall conditions	50%
Current sensors appear disconnected	24%
Bus Voltage under customer battery min	3%
Incorrect position offset	36%
Error with leg current sensors	35%
Invalid Sensor voltage	34%

When more than one limiting factor is present, the lowest limitation dominates. The most serious motoring limitation is Over Speed. This limitation can actually cause motor regeneration in order to brake the speed. Whether it does this is a customer choice. (See Speed Safeties within the System Configuration section 7.4.)

Potential Regeneration Limitations

Cause	Max. Limitation
Over temperature (Inverter/Stator/Rotor)	25%
Motor Leg Current Over Current	27%
Bus Current Under Negative Current	24%
Bus Voltage Over Safety Voltage	1%
CTL_LINK analog signal set	50%
CAN control, no CAN communication	0%
Bad controller calibration	13%
Bad driver safety	40%
Stall conditions	50%
Current Sensors appear disconnected	24%
Bus Voltage over Customer Battery Max	2%
Incorrect position offset	36%
Error with Leg current sensors	35%
Invalid Sensor voltage	34%

Again, when more than one limiting factor is present, the lowest limitation dominates. The most serious regeneration limitation is Over Safety Voltage. This limitation can actually change the motor’s control mode while the condition exists, because the inverter will be destroyed if the voltage remains above the allowable value. This control mode, called FORCED VOLTAGE CONTROL, takes priority over any other limit.

Software Watchdog Timer
In addition to all limit protection discussed above, a software watchdog timer is also enabled. If the watchdog timer is not maintained properly by the Inverter's firmware, the system will be reset automatically.

Under Voltage
If Bus voltage drops below the under voltage setting in the system configuration, the system may reset. User_12V input must be provided to prevent this. Operating time will reset to 0 seconds.

6.5 System Behavior on Inverter Fault

Inverter module faults occur because of over current, over temperature situations, or internal 15V supply problems. In the event of an inverter fault, the UQM Motor Diagnostic Software shows an Inverter Fault in the Status Group, (see section 7.3.) The system response to an inverter fault depends on its control type: Torque or Speed Control, or Voltage Control.

Torque or Speed Control:
When a fault first occurs the system will immediately limit both motoring and regeneration torque to 50%, and clear the fault after a 100ms delay. If the fault reoccurs the system will clear it a second time, after a one-second delay. (Torque is still limited to 50%.) If a fault occurs after these instances, the system will not clear the fault. The torque limitation is set to 50%, and can be only reset by cycling power to the system.

Voltage Control:
In Voltage Control mode, the system attempts to clear the fault, and continues to try to clear the fault every 100ms. No torque limitation is imposed.

6.6 System Error Codes

Table 6.1-5: List of Error Codes

Error Code	Name	Description
0x8000	Inverter Fault	One or more inverters shut down because of over current or over temperature.
0x4000	Inverter Fault Occurred	History that an inverter fault occurred.
0x2000	Over Power Limit	Power limit has been exceeded.
0x1000	Calibration Problem	The controller board, in the inverter box, is not calibrated properly. It could mean that flash memory has failed. Contact UQM Technologies, Inc., for assistance.
0x0800	Over Voltage Alarm	Bus voltage has gone over the allowable limit of the inverter, and inverter damage is possible. Controller will have gone into forced voltage control to try to keep the inverter safe.
0x0400	Over Speed Alarm	Motor speed has gone over the allowable safety limit and motor damage is possible. Controller will have taken away part or all of the ability to motor, and can actually be braking to try to slow the motor down, if authorized in the system configuration.
0x0200	Over Voltage Warning	Bus voltage has gone over the allowable limit of the battery, and battery damage is possible. The error can occur normally during

		large decelerations, as the controller tries to keep the bus voltage below the safety level.
0x0100	Over/under Speed Warning	Motor speed is nearing the allowable limit. The error can occur if the vehicle is coasting down a hill faster than the maximum set rpm limit. The error can also occur when the system is in voltage control mode, and the speed is below the minimum speed required for voltage control.
0x0080	Over Inverter Temp	Inverter's temperature has gone over the safety limit. The error can occur if the motor's allowable duty cycle is exceeded, (i.e. running the motor continuously at a torque level beyond its continuous specification.)
0x0040	Over Motor Temp	Motor's internal windings temperature has gone over the safety limit. The error can occur if the motor's allowable duty cycle is exceeded.
0x0020	Over Rotor Temp	Motor's rotor temperature has gone over the safety limit. The error can occur if the motor's allowable duty cycle is exceeded.
0x0010	Under Bus Voltage	Bus voltage is below operating values. This will occur if the microprocessor is powered but the inverter is not.
0x0008	Over allowable Phase Advance	A critical internal parameter has exceeded its limit and the motor is not performing at its best.
0x0004	Over Bus Current	The maximum bus current has gone over the safe limit.
0x0002	Over Leg Current / Locked Rotor	The maximum leg current of the motor has gone over the safe limit or the motor is not spinning (stalled) with high torque requested. This can endanger the inverters, and the controller will try to limit torque to control these events.
0x0001	Not Enabled	System is not enabled to run. Can be caused by the key-on state, the enable state, or the lack of high voltage.

These errors are combined in the System Error Word, available through the UQM Motor Diagnostic Software, (see section 7.5-6.). Numbers observed that are not listed above indicate multiple errors. For example, a 0x0083 would indicate "Over Inverter Temp," "Not Enabled," and "Over Leg Current," (0x0080+0x0002+0x0001). A 0x0A00 would indicate "Over Voltage Alarm," and "Over Voltage Warning," (0x0800 + 0x0200). Also, when both 0x0004 and 0x0002 are asserted at exactly the same time, this indicates that the inverter has had to go into Forced Open Loop (see Table 7.3-2 for more information.)

When high voltage is not applied, many measurements cannot be correctly made, and may be indicated in the System Error output. All these errors are cleared when high voltage is applied.

7 UQM Motor Diagnostic Software

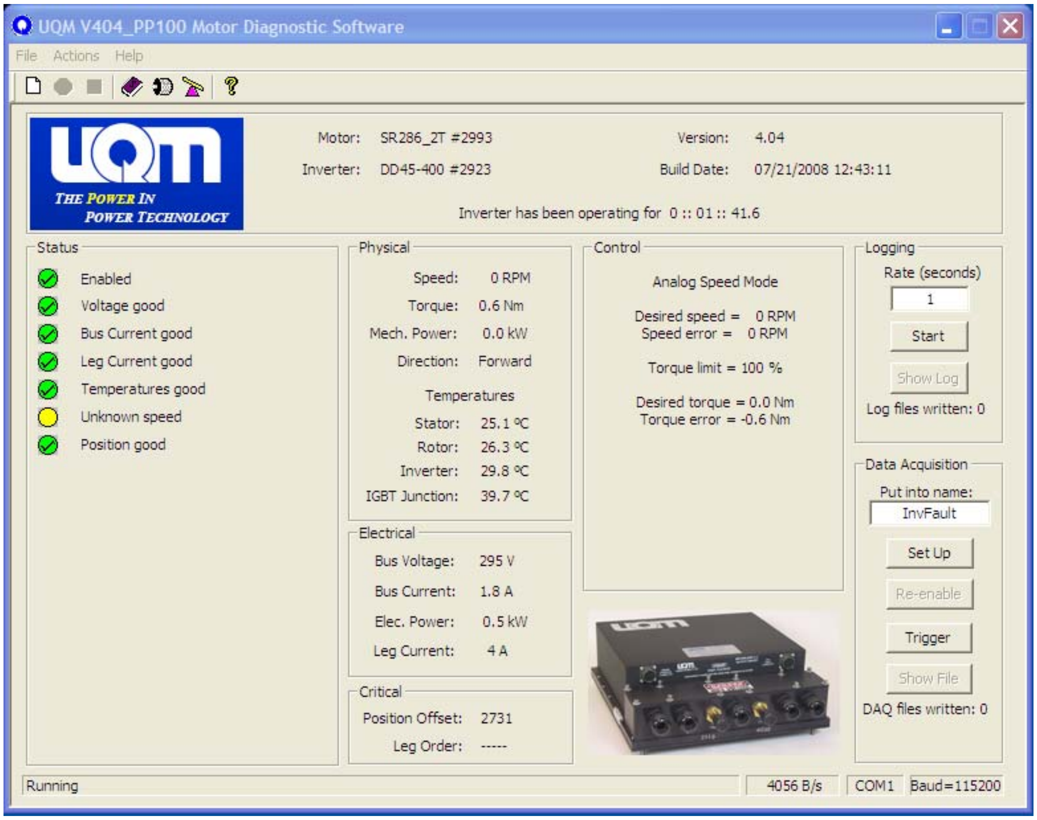


Figure 7.0-1: UqmMotor Diagnostic Software Front Panel

UQM Technologies Inc. provides diagnostic software with their motor systems. This software runs on Microsoft Windows XP, and provides an environment to monitor and record the motor system conditions. It also allows you to change motor system configuration settings. This section describes this software's use.

NOTE: starting with Version 4.04, the UQM Motor Diagnostic Software has one executable that supports all UQM motor systems (i.e. PP75, PP100, PP125, and PP150.) In addition, the executable file that ships with Version 4.04 systems can communicate with UQM Inverters with older firmware versions V4.03 and V4.02. It will offer a firmware upgrade option, but does not require it.

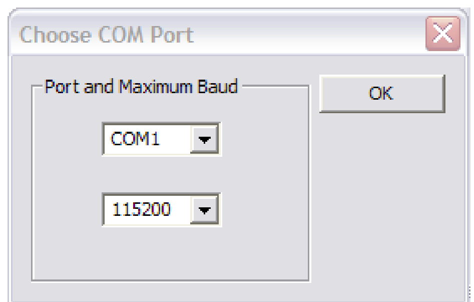
7.1 Software Setup

The UQM Diagnostic Software communicates to the motor system through the serial communication port. This is available through the user interface 19-pin Amphenol connector, described in section 3.3. On the User interface Hand Control Pad, these signals are available through the nine-pin connector P3 at pins 3(Serial_RXD), 4(Serial_TXD,) and 8(Serial_GND). See Appendix K for details on these connectors. When connecting to a PC's COM port, remember to USE A CROSSOVER CABLE where the transmit and receive lines are swapped within the cable. (Those are pins 2 & 3 on the DB9 connector of a common serial cable.) This type of cable is also sometimes called a Null Modem cable.

UQM Motor Diagnostic Software requires 5 Megabytes of hard disc space on a Microsoft Windows XP Personal Computer with a COM port. A USB to the Serial Converter can be used

to provide the COM port, but it must be installed prior to installing the UQM Motor Diagnostic Software. Install the software via the CD-ROM disc provided with the UQM motor system. The picture to the left shows the shortcut for the executable "UqmMotor.exe."

7.2 Software Start Up



When first started, the UQM Motor Diagnostic Software will ask for the COM port number where the serial cable is attached. In addition, it will ask for the fastest baud rate desired. Leaving it at its default top speed of 115200 is recommended. This does not mean that it will operate at 115200 baud, only that it will try. The software negotiates the baud rate it will use with the motor controller/inverter each time it is started, and it will find the fastest baud rate that can be maintained. You can, however, constrain it to a lower rate by setting that rate here. Normally, you will see this dialog box only once, upon first start. It will store these settings and reuse them on each restart. If you want to change these settings later, use the menu choice "Actions→Choose COM Port," to do so.

Note: We recommend that you save the original system configuration to a file for each motor as you start up your software with that motor for the first time. This will allow you to return the configuration to your original shipped state at any time. See "Save to file" in Table 7.4-1 of this manual.

Note on multiple motor operation: if a PC supports more than one COM port then multiple instances of the UQM Motor Diagnostic Software can be started to view the operation of multiple motor systems at the same time. The "Choose COM Port" dialog box would be seen on each wake-up since you have to specify which motor should be connected (it will always try to connect to the LAST motor connected to.) When multiple motor connections are desired as normal operation, UQM recommends that you copy the UqmMotor executable into another directory and put a shortcut on your PC desktop for this other executable. Each will retain the knowledge of which COM port they "own" and will communicate with only the motor connected to that COM port.

Status Bar

As the UQM Motor Diagnostic Software starts, it contacts the motor controller/inverter via the COM port given. The status bar at the bottom of the application window communicates all the particulars of that contact. Figure 7.2-1 points out the components of the Status Bar.

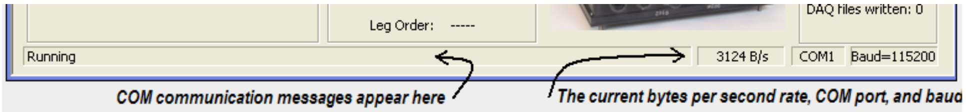


Figure 7.2-1: Status Bar

Table 7.2-1 shows the communication messages that occur in the Status Bar. When errors occur, the software provides additional information through message boxes or other dialog boxes. For example, if the software encounters a device that is an older version of firmware, the software will inform you of this information and inquire if you wish to update or just run. Updating the firmware is described in section 7.8. On the other hand, if communication is not possible, the software will either exit or return to the "Choose COM Port" dialog box.

Table 7.2-1: Status Bar Communication Messages

Message	*Description*
Have gotten the COM port	First message during opening contact.
Found device, initializing interface...	The device has answered, software is asking for identification.
Initializing Device...	Identification received, initializing communication with the device.
Negotiating baud...	Baud rate is being negotiated between the PC and the device. The highest supportable baud will be selected.
Reading Eerom...	The internal persistent memory is being read. This memory contains configuration, calibration, and error event data.
Running	Normal operation is occurring.
Fetching DAQ data	A DAQ trigger has occurred and data is being removed from the device into a file.
Communication down, continuing to try...	Communication between the PC and the device has failed. The PC will continue to try to establish communication every 5 secs. This will continue forever. Use 'Change Com Port' to stop.
Unable to communicate with device	Communication attempts have been unsuccessful.
Attached to a constantly talking device	A device has been encountered on the serial port that is outputting text all the time. Try connecting with Microsoft's HyperTerminal program to communicate with this device.
Bad DAQ directory	The software was unable to store a DAQ file in the present DAQ directory.
Downloading firmware	The software is downloading new firmware into the UQM controller/inverter.
Cannot operate	The system, motor, or inverter of the software does not match the system, motor, or inverter of the attached device.
Error count exceeded allowed. Letting go of COM port	Too many errors have occurred in the serial communication channel. The software is giving up communication.
COM port failure	Software unable to get COM port. Close the program that is using this COM port.

In normal operation, the software gets the COM port, initializes the interface, retrieves the device's initialization information, negotiates the baud, reads the EEROM, checks to see if a download could be done, and then begins running normally. These activities do not disturb the normal operation of the UQM controller/inverter as it manages its electric motor. You can connect the diagnostic software to a UQM controller/inverter at any time. One exception: do not initiate an actual firmware download if the electric motor is in use! A required download is a rare event that you most likely will not encounter, except when you have explicitly received a new version from UQM Technologies Inc. See section 7.8 for further details.

We recommend that you save your system configuration to a file as soon as you begin operating the software – this will allow you to return to your original system configuration at any time. You can also save different system configurations as you make changes to the configurations. See Table 7.4-1 for further details on saving system configurations.

7.3 System Operation

The UQM Motor Diagnostic Software consists of a front panel with menu, toolbar, and status bar. The status bar is described in section 7.2 above. Table 7.3-1 gives general descriptions of each group on the front panel. Figure 7.0-1 shows each of these groups.

Table 7.3-1: Front Panel Group Descriptions

General	Shows the motor, inverter, build version, and date of the firmware in the inverter. It also shows the present operating time of the inverter in hours::mins::secs. It displays the time since the last inverter power-up. The time cannot go past 95 hours. It will roll over to a time of zero after some 3 days of continuous operation.
Status	Shows the present status of the motor system. Voltage, current, temperature, and rotor position conditions are monitored and problems are reported in this section. Further details are shown in Table 7.3-2.  Indicates proper operation  Indicates a cautionary or questionable situation  Indicates a severely-limited or non-operation situation
Physical	Reports the present measurements for speed, torque, mechanical power, motor direction, and component temperatures. Most temperatures are measured values, but the IGBT Junction temperature is a calculated temperature based on conditions and predicts problems occurring in the inverter modules' silicon substrates. Any problem measurements will be noted in the Status Group.
Electrical	Reports the present measurements for DC bus voltage and current, electrical power, and the phase leg currents. Any problem measurements will be noted in the Status Group.
Critical	Reports the critical parameters of the position offset and the phase leg order. If these are incorrect, the situation is dangerous. This danger occurs only if an inverter is used with a motor not matched to it by the UQM factory.

Control	Reports the present control mode and control parameters of the motor system. Choices:
	`CANbus Control`
	`Analog Torque Control`
	`Analog Speed Control`
	`Generator Mode`
	The modes are selected via the System Configuration (see further information in section 7.4 and section 6.4.)

Logging	Along with menu and tool bar options, Logging controls the data logging capabilities of the software. Data logging records motor system measurement data to a spreadsheet file in real time at second or multiple-second rates. The software can log data at these slow rates indefinitely. Details on logging are located in section 7.5.

Data Acquisition	Controls the data acquisition (DAQ) capabilities of the UQM controller/inverter. DAQ records motor system measurement data at millisecond rates. The data is limited in length, and is recorded into a spreadsheet file after the acquiring event has occured. Significant time is required for extraction of the DAQ data from the inverter. Details on DAQ are located in section 7.6.

Measurement Update Speed

In normal operation, the front panel indicates the present operating conditions of the UQM Motor System. The measurements are updated four times per second at the higher baud rates. Slower rates, like 38400 and 19200, will slow down the measurement rate to about twice a second. Note, that the measurement rate is slowed when a DAQ file is being retrieved because removal of the DAQ data is using almost all of the bandwidth of the serial port.

Status Group

The status group is a very important area of the front panel because it shows the present status of the motor system. Conditions are monitored and problems are reported that are affecting the normal operation of the motor system. Whenever a red light is showing in the status group, the controller/inverter could be severely limited in operation. Table 7.3-2 shows the conditions that can cause red and yellow lights in the status group.

Table 7.3-2: Status Group problems

RED LIGHT	
EEROM failed	The persistent memory on board the controller/inverter has failed or is not programmed. The inverter cannot operate.
Bad System Configuration	The system configuration information in the persistent memory is unusable. The inverter cannot operate.
Unit not calibrated	The calibration data in the persistent memory is not present. The inverter is severely limited in operation.
Event Log disabled	The Event Log is inoperable. This does not affect motor operation.
Sensor voltage invalid	The voltage that powers the current and temperature sensors is invalid. This is normal when high voltage is not present, but if high voltage is present then the inverter is severely limited.
Key OFF	The Key signal is not present so motor operation is disabled. See Section 3 of this manual for more details on this signal.
Inverter Faulted	One or more inverter modules are presently faulted. This is normal when high voltage is not present, but if high voltage is present then the inverter is severely limited.
Over Voltage	Bus voltage is over the allowable limit. The inverter is likely to have gone into forced voltage control to bring this condition into control. The inverter is in danger of severe damage if this condition persists.
Over Speed	The motor is spinning faster than the allowable limit. Motoring is significantly limited, and the motor may be generating to try to slow itself down. If the over speed persists and is fast enough, the motor is in danger of damage.
Bus Current too large	Bus current is over the allowable limit. The inverter imposes limitations on its output during this condition.

Leg Currents sum not zero	The measured currents in the three motor phases should equal zero at any particular moment in time. If they do not, measurements are suspect and the inverter imposes limitations on its output during this condition. (Note, that on average, the currents in the legs can be large, but sum to 0.)
Bad (A/B/C lower/upper) driver	The inverter has detected a problem on one or more of the three motor phases (A, B, or C,) that it believes to mean a driver circuit is bad for the inverter module in question. The inverter imposes limitations on its output.
Phase limited	In high speed operation, the inverter's phase adjustment has reached its allowable limit. The inverter imposes limitations on its output during this condition.
Inverter/Stator/Rotor Temperature Disconnected	The inverter has detected a disconnected temperature sensor. The inverter imposes limitations on its output during this condition.
Inverter/Stator/Rotor/ IGBT Junction Temperature Over	The temperature measurement is over the allowable limit. The temperature limits are given on the "About UqmMotor" dialog box. The inverter imposes limitations on its output during this condition.
No Halls signals	There are no hall effect sensor inputs detected. The Halls cable is likely to be unattached. The inverter cannot operate and must be reset.
Rotor movement	The inverter has detected a condition that often indicates that the rotor or the position-sensing equipment has moved. The inverter imposes limitations on its output.
Position signal is bad	The position signal is bad. The inverter cannot operate and must be reset. Check the position signal cable.
Position problem	A position-sensing problem has occurred and the motor is still limited in output because of it.
Position signals are noisy	Electrical noise has been detected within the position-sensing signals. If severe enough, this can cause limitations to motor output. A red light means that there has just been a noise event. A constant red light means noise is occurring at a rate greater than four per second.
Forced Open Loop	The inverter is operating in forced open loop control and is limited in capability. This can occur because of bad sensor measurements or position problems.
CANbus communication error	The CANbus communication has ceased and the inverter is disabled. This is the CANbus watchdog error and must be reset via the watchdog reset command through CAN. See the CAN Manual for further details.
Hand control signals bad	In analog control, the analog control signals are outside their allowable limits (set in system configuration, see section 7.4.) The inverter is disabled.
Accel control signal bad	Specifically, the accelerator control signal is outside its allowable limits and motoring ability is disabled.
Brake control signal bad	Specifically, the brake control signal is outside its allowable limits and regeneration ability is disabled.

YELLOW LIGHT	
Disabled	The controller/inverter is disabled. It can be disabled by the hardware enable line, through CANbus, through Key OFF, or through a number of conditions outlined in the RED LIGHT section of this table.
Fault Occurred	One or more inverter modules was faulted in the past and the inverter is limited in operation.
Motoring limited to x%	This caution appears whenever motoring ability has been limited to less than its full 100%. Besides the conditions outlined throughout this table, motoring can also be limited by a control signal in Analog Speed Control and by CANbus command.
Regen limited to x%	This caution appears whenever the motor's generation ability has been limited to less than its full 100%. Besides the conditions outlined throughout this table, generation can also be limited by a control signal in Analog Speed Control and by CANbus command.
Power close to or over limit	Electrical power is close to or over the allowable limit of the motor system. This warning is seen by motors in voltage control.
Voltage Warning	Bus voltage is nearing its allowable limit. Regeneration is likely limited.
Under Voltage	Bus voltage is too low to operate normally.
Speed Warning	The motor is spinning near the allowable limit. Motoring will soon being limited in order to control the speed.
Unknown speed	There is no position-sensing input occurring. It is likely that the motor is not spinning.
Under speed	When the inverter is in Generator Mode, or in Voltage Control through CANbus, the motor's speed must attain a minimum rate before power can be produced. This warning indicates that this speed has not been reached.
Inverter/Stator/Rotor/ IGBT Junction Temperature warning	The temperature measurement is approaching the allowable limit. The temperature limits are given on the "About UqmMotor" dialog box. The inverter will soon impose limitations.
Position signals are noisy	Electrical noise was detected within the position-sensing signals. A yellow light indicates that a noise event has occurred in the last 15 seconds.
No CANbus communication	The inverter is in CANbus control but no CANbus communication has yet been detected. The inverter is disabled.
CANbus status unavailable	This warning is only seen when the diagnostic software is connected to older firmware versions V4.03 or V4.02. The software is unable to detect if CANbus activity is good. It will, however be able to detect if CANbus activity goes down after having been established properly.
CANbus limit acting	Limits imposed through the CANbus commands are acting on the motor's output.

Stall conditions	The motor is experiencing stall conditions, meaning that it is not spinning and large amounts of torque are being requested. While in stall condition, the motor is limited in output to prevent damage to the inverter modules.
Forced voltage control	The motor is in Forced Voltage Control, a condition normally encountered when the motor is spun without a battery connected to it. Forced Voltage Control is entered to keep the voltage from going over the allowable inverter limit which would cause the inverter's capacitors to blow. The inverter drops out of Forced Voltage Control automatically when the danger is past.
Direction mismatch	The desired direction (either through analog control signal or through CANbus command) does not match the present direction of motor movement. This condition can exist when the motor is stopped because the directions were mismatched on the last movement of the motor as it came to a stop.

There is further information on many of these problems in Section 6 of this manual, called "System Operation". For example, limitations on motoring and generation are further described there, as well as additional information on the system behavior in the event of an inverter fault.

Menu and Toolbar

The diagnostic software has a menu and toolbar to access other functionality beyond that of condition and measurement information. Table 7.3-3 describes the menu's choices and shows those that have Toolbar buttons.

Table 7.3-3: Menu and Toolbar Descriptions

Menu Choice		*Button*	*Description*
File	Start New Log		Starts a new data log (the slow logging option of the UQM controller/inverter.) If a log is already open, it will close it and open a new one. See Logging, section 7.5 for more details.
	Stop Logging		Closes the present data log. The file is closed and it is then available for viewing. See Logging, section 7.5 for more details.
	Toggle Logging		Toggles the logging of data to the presently open data log. First click pauses the writing of data; second click resumes the writing of data. Does not close the data-logging file. See Logging, section 7.5 for more details.
	Recent Files		Shows the four most recent logging or DAQ files written by the software.
	Exit		This menu choice exits the diagnostic software
Actions	Show Event Log		Shows the attached motor's event log in a dialog box. See Event Log, section 7.7 for more details.
	Date into Event Log		Marks the Event Log of the connected controller with today's date. The date is in the form yyyy/mm/dd. This occupies space in the Event Log itself. Only one marker is allowed per day.
	System Configuration		The menu choice opens another popup menu with multiple system configuration options. The tool bar button shows the current System Configuration dialog box for editing. See System Configuration, section 7.4 for more details.
	Change DAQ settings		Shows the Data Acquisition Set-up dialog box. See DAQ, section 7.6 for more details.
	Change Trigger Levels		Shows the DAQ trigger levels dialog box. See DAQ, section 7.6 for more details.
	Change COM port		Closes communication to the inverter through the serial port and brings up the "Change COM Port" dialog box. Canceling this dialog box will cause the diagnostic software to exit. See section 7.1 for more details.
	Show CAN tests		Shows the CANbus Test dialog box. This dialog box is used to cause CANbus errors and status condition messages to be generated and sent so that you can test that your connecting software is receiving them correctly. See the UQM CANbus Manual for more details.
	Allow PWMs at Stop		Normally, the pulse width modulation (PWM) that the UQM controller/inverter uses to control its motor is not present when zero torque is requested and the motor is not spinning. This menu toggle (checked when true) causes the inverter to PWM even when at rest. This is useful when you need to test your system's noise immunity to the PWM energy without actually operating the motor.
Help	About UqmMotor		Shows the "About UqmMotor" dialog box, showing the application's version number, and the attached inverter's temperature limits.

7.4 System Configuration

Besides providing access to conditions of the UQM Motor System, the UQM Motor Diagnostic Software also provides access to the system's configuration parameters. These parameters can be viewed and changed via the System Configuration menu choices.

WARNING: SOME PARAMETERS IN SYSTEM CONFIGURATION CAN SIGNIFICANTLY CHANGE THE SYSTEM RESPONSE AND EVEN MAKE THE SYSTEM NON-FUNCTIONING. POTENTIAL DAMAGE TO OTHER SYSTEMS (FOR EXAMPLE, BATTERY PACK OR INTERNAL COMBUSTION ENGINE,) CAN OCCUR IF THESE PARAMETERS ARE NOT SET CORRECTLY. MAKE SURE YOU FULLY UNDERSTAND THE PARAMETER BEFORE MAKING ANY CHANGE TO IT.

System Configuration is accessed via the menu choice "Actions →System Configuration." Table 7.4-1 describes the choices found in the popup menu accessed from this point.

Table 7.4-1: System Configuration Menu

Menu Choice	*Button*	*Description*
Edit Current		Shows the current System Configuration dialog box for editing. The motor system must be disabled and not spinning if the saved changes are to take effect.
Reset to Default		Shows the System Configuration dialog box loaded with all the default values for this system. These are not always the values that your system arrived with—you should "Load QSC file" with the file that shipped with your system (or that you saved on arrival) to return to YOUR defaults. This menu choice does not return the motor-specific parameters to default. These are retained from the current system configuration. See "Save to file", "Load QSC file", and "Load QSC as motor" for further details.
Compare		Shows a table that compares the current system configuration values to those of the default system. Values that are identical are not shown, only those values that differ from default are shown.
Save to file		Brings up a "File Save" dialog box and then saves the present system configuration settings to a QSC file. All settings are stored, including the motor-specific parameters.
Load QSC file		Brings up the "File Open" dialog box and then loads the template portion of the QSC file into the System Configuration dialog box. All motor-specific parameters are NOT loaded—those are retained from the current system configuration. This is the normal way of loading a QSC file—it allows the same file to be loaded into inverter after inverter while still allowing each motor to have its specific parameters untouched.
Load QSC as motor		Acts like "Load QSC file," but loads all motor-specific parameters as well as the template portion of the chosen QSC file. This menu choice will always ask you to reconfirm that you really want to do this, because damage can result if an inverter is used with the wrong motor parameters. Use this method if you are moving an inverter from one motor to another. It will cause the inverter's motor-specific parameters to be reloaded with the new motor's numbers. MAKE CERTAIN you are loading the correct motor's parameters.

The System Configuration dialog box is tabbed. The parameters are separated into three tabs: General, Torque/Analog, and Digital/CANbus. Each tab is checked for value correctness before another tab can be viewed. When you select the "OK" button the entire system configuration is written to the persistent memory in the controller/inverter. Once written, if the motor is quiescent (disabled and not spinning), the controller/inverter is reset and restarted so that the changes will take effect. Otherwise, the changes will not take effect until the next power-on of the controller/inverter.

General Parameters

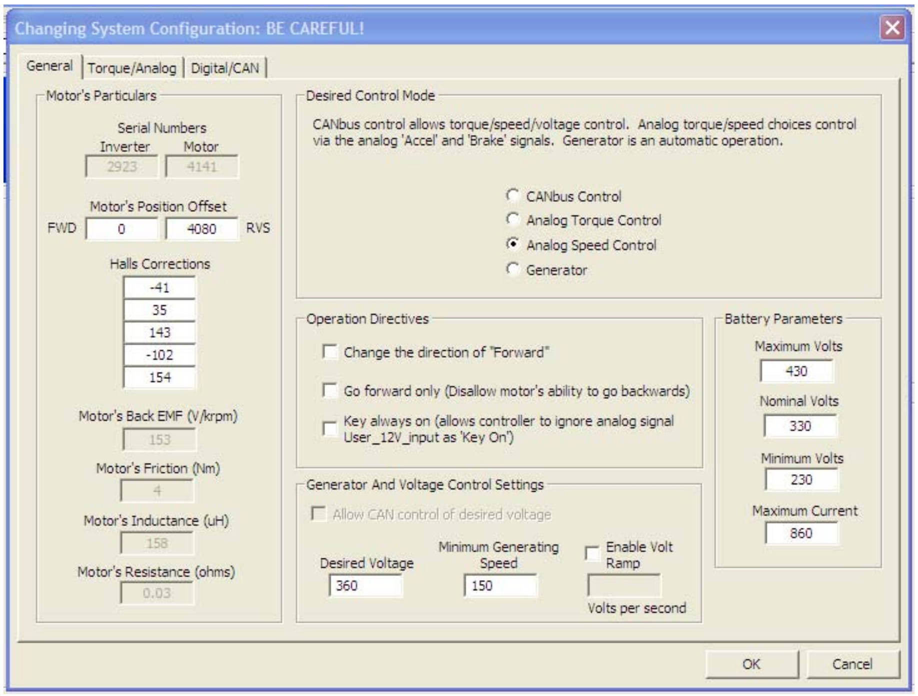


Figure 7.4-1: General System Configuration Parameters

The General tab on the System Configuration dialog box, shown in Figure 7.4-1, contains the Motor's Particulars, the Desired Control Mode, Operation Directives, Battery Parameters, and Generator Settings.

The **Motor Particulars** are the motor-specific parameters. These are set by the UQM factory, and in general should not be changed unless you are matching the inverter to a different motor. Loading a QSC file saved from this motor is the easiest way to alter these values. See menu item "Load QSC as motor" in Table 7.4-1.

The **Desired Control Mode** determines how the motor will be controlled. Further details about control modes can be found in "System Operation" (section 6) of this manual.

The **Operation Directives** allow you to tune very specific settings affecting operation:

Change the direction of Forward:

The UQM motor can perform equally in either direction. However, one direction is known as "forward" and the other is known as "reverse". If you would like the motor to change which direction it calls 'forward," check or uncheck this selection.

Go forward only:

To take away the motor's ability to go "backwards," check this box. (Remember, the "backwards" definition is your choice.)

***Key always on*:**

By default, the motor controller requires that 12V be delivered through the User_12V_input analog input line before the motor can operate (to indicate that the user has the key turned on.) However, the controller can operate via voltage derived from the high voltage, it does not require 12V. If the 'Key On' signal can be safely ignored then check this box to disable this safety feature.

The **Generator Settings** are only acted on in voltage control (Generator or CANbus Control.)

***Desired Voltage*:**

When in "Generator Mode," the voltage will be controlled to this voltage value. In CANbus voltage control, the desired voltage value is set by the CANbus command being sent to the controller and this value is ignored.

***Minimum Generating Speed*:**

When in voltage control, this is the minimum speed the motor must be spinning before it attempts to control the bus voltage. This prevents braking torque from being applied to an engine below its idle speed.

***Enable Volt Ramp and Value*:**

This checkbox/edit box manages the allowable voltage change rate in voltage control. If disabled, the voltage controller immediately tries for a new desired voltage supplied via the CANbus. If enabled, the edit box (in volts per second) sets the rate of change of the CANbus desired voltage from its former value to its new value.

***Allow CAN control of Desired Voltage*:**

When in "Generator Mode," the voltage will be controlled to the default voltage value. But the controller does support receiving other desired voltage levels via the CANbus, if this is checked. All other CANbus commands are ignored in "Generator Mode."

The **Battery Parameters** allow you to specify the Over and Under Voltage and Current settings that will cause output limiting when approached:

***Maximum Voltage*:**
The controller will limit regeneration when the voltage is above this setting.

***Minimum Voltage*:**
The controller will limit motoring when the voltage is below this setting.

***Maximum Current*:**
The controller will limit torque when this bus current is reached.

Torque/Analog Parameters

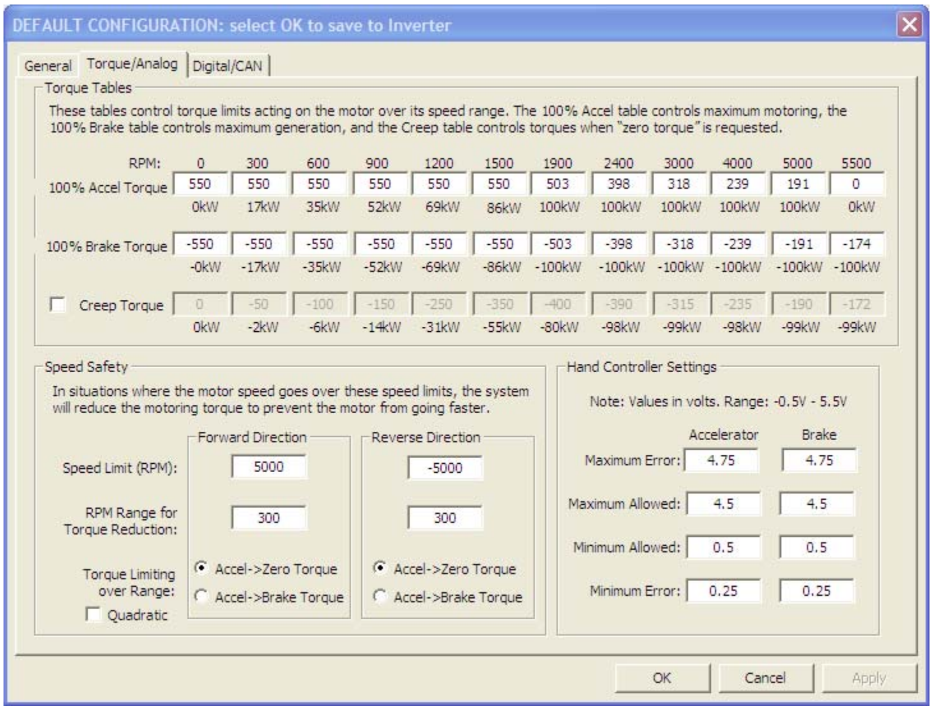


Figure 7.4-2: Analog System Configuration Parameters

The Torque/Analog tab on the System Configuration dialog box, shown in Figure 7.4-2, contains the Torque Tables, the Speed Safety, and the Hand Controller Settings.

The **Torque Tables** control the torque limits acting on the motor over its speed range. The 100% Acceleration Table controls the maximum motoring that the motor can do. The 100% Brake Table controls the maximum generation the motor can do. The Creep Table controls the torques occurring when “zero torque” is requested. Note, that at a given speed, the torque value in the 100% Acceleration Table must be greater than the torque in the Creep Table, and the Creep Table must be greater than the torque in the 100% Brake Table. The Creep Table only acts when the system is in analog control, whereas the Acceleration and Brake Tables act on the system at all times.

WARNING: THE CREEP TABLE IS RESERVED FOR SOME SPECIAL APPLICATIONS, SUCH AS SIMULATING AN AUTOMATIC TRANSMISSION OR COMPRESSION BRAKING OF AN INTERNAL COMBUSTION ENGINE. BY DEFAULT, THE CREEP TABLE HAS BEEN SET TO ZERO ACROSS THE WHOLE SPEED RANGE. <u>PUTTING NON-ZERO VALUES INTO THIS TABLE CAN CAUSE UNEXPECTED MOTOR MOVEMENT.</u> CONTACT UQM TECHNOLOGIES, INC. BEFORE MAKING ANY CHANGE TO IT.

Here are three examples of reasons why the torque tables might be changed:

Limited Torque of a Drive Train Component

In this case the maximum motoring torque must be reduced to prevent premature failure of a limiting drive train component. The overall power is not reduced, only the torque. If the drive train component were limited to 450 N·m, then the 100% Acceleration Table would have its values from zero rpm through 1900 rpm, reduced to 450. All the others would remain the same.

Limited Speed of a Drive Train Component

If a drive train component has a critical speed limit, then the maximum motoring torque can be reduced to 0 before the critical speed. In the system illustrated in Figure 7.4-2, if the drive train component were limited to 2400 rpm, then all values above this speed on the 100% Acceleration Table would be set to 1 N·m.

Reduction of Large Braking Torque Near 0 Speed

A vehicle can stop too abruptly at slow speeds due to a large braking torque desired by the analog braking signal, and the inability of the drive system to actually reach this torque (See the regeneration specification sheet near zero speed). In this case, you can reduce the maximum braking torque, at the slow speeds so the stop is less abrupt. In the system illustrated in Figure 7.4-2, say you wanted to have less braking torque below 900 rpm. You would put –1 at 0 rpm, -50 at 300 rpm, -250 at 600 rpm, and then leave all other values at their default.

Speed Safeties

The Speed Safeties allow you to set a speed limit lower than the maximum specification for operational reasons of your particular application. The speed limit can be set for both the Forward and the Reverse direction. In a situation that the motor speed goes over the speed limit threshold, the system will reduce the motoring torque to prevent the motor from going faster, (refer to section 6.4, “Limit Features.”)

***Speed Limit*:**

The RPM speed is where you want the limit to begin acting. (The torque will begin to be limited at this speed.)

***RPM Range*:**

The limit will be fully acting if the speed were to reach the speed limit plus this RPM range.

***Torque Limiting*:**

The controller will limit the motoring torque over the RPM Range in the way you specify in this selection. If you select Accel→Zero Torque, then at the speed limit the motoring torque will start to be removed and it will be completely removed by the time the speed reaches the top of the RPM Range (speed limit plus range). If you select Accel→Brake Torque, it will remove motoring torque and, if still speeding up, will start applying braking torque. If the speed were to reach the top of the RPM Range (speed limit plus range) then the motor would be at its maximum braking (regeneration) torque.

***Quadratic*:**

By default the "Torque Limiting Over Range" is applied in a linear fashion. By checking this box you cause the limitation to be applied in a quadratic fashion (applied later but faster.)

Hand Control Settings

The Hand Control Settings allow you to control how the analog control signals are interpreted. In Analog Control Mode (torque or speed control), the system is controlled by two analog signals (Accelerator and Brake) through the user interface connector, (refer to section 3.3.) Input voltage between the "minimum error" value and the "minimum allowed" value is considered to be a 0% input. Input voltage between the "maximum allowed" value and the "maximum error" value is considered to be a 100% input.

***Maximum Error*:**

The maximum input voltage that the system considers in-range. Beyond this value the input will be considered invalid and it will be interpreted as 0%.

***Maximum Allowed*:**

The input voltage that the system interprets as full-on (100%.)

***Minimum Allowed*:**

The input voltage that the system interprets as full-off (0%.)

***Minimum Error*:**

The minimum input voltage that the system considers in-range. Below this value the input will be considered invalid and it will be interpreted as 0%.

Setting up the accelerator and brake in this way prevents a single wire failure from causing a dangerous situation. For example, if the ground wire came off the accelerator potentiometer, the voltage would go to 5V. Without the maximum error setting, this would cause the motor to go to 100% torque, which would be very dangerous.

Digital/CANbus Parameters

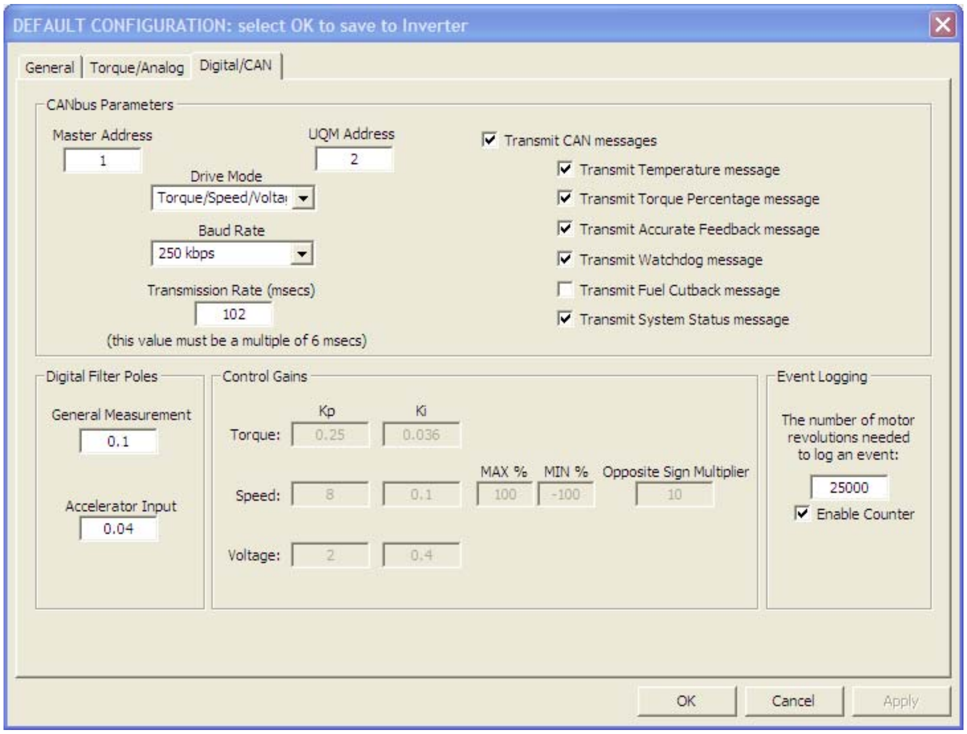


Figure 7.4-3: Digital System Configuration Parameters

The Digital/CAN tab on the System Configuration dialog box, shown in Figure 7.4-3, contains the CANbus Parameters, the Digital Filter Poles, and the Control Gains (which cannot be edited.)

The **CANbus Parameters** configure the CANbus control functionality. (See the CANbus Manual for complete details.)

***Master Address and UQM Address*:**

The CANbus address of the master who will be commanding the UQM motor, and the address that the master expects the UQM controller/inverter to answer to.

***Drive Mode*:**

The UQM motor can be constrained to support only one control mode (torque, speed, and voltage control,) or it can be allowed to do all three.

***Baud Rate and Transmission Rate*:**

The CANbus baud rate and how often the UQM controller/inverter should transmit its messages.

***Transmit CAN Messages*:**

Even when the UQM controller/inverter is not CANbus controlled, it can transmit its information messages when this box is checked. All the boxes below this choice determine which of its CAN messages it will send at the transmission and baud rate specified.

***Digital Filter Poles*:**

These values control the amount of filtering that the inverter will do to its measurements and its analog control signal Accelerator. Decrease these values for more filtering and increase these values for less filtering.

***Event Logging*:**

This value and enable checkbox control the motor revolutions counter. When disabled, no revolution count events will be logged. When enabled, an event will be entered each time the revolution counter counts up to the number in the edit box. See Event Log, Section 7.7, for more information.

7.5 Logging Data

Data Logging is a powerful diagnostic tool that records motor system measurement data to a spreadsheet file in real time, at second, or multiple-second rates. The software can log data at these slow rates indefinitely.

Figure 7.5-1: Front Panel Components of Logging

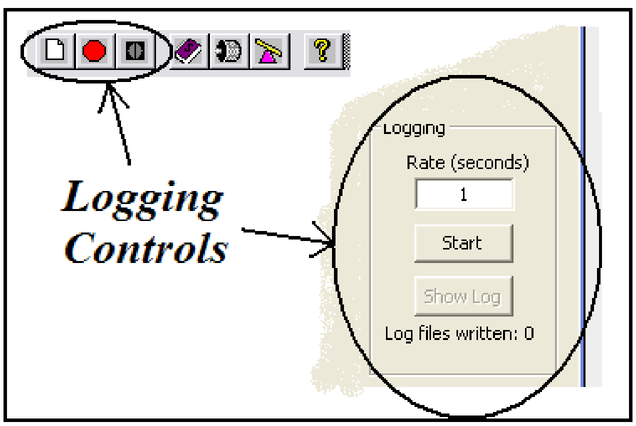


Table 7.5-1: Front Panel Logging Group Components

Label	*Description*
Rate(seconds)	This edit box sets the rate at which you can log data.
Start/Pause/Continue	When this button is labeled Start, it is the equivalent of the menu choice Actions→Start New Log When this button is labeled Pause, a data log file is open and logging. Clicking on it will pause data logging. The file remains open. When this button is labeled Continue, a data log file is open and paused. Clicking on it will cause data logging to continue. This is the equivalent of the menu choice Actions→Toggle Log

Show Log	Starts your spreadsheet program with the last closed data log file. This feature will only work if you have a spreadsheet program that has registered itself for files with the CSV (comma separated variable) file format.

In general, Data Logging stores one snapshot of measurement data every second or at an integer multiple of seconds. The one exception is if you enter a zero in the Rate edit box, then a snapshot of measurement data is stored four times a second (the measurement acquisition rate). There is no other sub-second rate in data logging. If faster data acquisition is needed then you should use the data acquisition feature of the UQM Motor System (see section 7.6).

This data is stored into a spreadsheet file, a snapshot of data measurements forming one row in the spreadsheet. The file format used is the comma separated variable (CSV) format.

NOTE: if using the fastest rate (the zero rate), then large files can be logged. Do not leave the system logging indefinitely. Your spreadsheet will have a row count limitation and you should not log past that value. The number of rows in the log file is shown in the logging group of the front panel while it is logging.

Data logging of measurements can be paused and continued into the same file. It is not possible to reopen a file and continue logging into it if that file has been closed. Selecting an already existing file will overwrite that file with the new data.

The toolbar buttons are described in Table 7.3-3. In addition to these buttons, there is a "Start/Pause/Continue" button and a "Show Log" button located in the Logging Group of the front panel. When the first button is labeled "Start", it acts like the Actions→Start New Log menu choice. Once a data-logging file is opened, this button becomes a toggle button. It is labeled "Pause" while logging is occurring, and "Continue" when logging is paused.

There is no way within the front panel's Logging Group to close a logging file. Either the toolbar or the File Menu must be used to do that. You can use Actions→Stop Log or you can use Actions→Start New Log (starting a new log closes the open log and starts a new one) to close a logging file.
One row of data contains the measurements shown in Table 7.5-2.

Table 7.5-2: Logging and DAQ Measurement Columns

Column Label	*Description*
General	A column containing the motor and inverter names, the firmware's version number/build date, and the file storage date/time.
Index	An incrementing line number starting from zero.
SysErr History	This will display the inverter's System Error History. This is the on-going history of the System Error word. The first line shows the History as the file started. It is then cleared so that all subsequent snapshots will show what has happened since the file was opened.
System Error	The inverter's System Error word in decimal format. See System Error Codes, section 6.6, for further details.
Operating Time(secs)	The inverter's operating time; the number of seconds since the inverter was last powered up, reset, or operated over 95 hours.

Speed(RPM)	The spinning speed of the motor in revolutions per minute. This number is a positive number no matter what direction it is going. The direction is indicated in the Motor Direction column.
Actual Torque(Nm)	The torque in Newton meters, as calculated by the inverter.
Mech Power(W)	The mechanical power in watts, as calculated by the inverter from the actual torque and speed.
Motor Direction	The direction of the motor. A 1 is “Forward” and a –1 is “Reverse”
Stator Temp(ºC)	The measured temperature of the stator of the motor in degrees Celsius.
Rotor Temp(ºC)	The measured temperature of the rotor of the motor in degrees Celsius.
Inverter Temp(ºC)	The measured temperature of the inverter at its cooling block in degrees Celsius.
IGBT Junction Temp(ºC)	The calculated temperature of the IGBT switches’ silicon substrates.
Bus Voltage(V)	The measured bus voltage in volts.
Bus Current(A)	The measured bus current in amperes.
Elec Power(W)	The electrical power in watts as calculated by the inverter from the bus voltage and current.
Leg Current(A)	The measured envelope of the current motor’s phase legs.
Desired Direction	The requested direction of the motor. A 1 is “Forward” and a –1 is “Reverse.”
Desired Torque(Nm)	The requested torque demand in Newton meters.
Desired Speed(RPM)	The requested speed demand in revolutions per minute. If the inverter is not in speed control this number is meaningless.
Desired Voltage(V)	The requested voltage demand in volts. If the inverter is not in voltage control this number is meaningless.
Motoring Limit(%)	If any limits are acting on any motoring torque demand, this will be a value below 100%.
Regen Limit(%)	If any limits are acting on any regeneration torque demand, this will be a value below 100%.
Noisy Positions	The count of noisy position events that have occurred since wake-up.
CAN Comm	A one indicates that CAN communication is active. A zero indicates that it is not.
Enabled	A one is displayed if the inverter in enabled. A zero indicates it is not.
Turbo Mode	A one is displayed if the inverter is in Turbo Mode, a zero if it is not. Turbo Mode is UQM’s proprietary control algorithm that produces outstanding power and efficiency at high speeds.
Torque Control	A one is displayed if the inverter is in torque control, a zero if it is not.
Speed Control	A one is displayed if the inverter is in speed control, a zero if it is not.
Voltage Control	A one is displayed if the inverter is in voltage control, a zero if it is not.
Forced Voltage Control	A one if the inverter has entered forced voltage control (a safety response to dangerous voltage levels), a zero if it is not.

7.6 Data Acquisition

UQM's data acquisition feature is a formidable diagnostic tool for your system design. The UQM Motor System is measuring the torque, voltage, current, and speed of your system. DAQ makes that information available to you with fast and accurately timed sampling rates. DAQ records motor system measurement data at sub-second rates. The data is limited in length, and is recorded into a spreadsheet file after the acquiring event has occurred. Significant time is required to extract the DAQ data from the UQM controller/inverter.

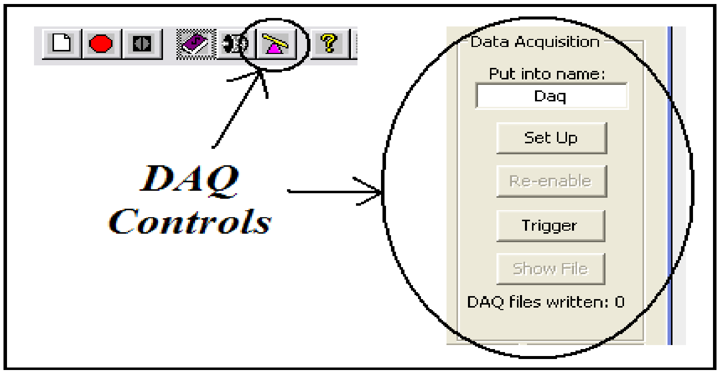


Figure 7.6-1: Front Panel Components of DAQ

Table 7.6-1: Front Panel DAQ Group Components

Label	*Description*
Put into name	This edit box is a short cut to setting the name portion of a DAQ filename. Normally, this name is set in the DAQ Set Up, but when using the manual trigger it is more convenient to be able to change the filename without going into the Set Up dialog box.
Set Up	This button is the equivalent of the menu choice Actions→Change DAQ Settings. It invokes the DAQ Set Up dialog box. This functionality is described in detail later in this section.
Re-enable	After a DAQ trigger, all triggers are disabled. This button quickly re-enables the last set of trigger settings. Alternatively, you can use the DAQ Set Up to re-enable them or change them.
Trigger/Cancel	When this button is labeled "Trigger," it causes an immediate DAQ trigger following the settings already set in DAQ Set Up. While a DAQ file is being uploaded from the controller/inverter into the PC, this button's label changes to "Cancel." Clicking on it causes the upload to be cancelled and the controller/inverter's buffer to be cleared. It also disables all triggers.
Show File	Starts your spreadsheet program with the last uploaded DAQ file. This feature will only work if you have a spreadsheet program that has registered itself for files with the CSV

	(comma separated variable) file format.

As noted, the data buffer length is limited, but DAQ has extensive triggering that allows you to capture the exact data that you need. Table 7.6-2 lists the triggers available.

Table 7.6-2: DAQ Trigger Descriptions

Trigger	*Description*
Absolute value of leg current exceeds specified level	You set an amperage level and the trigger occurs when the composite leg current exceeds that level.
Bus current reaches trigger level	You set an amperage level and the trigger occurs when the bus current passes through that level from either direction.
Bus voltage reaches trigger level	You set a voltage level and the trigger occurs when the bus voltage passes through that level from either direction.
CANbus changes the control mode	A trigger occurs when the controller/inverter's control mode (torque, speed, voltage control) changes through the CANbus.
Cruise control is enabled	A trigger occurs if the controller/inverter is in speed control.
Direction (actual) changes	A trigger occurs when the motor's direction changes from forward to reverse, or reverse to forward.
Direction (desired) changes	A trigger occurs when the demanded direction changes from forward to reverse, or reverse to forward
Electrical Power reaches trigger level	You set a wattage level and the trigger occurs when the electrical power passes through that level from either direction.
Fault Arm transitions from 0 to 1	Fault arm occurs when enough bus voltage is present to allow the controller/inverter to actively pursue control, resulting in a trigger.
Forced voltage control occurs	A trigger occurs when the controller/inverter is in forced voltage control, which is a safety mode entered only when bus voltage reaches a dangerous level.
Inverter fault occurs	A trigger occurs when any inverter module faults. Over current and over temperature problems can cause these modules to fault when they are switching power. A drop in the 15V supplying the modules will also trigger an inverter fault. It is also possible for a false trigger to occur when the bus voltage drops below the necessary level for inverter module operation. This trigger is a default trigger.
Motoring is limited below trigger level percentage	A percentage level is set, and the trigger occurs when the limit acting on the motoring torque is below that level.
Over voltage	A trigger occurs when the bus voltage is over the maximum battery voltage.
Position signal is bad	A trigger occurs when the position signal is judged bad.
Position signals are noisy	A trigger occurs when electrical noise is detected on the position sensor signals.
Regen is limited below trigger	A percentage level is set, and the trigger occurs when the

level percentage	limit acting on the regeneration torque is below that level.
Speed reaches trigger level	An signed RPM level is set, and the trigger occurs when the motor speed passes through that level from above or below. Remember that if spinning in reverse then this value must be signed to cause a trigger.
Torque (actual) reaches trigger level	A Newton meter level is set, and the trigger occurs when the calculated torque passes through that level from either direction.
Torque (desired) reaches trigger level	A Newton meter level is set and the trigger occurs when the demanded torque passes through that level from either direction.
Turbo Mode exits	A trigger occurs when Turbo Mode exits. Turbo Mode is UQM's proprietary control algorithm that produces outstanding power and efficiency at high speeds.
Turbo Mode occurs	A trigger occurs when the motor enters Turbo Mode. Turbo Mode is UQM's proprietary control algorithm that produces outstanding power and efficiency at high speeds.

In addition to these triggering capabilities, DAQ allows you to specify the percentage of the data that will be recorded on either side of the trigger event, from 10→90% through 90→10%. There are also seven different sampling rates, from 80 microseconds to six milliseconds, allowing for a wide range of time windows. The measurements recorded are identical to Data Logging; see Table 6.4-2 for a list of the measurements recorded into the CSV file.

Since the software monitors DAQ triggers and automatically uploads the DAQ event capture buffer on trigger completion, the CSV file is automatically generated. You can specify the directory it is placed in, and you can specify a name that will be included in the filename. By default the name is "InverterFault" because this is the default trigger source. For example, a couple of Inverter Fault triggered DAQ files, occurring in a row on January 2, 2007, would be named:

```
20070102_InverterFault00.csv
20070102_InverterFault01.csv
```

DAQ Set Up

It is important to configure DAQ before using it. The configuration parameters of trigger events, fill line, sampling speed, file directory, and 'name to be included' in filename must all be set. The DAQ Set Up dialog box provides this functionality. Figure 7.6-2 shows this dialog box.

Figure 7.6-2: DAQ Set Up

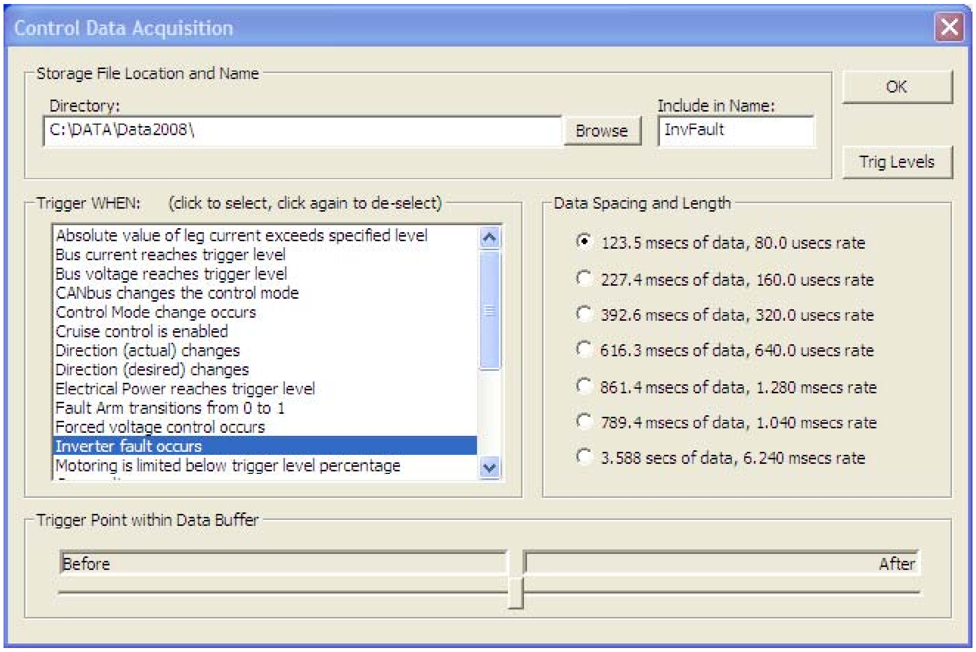


Table 7.6-3: DAQ Set Up Components

Label	*Description*
Directory: Browse button	Enter the directory where DAQ files should be written. Browse brings up a File Open dialog box. Use it to point to the directory you want to use.
Include in Name	Text that you want included into the DAQ filename. It will include the date, this text, and an incrementing number.
Trigger WHEN:	Select the triggers desired. If you select a trigger that depends on a trigger level then click on the Trigger Level button to set the value for that trigger.
Trig Levels button	Button brings up the DAQ Trigger Level dialog box. It is also possible to reach the Trigger Level dialog box directly from the front panel through Action→Change Trigger Levels. Figure 7.6-3 shows this dialog box.
Data Spacing and Length	Select the sampling rate from 80 microseconds, to 6 milliseconds.
Trigger Point within Data Buffer	Move the slide bar to indicate how much of the data you want before the trigger event and how much after it.

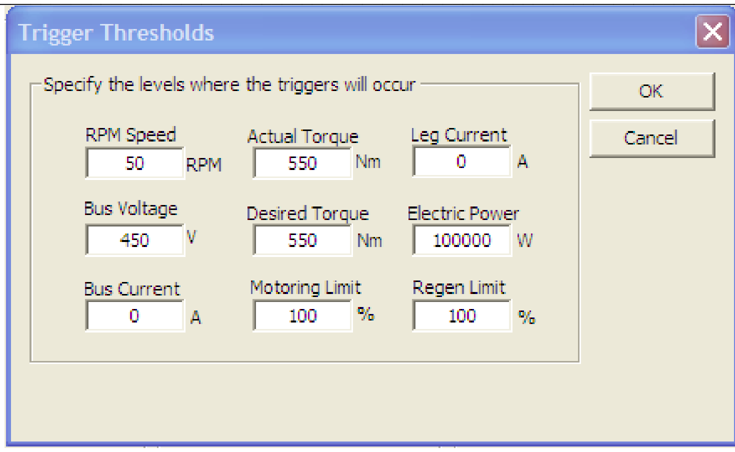


Figure 7.6-3: DAQ Trigger Levels

DAQ Set Up Example

The DAQ feature of the UqmMotor Diagnostic Software is very useful when you need to diagnose a dynamic problem in your system. Because the UQM motor is connected to most of your system's components, its measurements can help you find problems. For example, say your soft-start functionality is connecting and then disconnecting a short time later. UqmMotor's DAQ can be used to trigger and collect fast data around this event so that you can see what your high voltage bus is doing during this time. In this example you will trigger on the event of the voltage bus value passing through 250V. You want several seconds of data taken, and most of the data you want taken after the triggering event occurs. To use the DAQ system to capture this event, you would:

1. Select the "Set up" on the front panel to bring up the DAQ Set Up dialog box.
2. Using the browse button, select a directory where DAQ files should be placed.
3. Enter "softStart" in the "Include in Name" box.
4. Click on the trigger WHEN: "Bus voltage reaches trigger level."
5. Click the "Trig Levels" button to enter the Trigger Thresholds dialog box, enter 250 in the Bus Voltage box, and select OK to close the Trigger Thresholds dialog box.
6. Select the last radio button in the "Data Spacing and Length" area that is labeled "4.168 secs of data, 6 secs apart."
7. Drag the "Trigger Point within Data Buffer" slider bar to the left until it is close to the left side (it cannot get closer than 10% of the buffer).
8. Select "OK" on the DAQ Set Up dialog box.

You are now ready to begin the soft-start procedure. Once the bus voltage goes through 250V, UQM's DAQ system will trigger and capture the event. The data will then be extracted automatically by the UQM Motor Diagnostic Software and written to a file placed in the directory you selected. During the extraction the status message area, found at the bottom of the front panel, will show the progress. Once the file is finished, the "Show File" will be available. Clicking on it will start your spreadsheet program, using the file last written by DAQ.

If the data points are too far apart when you look at the data, re-open the DAQ Set Up dialog box and change the "Data Spacing and Length" selection to a faster rate. (It will, of course, record over less time.) Select "OK" to close the dialog box and re-initiate the event in your system. Again, when the voltage passes through 250V, data will be captured and a new file will be written in the same directory with the same name, except for an incrementing number. It will NOT write over old data.

7.7 Event Log

Another strong diagnostic tool in UQM Motor Systems is the Motor Event Log. The UQM controller/inverter tracks and stores, in persistent memory, all the system error events and when they occurred. The diagnostic software provides access to this information through the Event Log dialog box, which is available through the menu choice Actions→Show Event Log or its toolbar button.

The Event Log shows when error events occurred during operating time. It also logs the wake up condition of the controller/inverter. Table 7.7-1 lists the possible logging entries.

Version 4.03 has a new feature: a revolution counter event. This feature logs an event into the Event Log representing that a customer-settable number of motor revolutions have occurred. This can be thought of as a "mileage counter" when the number of revolutions equates to a distance.

Table 7.7-1: Possible Entries in Event Log

Entries	*Description*
*** Start of data ***	This marks the beginning of the oldest data
****XX blank events****	Means that the Event Log is not yet full. Once it is full then the oldest event is written over by the newest event and there are no more blanks.
Processor start up	This marks that the controller/inverter went through a power up or a reset. The operating time is zero at this point.
NEW FIRMWARE DOWNLOADED	This marks the point when the controller/inverter has just received new code. When new firmware is downloaded, older events may not be interpreted correctly in this listing. Always save the Event Log to a text file before downloading new firmware.
Diagnostic software marker of	This marks the point when the diagnostic software inserted a date marker. It will show the date in year/month/day format.
Inverter Fault ON Inverter Fault OFF	These events mark when an inverter fault occurred.
Bad driver occurred	Similar to inverter fault, but indicating the driver circuitry.
Forced open loop ON Forced open loop OFF	These events mark when the controller has had to go into forced open loop because of measurement problems.
Over mechanical danger speed Under mechanical danger speed Over speed occurred Over speed problem OFF	These events mark when speed problems have occurred.

Over Inverter Voltage ON Over Inverter Voltage OFF Over battery voltage ONCE Under battery voltage ONCE	These events mark when bus voltage problems occurred. ONCE means that as soon as it has been logged, further such events will not be logged until the controller is reset. Inverter voltage
Sensor voltage good Sensor voltage invalid	These events mark when the voltage, that powers the controller's sensors, is not at an acceptable level.
Leg sums not zero Over Leg Current	These events mark errors on the motor's phase legs.
Over Inverter Temperature ON Over Inverter Temperature OFF Over Stator Temperature ON Over Stator Temperature OFF Over Rotor Temperature ON Over Rotor Temperature OFF	These events mark when the temperatures reached unacceptable levels, and when they subsequently reached an acceptable level.
Over Positive Phase Advance Under Negative Phase Advance	These events mark when the controller has encountered the phase limits of the motor.
Position signal is bad Apparent rotor movement occurred	These events mark a problem with the position sensor signals. Either a cable was removed or the position offset is suspect.
Position signals are noisy	This event marks a rapid series of noise errors detected on the positions signals.
CANbus watchdog occurred	CANbus commands ceased.
Mechanical revolution count occurred	The customer-settable number of motor revolutions has occurred. This entry will be made each time that counter counts this number of revolutions.
Position signals are noisy	Electrical noise occurred on the position signals at a frequency greater than a 170 Hz rate. This is a potentially dangerous condition because it could cause motor mis-commutation.

The Event Log dialog box has a "Save to File" button that allows you to save a listing of the events to a text file. It is a good idea to do this from time to time. It will be saved automatically if a firmware download is initiated. The button brings up a "File Save" dialog box. Select the directory and file name where the text file can be saved, then select "OK." The file will be created and saved in the desired location. It will have a ".txt" extension.

7.8 Firmware Downloading

The UQM Motor Diagnostic Software has automatic firmware download capabilities. In general you will never encounter the download functionality unless you receive a new firmware version from UQM Technologies. A new firmware version would arrive as a new installation disk for the UQM Motor Diagnostic Software. Upon receipt you would install and run this new version.

NOTE: This version of the Diagnostic Software will store a file containing the Event Log before doing a download. This file will be located with the UqmMotor executable. Event Log information logged before a firmware download may be interpreted incorrectly by the new firmware once it is downloaded. UQM Technologies recommends marking the date after a download. See section 7.3 under the Action menu.

The UQM Motor Diagnostic Software always checks the motor controller/inverter as it connects to see if the inverter's firmware is the correct version for the software. If it finds that the inverter firmware is older than its version, it will ask if a download is desired. The dialog box shown in Figure 7.7.1 will appear.

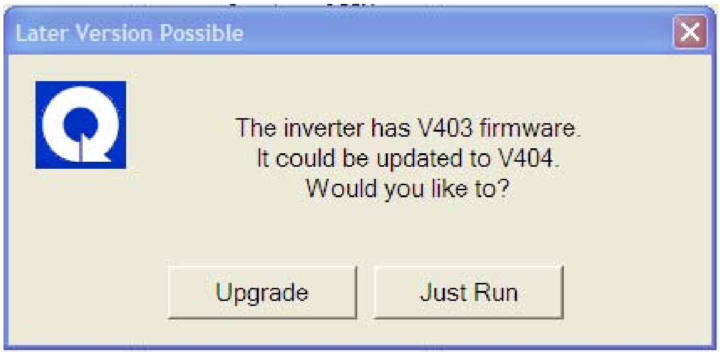


Figure 7.8-1: Download Firmware Dialog Box

> **WARNING**: You must make certain that the motor is NOT in use (i.e., not spinning or in any way likely to spin) during this procedure. DO NOT click on the Upgrade button unless it is safe to do so.

Once you know it is safe to download the new firmware into your UQM motor controller/inverter, select the "Upgrade" button. The download will take several minutes, but it will finish automatically. If you do not want to change the firmware in your controller/inverter then select "Just Run" and the UQM Motor Diagnostic Software will move into normal operation. The diagnostic software will ask you this question every time it starts and every time the controller/inverter resets or renews communication after a disconnect if the firmware is older.

Note that the "Just Run" choice is only available to controller/inverters running V4.03 or V4.02 versions. V4.00 and V4.01 are not supported and must be upgraded to use the UQM Diagnostic Software. If you would prefer to stay with the old firmware then you must close this version of the diagnostic software and use the older version that shipped with your controller.

8 Troubleshooting

Note: When troubleshooting the system, always connect the serial port to Terminal so you will get system status information (see section 6.1.)

8.1 Installation

1. All connections are completed, and the motor does not spin smoothly or does not run at all.

If the motor does not run at all, first check all power supplies (both the high voltage traction drive and low voltage auxiliary power). If all power supplies comply with system requirement, check the motor lead and Rotor Position cable connections on the inverter. The motor will fail to spin smoothly or not spin at all if the motor leads are not connected as labeled.

2. The motor spins in the opposite direction as indicated on the user interface control pad.

Check the motor lead connections on the inverter. DO NOT ATTEMPT TO SWAP MOTOR LEADS TO REVERSE MOTOR DIRECTION FOR NORMAL OPERATION. IT MIGHT RESULT IN SEVERE SYSTEM DAMAGE.

Contact UQM Technologies Inc. at (303) 278-2002 or sales@uqm.com.

3. Motor has intermittent or jerky operation.

Connect the motor case to the inverter case. This will require removing the black anodizing (if applicable) from a portion of both cases, and connecting a 6AWG wire directly from one to the other (see Section 3.6.)

8.2 System Operation

Listed below are some of the problems you may encounter when operating your drive system, and the possible cause. To troubleshoot the system, first connect the serial port to your computer, and apply either low or high voltage. Open the UQM Motor Diagnostic Software program and check for red or yellow status messages. NOTE: Some red and yellow Status messages will occur if only low voltage is connected. See section 7 for a description of different status messages. If you cannot solve the problem, collect data logging and/or data acquisition data and contact the Applications Department at UQM Technologies. (Refer to sections 7.5 and 7.6 for details on how to collect data.)

Tel: (303) 278-2002
Email: sales@uqm.com.

Drive_Ready LED Does Not Come on

- External User_xxV not connected. (See section 5.1.)

- Bus voltage may be less than the minimum bus voltage. (Yellow status message: under voltage).
- Enable switch is in the disable position. (Yellow status message: disabled). Move enable switch to the enable position.

Drive_Ready LED is on but the Motor Does Not Spin

- No accelerator command. (Accel=0 even though knob or potentiometer is turned on.) Check user interface cable connection.
- System is in CAN control.
- System is in Speed control when it needs a speed command and a non-zero torque limit to spin.
- The brake potentiometer is turned fully clockwise, instead of fully counter clockwise. (Brake =100.)
- Motor output shaft is locked. (Yellow status message: stall conditions).
- Check desired torque value. (Control messages on main menu). Make sure desired torque is greater than 0. If desired torque is 0, check Accel and Brake potentiometers. Accel must be greater than Brake, for motor rotation.
- Check system limits (yellow status message: motoring/regen limited to x%). An error is limiting motoring regen torque. See section 6.4 and Table 7.3-2 for more information.

Motor Spins Very Erratically

- The case of the motor is not connected to the case of the inverter. (See Section 3.6.)
- The shield of the Rotor Position cable is connected to the motor case. The shield of the Rotor Position cable should only be connected to a ground pin in the connector on the controller side and should be open on the motor side.
- The voltage ripple on the bus power supply is excessive. Check the bus current signal value under the "electrical" section of the main menu. If the motor is not spinning, then this signal should be greater than -2A, less than 2A, and should be constant.

Inverter Fault, System Fault Pin

- During operation this pin indicates a serious fault with an IGBT module. Either something is not connected correctly, or the module has failed. Check for shorted motor leads, no cooling, or over voltage. Contact the Application Department at UQM Technologies, Inc., noting the conditions when the problem occurred (i.e., Ambient temperature, acceleration/deceleration, uphill/downhill, etc.) The only way to clear this fault is to power down the inverter, then power it up again; see Inverter Faulted in Table 7.3-2.

Formatted: Bullets and Numbering

Erratic Behavior during Regeneration

- Power source is not accepting the regenerated current, causing the bus voltage to quickly increase. The software must take drastic measures to prevent an over voltage. Check the main panel of the UQM Motor Diagnostic Software to note the bus voltage, bus current, and the status messages. An over inverter voltage error implies that the voltage is getting dangerously high. (See Table 6.1-5). Switch to a power source that can accept regeneration power.

Intermittent Operation on a Hill or during a Locked Rotor Condition

- The software is detecting a locked rotor condition (stall) and is protecting the power IGBT devices from overheating. See Section 7.3 on limitations for a further explanation.

EEROM Failed status message on UQM Motor Diagnostic Software

- Serial EEPROM was erased. Call UQM Technologies, Inc. for assistance.

  Tel: 303-278-2002
  Email: sales@uqm.com

Appendix A: PowerPhase® 150 System Specifications

HPM150 Motor			
Dimensions			
	Length (w/o shaft & termination housing)	9.49 in	240.9 mm
	Diameter	15.94 in	405 mm
	Weight	200 lb	86 kg
Performance			
	Motoring power (peak)	200 hp	150 kW
	Motoring torque (peak)	479 lbft	650 Nm
	Regeneration torque (peak)	442 lbft	600 Nm
	Max. speed	5000 rpm	

DD45-500LWB Inverter/Controller			
Dimensions			
	Length	14.96 in	380 mm
	Width	14.37 in	365 mm
	Height	4.69 in	119 mm
	Weight	35.0 lb	15.9 kg
Operating Voltage			
	Nominal input range	300 to 425 V dc	
	Full performance voltage input range	300 to 425 V dc	
	Minimum voltage limit	200 V (With degraded performance)	
	Input current limitation	550 A	
Inverter Type			
	Control type	PWM and FWC, FOC, 3-phase brushless dc	
	Applicable max current	600 A peak	
	Power device	IGBT module half bridge x 3	
	Switching frequency	12.5 kHz	
	Standby power consumption (inverter and microprocessor)	17 W	
Liquid Cooling System			
	Minimum inlet coolant flow (Glycol or equivalent)		7.5 l/min (2 gpm)
	Max inlet temp of controller	131 ^{o}F	55 ^{o}C
	Inner diameter of hose	5/8 in	16 mm
	Max inlet pressure	10 psi	
TMS2812 Microprocessor (Internally Packaged)			
	Nominal input voltage (User_xxVDC)	12 Vdc	
	Input supply voltage range	8 to 16 Vdc	
	Input supply current range	0.2 to 0.5 Adc	

Appendix B: PowerPhase®100 System Specifications

SR286 Motor			
Dimensions			
	Length (w/o shaft & termination housing)	9.49 in	240.9 mm
	Diameter	15.94 in	405 mm
	Weight	190 lb	86 kg
Performance			
	Motoring power (peak)	134 hp	100 kW
	Motoring torque (peak)	405 lbft	550 Nm
	Regeneration torque (peak)	368 lbft	500 Nm
	Max. speed	5000 rpm	

DD40-400LWB Inverter/Controller			
Dimensions			
	Length	14.96 in	380 mm
	Width	14.37 in	365 mm
	Height	4.69 in	119 mm
	Weight	35.0 lb	15.9 kg
Operating Voltage			
	Nominal input range	250 to 425 V dc	
	Full performance voltage input range	250 to 425 V dc	
	Minimum voltage limit	200 V (With degraded performance)	
	Input current limitation	450 A	
Inverter Type			
	Control type	PWM and FWC, FOC, 3-phase brushless dc	
	Applicable max current	600 A peak	
	Power device	IGBT module half bridge x 3	
	Switching frequency	12.5 kHz	
	Standby power consumption (inverter and microprocessor)	17 W	
Liquid Cooling System			
	Minimum inlet coolant flow (Glycol or equivalent)		7.5 l/min
	Max inlet temp of controller	160 ^{o}F	71 ^{o}C
	Inner diameter of hose	5/8 in	16 mm
	Max inlet pressure	10 psi	
TMS2812 Microprocessor (Internally Packaged)			
	Nominal input voltage (User_xxVDC)	12 Vdc	
	Input supply voltage range	8 to 16 Vdc	
	Input supply current range	0.2 to 0.5 Adc	

Appendix C: PowerPhase®75 System Specifications

SR218 Motor			
Dimensions			
	Length	8.91 in	226 mm
	Diameter	11.00 in	280 mm
	Weight (w/o cables)	89 lb	40 kg
Performance			
	Motoring power (peak)	100 hp	75 kW
	Motoring torque (peak)	176 lb·ft	240 N·m
	Regeneration power (peak)	100 hp	75 kW
	Max. speed	8000 rpm	

DD40-400LWB Inverter/Controller			
Dimensions			
	Length	14.96 in	380 mm
	Width	14.37 in	365 mm
	Height	4.69 in	119 mm
	Weight	35.0 lb	15.9 kg
Operating Voltage			
	Nominal input range	250 to 425 V dc	
	Full performance voltage input range	250 to 425 V dc	
	Minimum voltage limit	180 V (with derated power output)	
	Input current limitation	450 A	
Inverter Type			
	Control type	3-phase brushless dc	
	Applicable max current	600 A peak	
	Power device	IGBT module half bridge x 3	
	Switching frequency	20 kHz	
	Standby power consumption (inverter and microprocessor)	17 W	
Liquid Cooling System			
	Minimum inlet coolant flow (Glycol or equivalent)		7.5 l/min
	Max inlet temp of controller	160 ^{o}F	71 ^{o}C
	Inner diameter of hose	5/8 in	16 mm
	Max inlet pressure	13 psi	
TMS2812 Microprocessor (Internally Packaged)			
	Nominal input voltage (User_xxVDC)	12 Vdc	
	Input supply voltage range	8 to 15 Vdc	
	Input supply current range	0.3 to 0.5 Adc	

Appendix D: PowerPhase®125 System Specifications

SR218 Motor			
Dimensions			
	Length	8.91 in	226 mm
	Diameter	11.00 in	280 mm
	Weight (w/o cables)	89 lb	40 kg
Performance			
	Motoring power (peak)	100 hp	75 kW
	Motoring torque (peak)	176 lb·ft	240 N·m
	Regeneration power (peak)	100 hp	75 kW
	Max. speed	8000 rpm	

DD45-500LWB Inverter/Controller			
Dimensions			
	Length	14.96 in	380 mm
	Width	14.37 in	365 mm
	Height	4.69 in	119 mm
	Weight	35.0 lb	15.9 kg
Operating Voltage			
	Nominal input range	300 to 425 V dc	
	Full performance voltage input range	300 to 425 V dc	
	Minimum voltage limit	200 V (With degraded performance)	
	Input current limitation	550 A	
Inverter Type			
	Control type	PWM and FWC, FOC, 3-phase brushless dc	
	Applicable max current	600 A peak	
	Power device	IGBT module half bridge x 3	
	Switching frequency	12.5 kHz	
	Standby power consumption (inverter and microprocessor)	17 W	
Liquid Cooling System			
	Minimum inlet coolant flow (Glycol or equivalent)		7.5 l/min (2 gpm)
	Max inlet temp of controller	131 ^{o}F	55 ^{o}C
	Inner diameter of hose	5/8 in	16 mm
	Max inlet pressure	10 psi	
TMS2812 Microprocessor (Internally Packaged)			
	Nominal input voltage (User_xxVDC)	12 Vdc	
	Input supply voltage range	8 to 16 Vdc	
	Input supply current range	0.2 to 0.5 Adc	

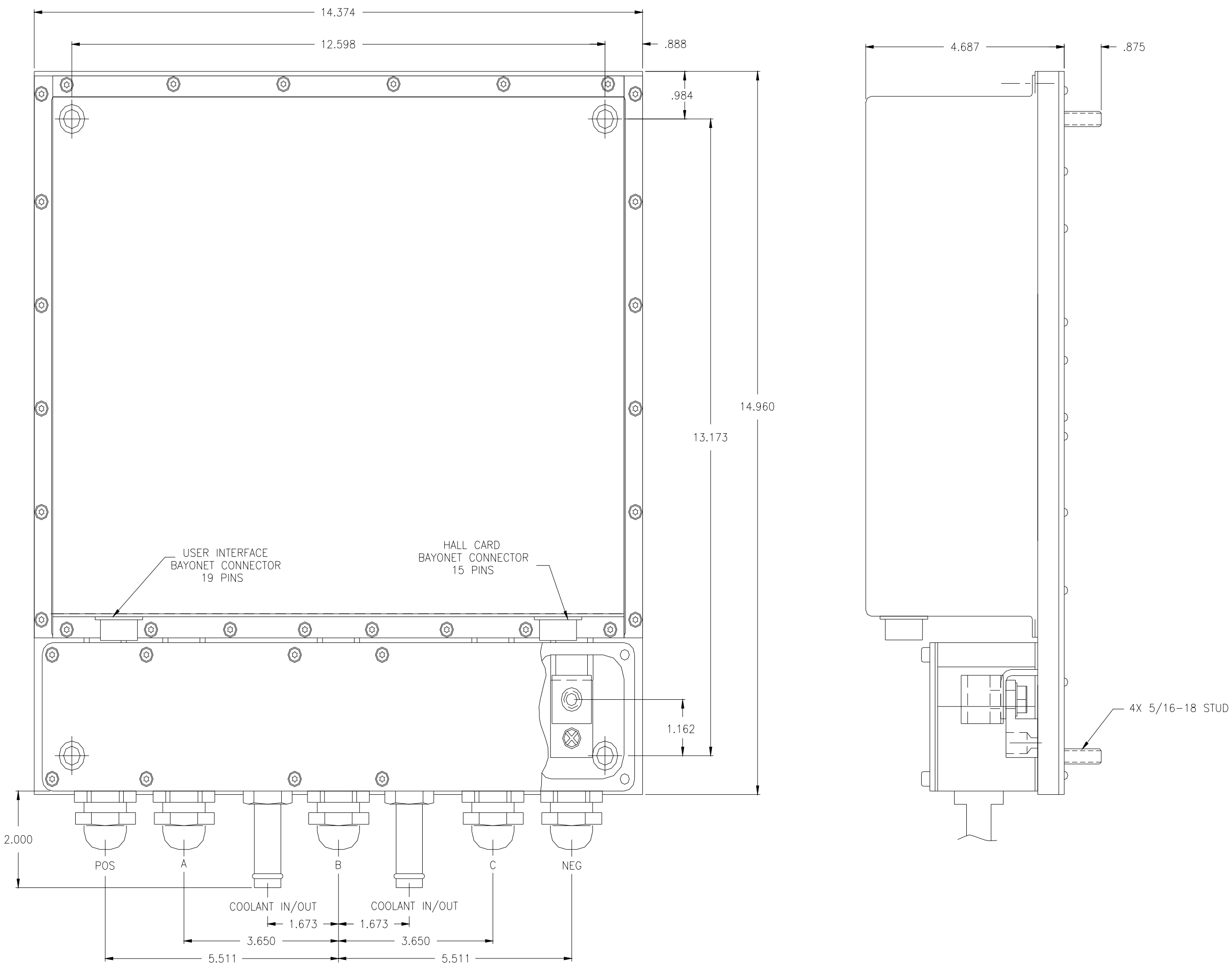
Appendix E: HiTor System Specifications

SR218 Motor			
Dimensions			
	Length	8.91 in	226 mm
	Diameter	11.00 in	280 mm
	Weight (w/o cables)	89 lb	40 kg
Performance			
	Motoring power (peak)	67 hp	50 kW
	Motoring torque (peak)	308 lb·ft	440 N·m
	Regeneration power (peak)	67 hp	50 kW
	Max. speed	4800 rpm	

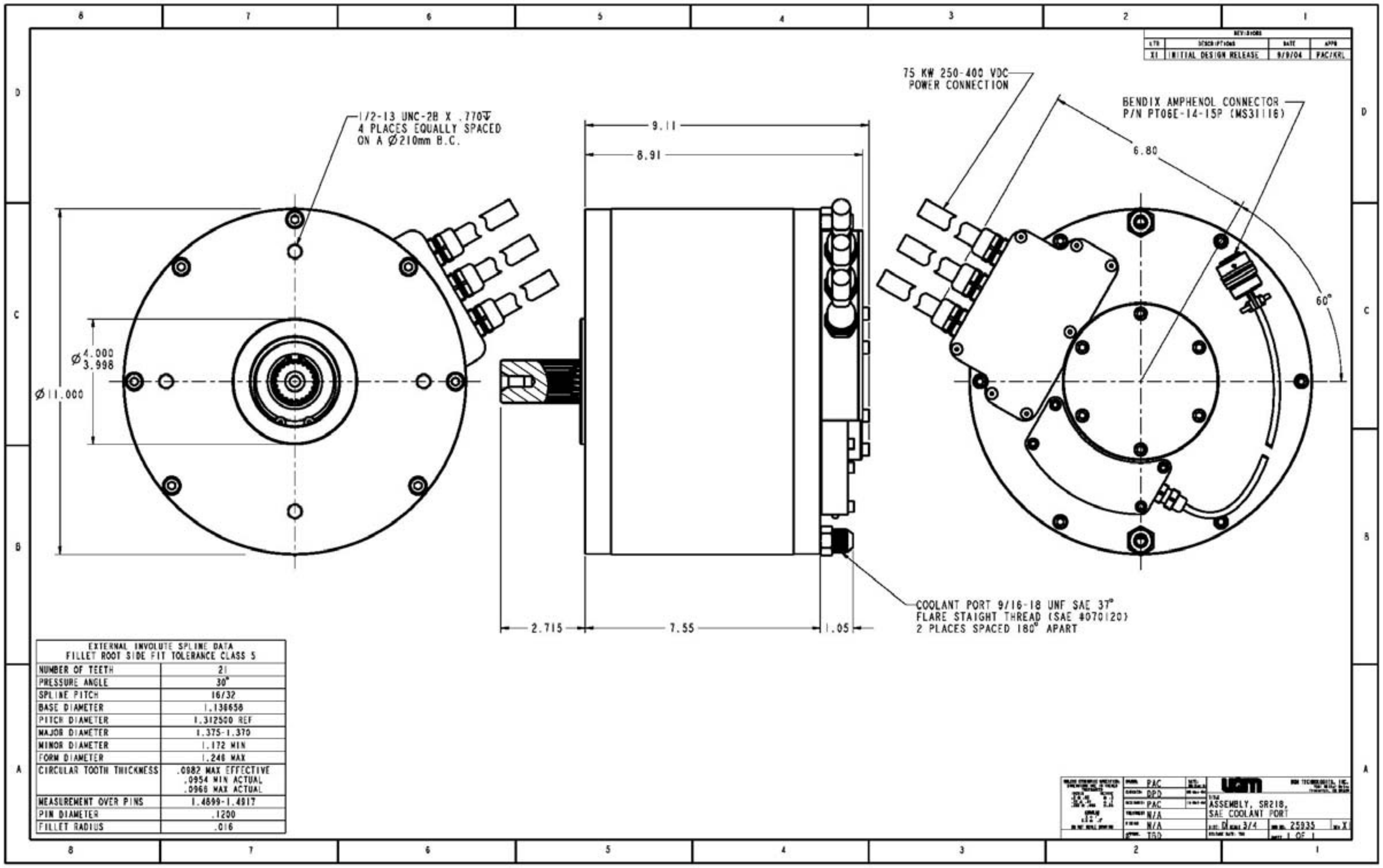
DD40-400LWB Inverter/Controller			
Dimensions			
	Length	14.96 in	380 mm
	Width	14.37 in	365 mm
	Height	4.69 in	119 mm
	Weight	35.0 lb	15.9 kg
Operating Voltage			
	Nominal input range	250 to 425 V dc	
	Full performance voltage input range	250 to 425 V dc	
	Minimum voltage limit	180 V (with derated power output)	
	Input current limitation	450 A	
Inverter Type			
	Control type	3-phase brushless dc	
	Applicable max current	600 A peak	
	Power device	IGBT module half bridge x 3	
	Switching frequency	20 kHz	
	Standby power consumption (inverter and microprocessor)	17 W	
Liquid Cooling System			
	Minimum inlet coolant flow (Glycol or equivalent)		7.5 l/min
	Max inlet temp of controller	160 ^{o}F	71 ^{o}C
	Inner diameter of hose	5/8 in	16 mm
	Max inlet pressure	13 psi	
TMS2812 Microprocessor (Internally Packaged)			
	Nominal input voltage (User_xxVDC)	12 Vdc	
	Input supply voltage range	8 to 15 Vdc	
	Input supply current range	0.3 to 0.5 Adc	

Specifications subject to change without notice.

Appendix F: Inverter Dimensions

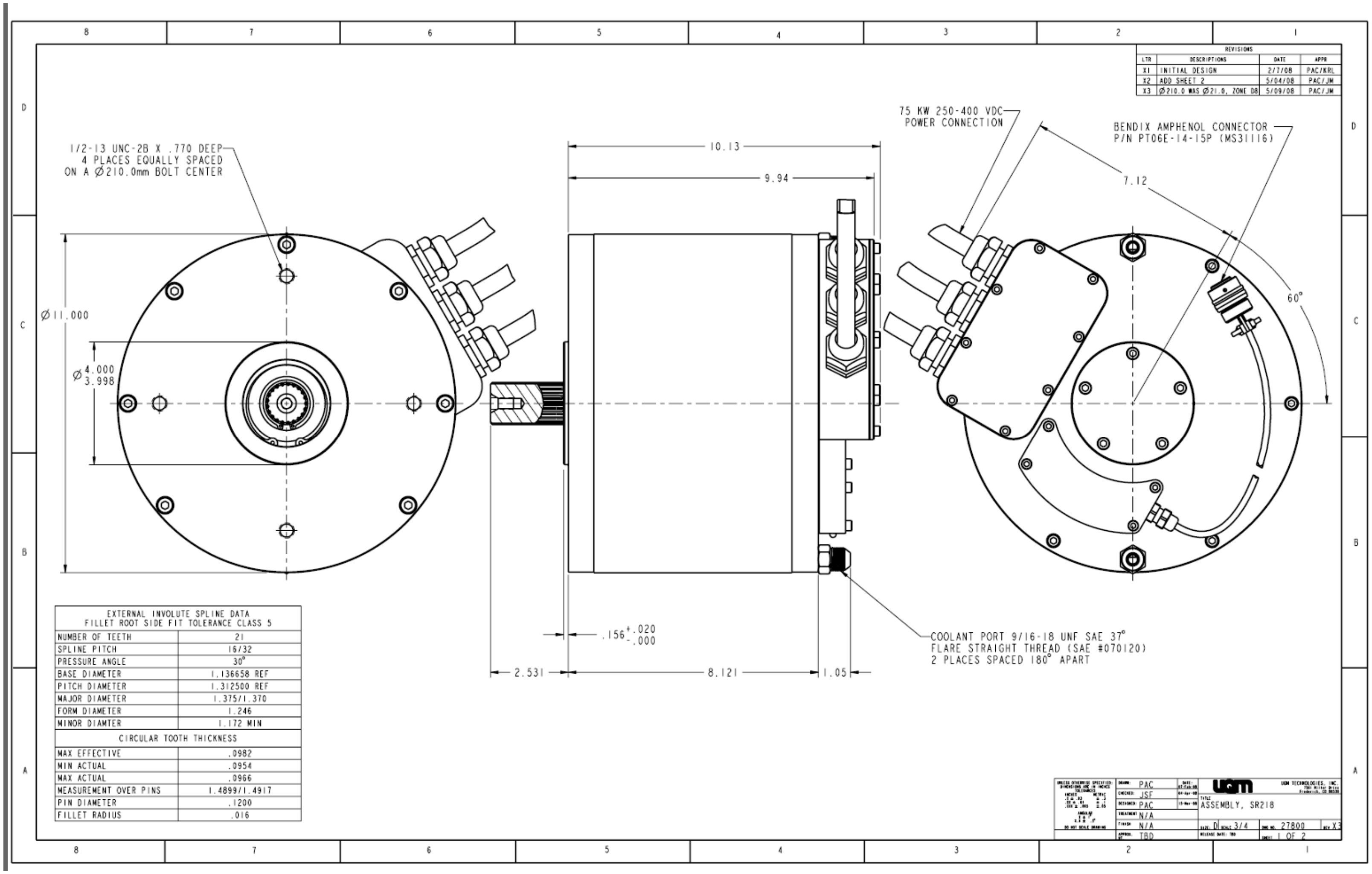


Appendix G: PowerPhase®75 and Hi-Tor Motor Dimensions

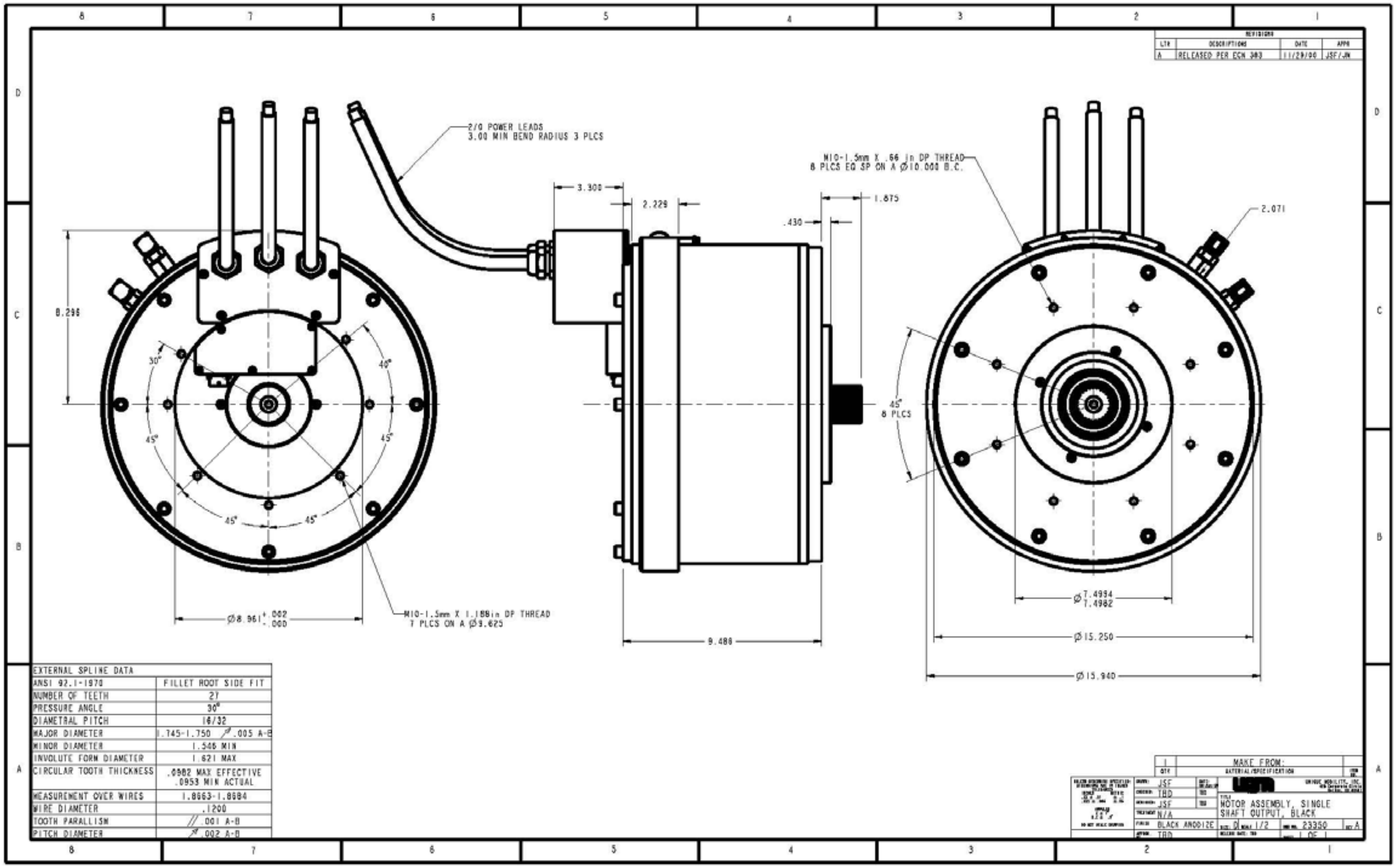


EXTERNAL INVOLUTE SPLINE DATA FILLET ROOT SIDE FIT TOLERANCE CLASS 5	
NUMBER OF TEETH	21
PRESSURE ANGLE	30°
SPLINE PITCH	16/32
BASE DIAMETER	1.136658
PITCH DIAMETER	1.312500 REF
MAJOR DIAMETER	1.375-1.370
MINOR DIAMETER	1.172 MIN
FORM DIAMETER	1.248 MAX
CIRCULAR TOOTH THICKNESS	.0982 MAX EFFECTIVE .0954 MIN ACTUAL .0966 MAX ACTUAL
MEASUREMENT OVER PINS	1.4899-1.4917
PIN DIAMETER	.1200
FILLET RADIUS	.016

Appendix H: PowerPhase®125 Motor Dimensions



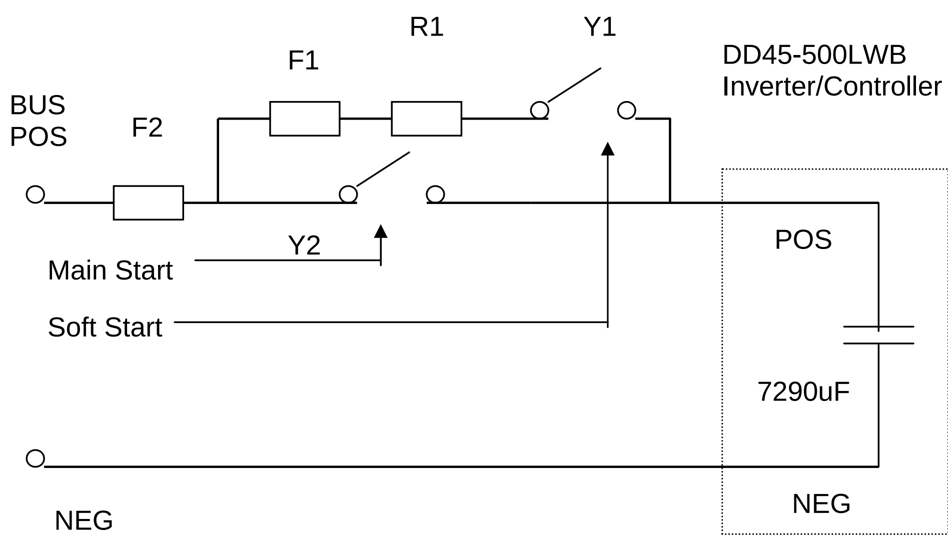
Appendix I: PowerPhase®150 and PowerPhase®100 Motor Dimensions



Appendix J: Soft Start Guidelines

A soft start circuit (NOT INCLUDED) must be used to avoid high inrush currents to the inverters. Charging the internal capacitance will cause this. This high current would decrease the life of the Y2 contactor and the internal inverter capacitors.

A resistor (R1) and a small contactor (Y1) are used to charge the internal inverter capacitors before the main contactor (Y2) is closed, to avoid high inrush currents. The R1 resistor should be selected to charge the capacitors in 100 to 750 milliseconds. When selecting the charge resistor size the standby current of the inverter must be considered. The typical standby power is approximately 10 watts. We must also be concerned with the final value of voltage that is reached with the standby power drain of the inverter. If the resistor is too high of a value, the voltage drop across the resistor will be too large, and the desired charge voltage will not be reached. The R1 resistor and Y1 contactor must also be sized to handle a full load inverter short (worst case) until the F1 fuse opens. The F1 fuse size should be selected to open if more than 1 second of time is required to charge the internal inverter capacitors. Fuse F2 and contactor Y2 must be sized to handle the voltage and current of the inverter.

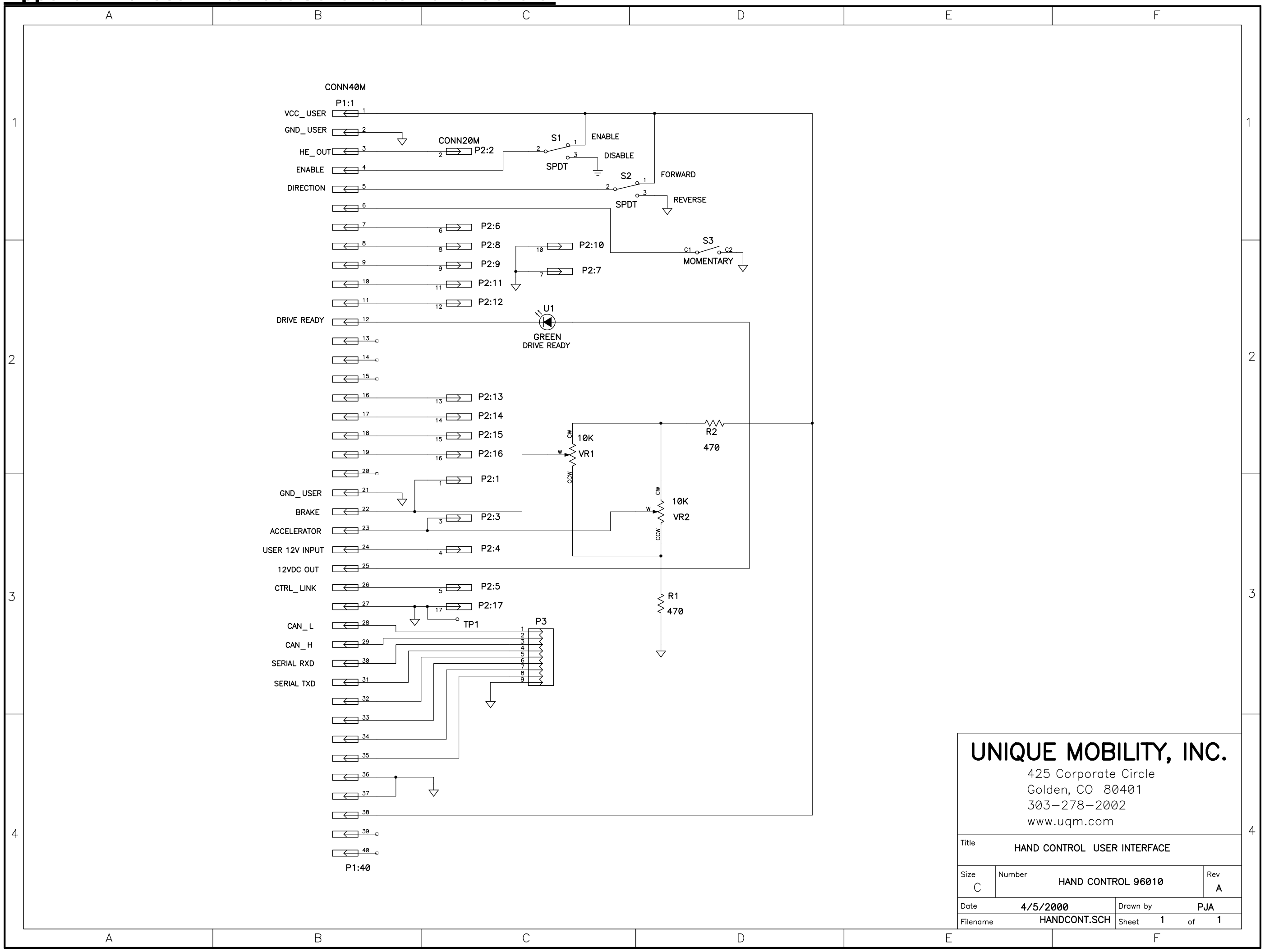


Closing contactor Y1, when the vehicle key is turned on operates the soft start circuit. A voltage sense circuit, external to the controller (not shown,) should be used to measure the rate of change of the voltage on the inverter capacitors. When the voltage on the inverter is determined to be within 10% of the voltage of the DC power, then contactor Y2 should close and the system is ready to operate.

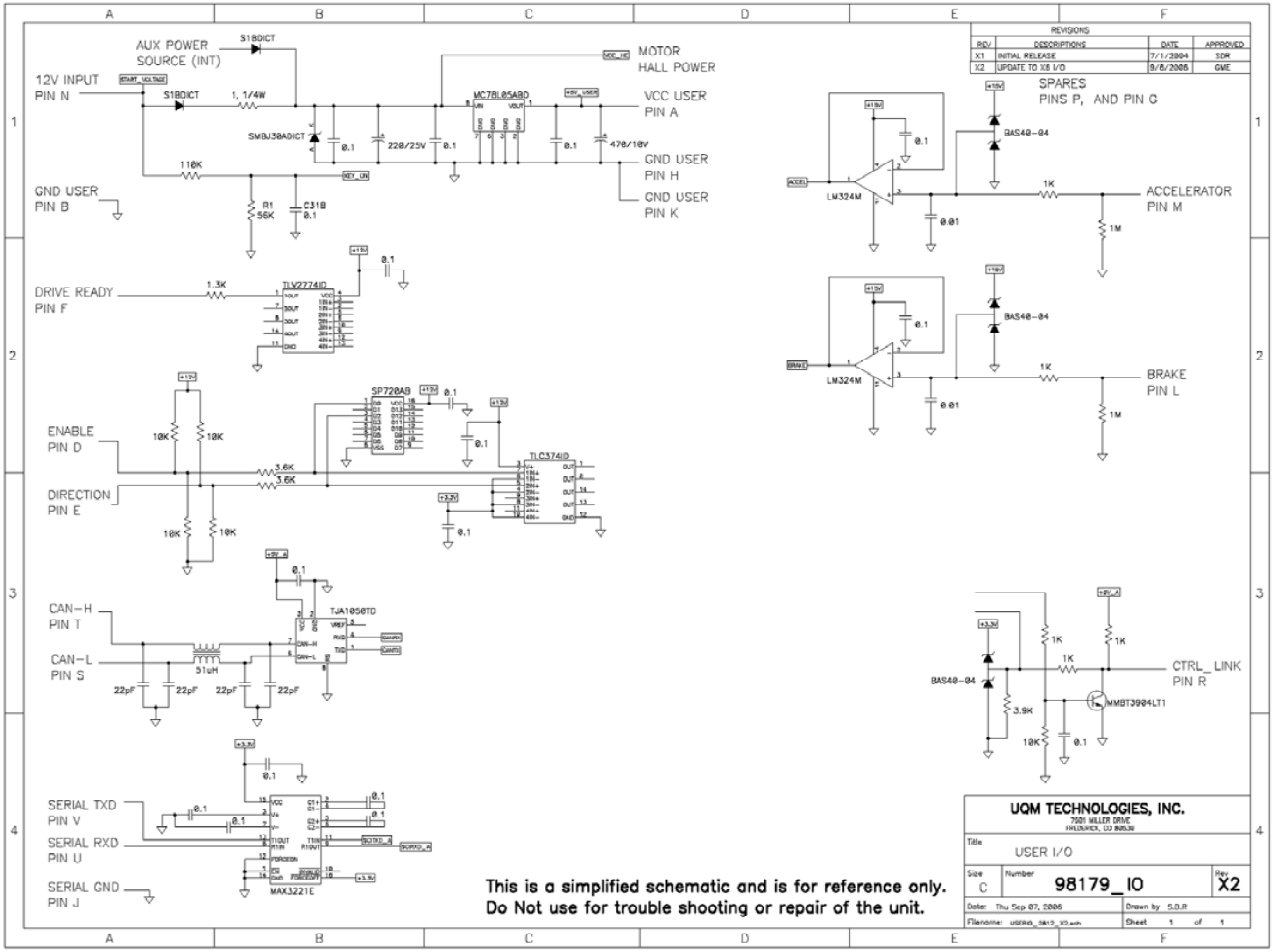
Recommended components for soft start circuit for DD45-500LWB.

Y1	contactor	20 A, 500 V DC	Kilovac or Aromat
Y2	contactor	400 A , 500 V DC	
F1	Fuse	20 A, 500 V DC rated	
F2	Fuse	400 A , 500 V DC rated	
R1	Resistor	25 Ω , 200 W	

Appendix K: User Interface Schematic Hand Control



Appendix L: First stage I/O Circuits of User Interface



Index

Glossary

Amphenol: References a specific connector type manufactured by Amphenol Corporation.
Analog: Of or pertaining to a mechanism that represents data by measurement of a continuous physical variable, in this case voltage.
Baud: The unit in which the information carrying capacity or signaling rate of a communication channel is measured. One baud is one symbol per second.
Bayonet: Another reference to a connector type with pins projecting from the side. Used for securing the connector in a bayonet socket.
Bi-directional: Involving, moving, or taking place in two usually opposite directions.
Brushless DC Motor: A synchronous electric motor that from a modeling prospective looks exactly like a DC motor, having a linear relationship between current, torque, and rpm. It utilizes an electronically controlled communication system (Hall feedback), instead of a mechanical communication system.
Bus: A subsystem that transfers data or electric power between two or more components.
CANbus (Controlled Area Network): A broadcast, differential serial bus standard, originally developed in 1988 by Intel Corporation and Robert Bosch, for connecting electric controlled units. CAN is a communication system whereby multiple nodes connect to over a single connection medium called the Bus.
Capacitors: An electric current element used to store charge temporarily, consisting in general of two metallic plates separated and insulated from each other by a dielectric.
Controller: A mechanism that controls the operation of a machine.
DC/AC (direct current/alternating current): Unidirectional flow of electric charge to electrical current whose magnitude and direction vary cyclically.
DSP (Digital Signal Processor): A specialized microprocessor designed specifically for the study of signals in digital representation.
Dynamometer: A device for measuring mechanical power, especially one that measures the output or driving force of a rotating machine.
EMI/EMC (Electromagnetic Interference/Electromagnetic Compatibility): EMC is the branch of electrical science, which studies the unintentional generation, propagation, and reception of electrical magnetic energy with reference to the unwanted effects (EMI,) that such energy may induce.
Fault: A partial or total local failure in the insulation or continuity in the conductor or functioning of an electric system.
Firmware: Computer programming instructions that are stored in a read-only memory unit rather than being implemented through software.
Generator: A machine that converts one source of energy into another especially mechanical energy into electrical energy, as a dynamo.
Inverter: A device that converts direct current into alternating current.
Microprocessor: An integrated circuit that contains the entire central processing unit on a single chip.
Motor: A machine that converts electric energy into mechanical energy.
O-ring: A loop of elastomer with a round (o-shaped) used as a mechanical seal or gasket.
Potentiometer: A variable tapped resistor that can be used as a voltage divider.

Regenerative: To magnify the amplification of, by relaying part of the output circuit power into the input circuit.
Ripple: The alternating current component from a direct current power supply arising from sources within the power supply.
Shaft: A rotating or oscillating round, straight bar for transmitting motion and torque, usually supporting on bearings and carrying gears, wheels, or the like, as a draft shaft of an engine.
Sine wave: A geometric waveform that oscillates periodically, as it is defined by the function y = sin x. In other words, it is an s-shaped smooth wave that oscillates above and below zero.
Soft Start: A term describing any circuit, which is current limited during initial power up.
Software Watchdog Timer: An independent parallel component, which detects software errors and hardware errors reliability.
Torque: Something that produces or tends to produce torsion or rotation; the moment of a force or system of forces tending to cause rotation.