INSTALLATION AND OPERATION MANUAL

POWERPHASE® HD TRACTION SYSTEM
WITH INVERTER/CONTROLLER AND MOTOR
USING V4.12 SOFTWARE

P/N 87510-011
REV C- ECN 1191

UQM TECHNOLOGIES

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Table of Contents

List of Tables

1 Introduction

Thank you for your purchase of a UQM™ PowerPhase® HD System Motor and Controller package. Notify UQM Technologies immediately if any damage has occurred during shipment.

PLEASE READ THIS ENTIRE MANUAL BEFORE APPLYING VOLTAGE TO THE SYSTEM.

This state-of-the-art system is specifically designed for high performance drive applications. The package consists of a high performance, liquid cooled, Brushless Permanent Magnet (PM) motor and a high-power, liquid-cooled inverter with a full-featured digital signal processor (DSP) controller (referenced in this manual as a controller or inverter). This manual covers installation and operation of the PowerPhase® HD System. The system is ready to use, powerful, lightweight, rugged, reliable, and designed based upon UQM's years of experience developing and manufacturing motors and controllers for electric drive systems.

The system provides many features required to develop a customized, high performance drive application. The system is capable of fully regenerative, four-quadrant, bi-directional torque-controlled operation. The controller is user programmable to allow for flexibility.

The PP HD system has been validated as a propulsion system. For applications other than propulsion systems, please contact UQM to determine if the PP HD system is capable of operation in your desired application.

This guide gives a broad description of the motor and controller package. We highly recommend that you read through these instructions to familiarize yourself with the operation and installation of the package before you begin installation. Please feel free to contact UQM Technologies, Inc. if you have any questions regarding installation, application, or service.

DANGER	*Dangerous voltages, currents, and energy levels exist in this product. Exercise extreme caution in the application of this equipment. Only qualified individuals should attempt to install, set-up, and operate this equipment.*

DANGER	*Incorrect motor and controller wiring can cause catastrophic failure. Proper connection of motor cables, signal cable, and DC cable are necessary for safe operation. Do not swap motor windings to reverse direction.*

1.1 Revision History

Revision	Date	Changes
A	03/27/2014	Initial Release
B	10/06/2015	New Event Log entries Deutsch Connector Enable pin
C	01/28/2015	New Event Log entry Update torque limit table

1.2 About this Guide

This installation guide provides instructions and guidelines for mounting, starting, testing, and operating your PowerPhase® HD electric motor system. These instructions are intended for an experienced audience with a high level of relevant knowledge.

This manual utilizes textual explanations, diagrams, photographs, computer-aided design (CAD) renderings, and interface control drawings (ICDs) to guide the user through installation and operation. The latest ICD drawings for the PP HD system are available by contacting UQM.

Section 8 contains a Glossary.

1.2.1 Conventions

The **inverter/controller** assembly may be referred to as either a '**controller'** or '**inverter**.'

You, the customer and reader of this manual, are referred to as 'the **user**.'

The **signal cable** may be referred to as **motor position** or **temperature cable**.

Clickable links to other sections in the manual, such as figures or appendices, are blue.

1.2.2 Safety Information

The procedures described in this guide are highly technical and involve high voltage equipment. Accidents involving this equipment could result in severe injury or death. Please read and understand the entire guide before beginning to install the motor or controller.

The following notices signal possible hazardous situations or other important information:

⚠	***DANGER***	*Indicates a hazardous situation that, if not avoided, will result in death or serious injury.*
⚠	***WARNING***	*Indicates a hazardous situation that, if not avoided, could result in death or serious injury, or catastrophic damage to the equipment.*
⚠	***CAUTION***	*Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury or damage to the equipment.*

NOTICE Emphasizes important information or advice.

1.2.3 High Voltage Safety Information

⚠	***DANGER***	*Exposure to high voltage can cause shock, burns, and even death.* *Technicians with special training and knowledge are required to service the high voltage components in the vehicle.* *High voltage components are identified by labels. Do not remove, open, take apart, or modify these components.* *High voltage cable or wiring has an orange covering. Do not probe, tamper with, cut, or modify high voltage cable or wiring.*

1.3 Packaging and Disassembly

The standard packaging for the PP HD system total container size is 30" x 28" x 39" and has a total weight of 355 lbs.

WARNING	*Both the motor and controller are very heavy! Be careful while removing the products from packaging to avoid dropping the components and potentially damaging the products.*

1.3.1 Packing List

Item #	Description	Quantity	Usage
1	Motor – Liquid Cooled PM Motor	1	Traction motor
2	Controller – Liquid Cooled Controller	1	Controller
3	Signal Cable (Length defined with purchase order)	1	Cable between Motor and Controller
4	DC, CABLE, CONN, EXT (Length defined with purchase order)	1	High Voltage Battery Pack to Controller
5	M6x16 SHCS (Screw, M6-1x16 SHCS Zinc)	8	Phase Cable and DC Cable connection to Controller
6	O-ring, Termination Cover to Housing	1	Controller Termination Cover sealing
7	Screw, M5-0.8x16, HHCS, SS	10	Controller Termination Cover Attachment
8	Screw, M8x1.25x16 lg, Flanged HHCS	5	Phase Cable and DC Cable Lug bolts
9	Flange Nut, M8x1.25, SS	1	Nut for ground cable (customer supplied) attachment to controller
10	Deutsch, DT06-12SA	1	User Interface cable connector parts
11	Deutsch Sockets	12	User Interface cable connector parts
12	Plugs, Deutsch	6	User Interface cable connector parts
13	Wedge Lock	1	User Interface cable connector parts

The cardboard box contains the Controller (Item 2), Cable assembly (Item 3), and hardware (Items 5-13).

The plywood box contains the Motor with phase leads attached (Item 1) and the DC cable assembly (Item 4).

1.3.2 Unpacking the Controller

Remove the foam packaging; then, remove the controller using appropriate equipment to manage the weight without dropping it.

1.3.3 Unpacking the Motor

1. Remove the Phillips head wood screws from the bottom edge of the top cover. Screws are located on opposite sides.

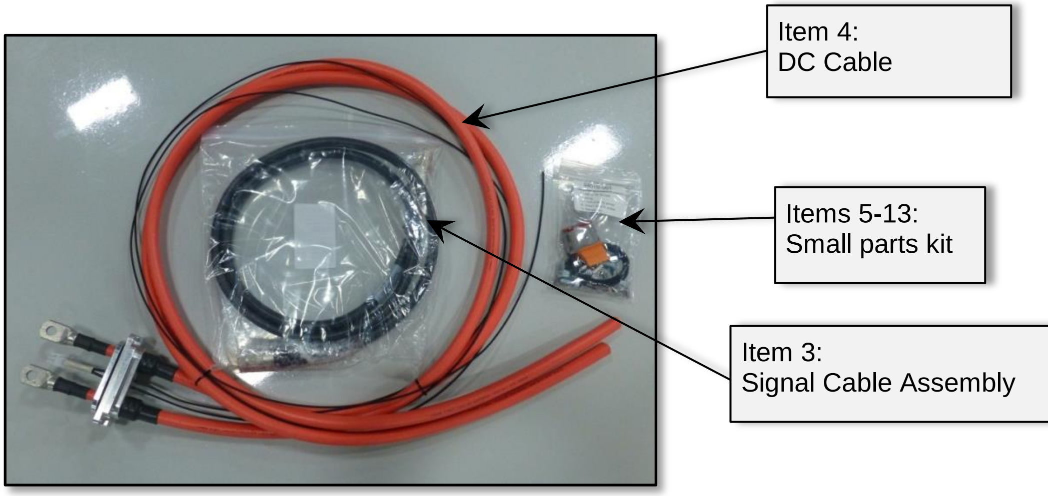
CAUTION	*The motor is bolted to the bottom of the plywood crate to ensure it is not damaged during shipment.*

2. Remove the six bolts from the bottom of the crate (bolts are M10 X 140, you will need a 17mm tool to remove them).

⚠	***CAUTION***	*Dropping the motor on the shaft will cause damage to the motor.*

3. Ensure that the bolts are disengaged from the motor.
4. Use appropriate handling equipment to lift the motor from the crate.

1.3.4 Cables and Small Parts



Small Parts Kit

1.4 System Overview

The UQM Motor and Controller convert the High Voltage DC battery voltage into torque as an input into the transmission. The system overview block diagram is shown below, Figure 1.1.

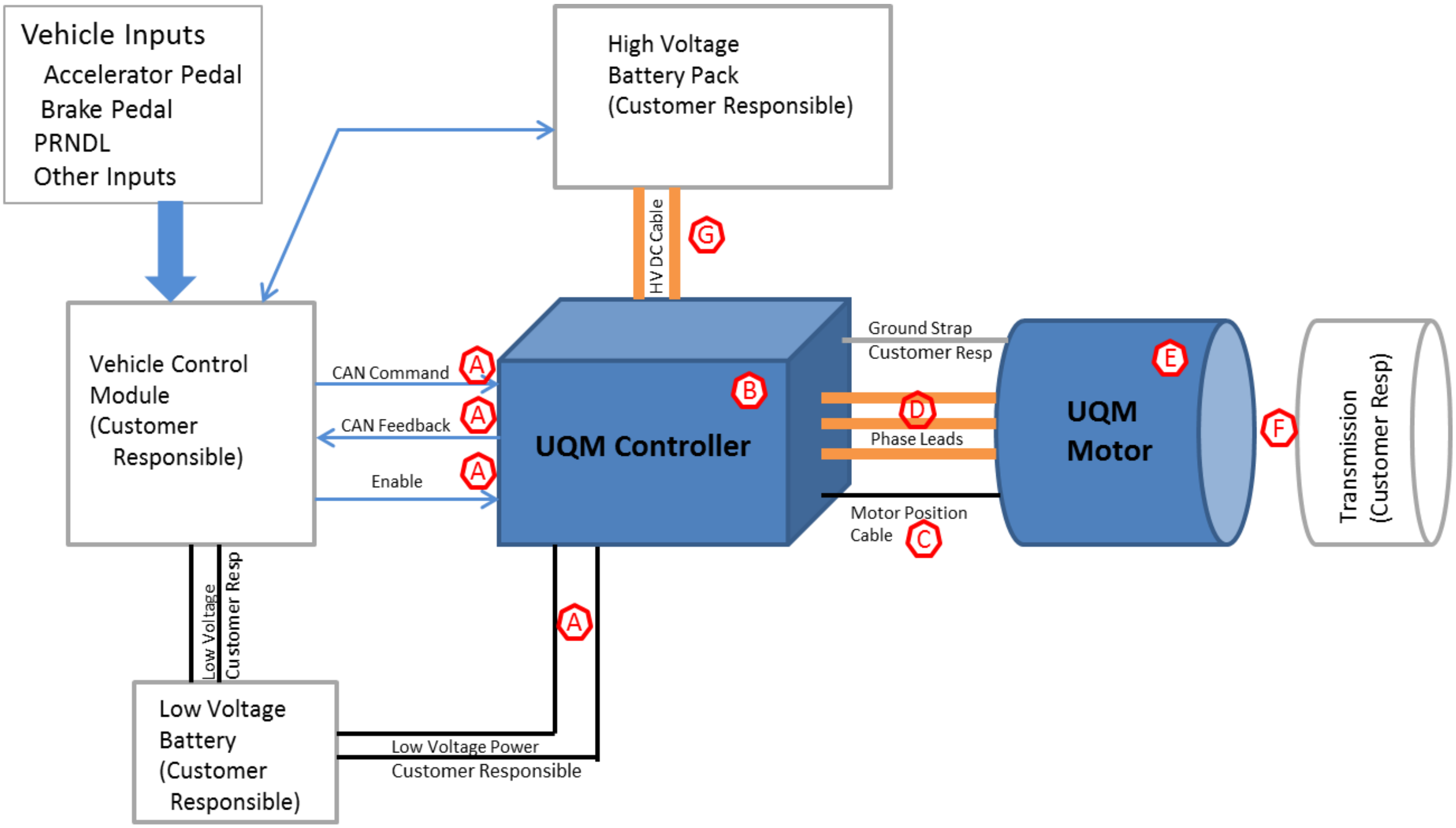


Figure 1.1: Block Diagram of the Total System

A. **User Interface Cable —** customer builds using ship kit components. The customer is responsible for the User Interface Cable. UQM supplies controller mating connector parts for the customer to produce cable. Reference the ship kit for additional information.

B. **Controller —** Installation of the Controller is defined in this user/installation manual.

C. **Signal Cable —** UQM supplies this Signal Cable. The cable length is defined as part of the purchase order.

D. **Phase Cable —** Included as part of the motor. UQM supplies the Phase Cable. The cable length is defined as part of the purchase order.

E. **Motor —** Installation of the Motor is defined in this user/installation manual.

F. **Motor Interface —** instructions provided in this manual. Motor Interface and attachment to transmission are illustrated in Section 2.3 of this manual.

G. **High Voltage DC Cable —** See the documented ICD drawing. The cable length is defined as part of the purchase order.

1.4.1 Vehicle Control Module

The UQM system *requires* a Vehicle Level Controller with the following expectations:

- UQM propulsion systems are designed to act as slaves within the vehicle system, to receive either a torque or speed command from a vehicle level controller and react with a matching torque or speed response.
- The vehicle control module is the system that takes various vehicle inputs (e.g., accelerator, brake pedals, and PRND), then determines the desired action for the UQM system and communicates the desired command to the UQM controller.
- The vehicle control module must include hardware and software to ensure that accurate commands are issued to the UQM controller.
- All vehicle level feedback and safety features are the responsibility of the vehicle system and NOT the UQM system.
- The user is responsible for integrating the UQM system into the vehicle and must implement any regulatory requirements to ensure compliance. For example, if traction drive on-road vehicle torque security is a requirement, use of speed control with torque control could be a violation of regulatory requirements.
- It is the user's responsibility to determine and control the UQM system properly.

This section provides information on mounting the motor and controller in your vehicle. The installation process for the UQM system is fairly straightforward, but requires planning and caution to avoid potential injury and/or damage to you or the equipment.

2.1 Avoiding Installation Problems

Please be aware of the following potential installation issues, which will cause damage or non-operational equipment:

⚠	**WARNING**	*Do not modify, or cut and re-solder, the Signal cable length. If you need an alternate length, contact UQM.*

⚠	**WARNING**	*Do not modify, or cut and re-solder, the Phase cable length. If you need an alternate length, contact UQM.*

⚠	**WARNING**	*The DC cable length can be shortened if necessary. The customer is responsible for the termination to the battery system and for ensuring proper termination of the shielding is achieved.*

⚠	**WARNING**	*Ensure that the motor shaft will remain unobstructed during acceleration.*

⚠	**WARNING**	*Do not open the controller or motor housings.*

⚠	**CAUTION**	*Ensure that there is sufficient liquid cooling and flow rate of coolant.*

2.2 Installing the Controller

This section describes the guidelines for installing the controller for optimum performance and maximum life. Mounting dimensions of the liquid-cooled controller are shown in ICD drawing.

The controller may be mounted in any orientation. UQM advises that the cable entry points are NOT located on the top of the assembly, to avoid fluids wicking into the controller via the signal cable or user interface cable. Secure the controller using four M10 bolts (user supplied), thru the mounting holes on the corners of the case. The mounting points should be flat within 0.25 mm. The user is responsible for determining the correct torque to apply to the M10 bolts.

Route the cables in a way that avoids unnecessary binding and premature wear. Do not locate connections in close proximity to any surface or connector that could short the motor leads.

⚠	**CAUTION**	*The customer must secure the phase cables, DC cable, and signal cables to ensure the sealing interfaces are not stressed during operation.*

2.2.1 Preparing the Coolant Loop

UQM recommends that the controller be the first component in the coolant loop. The controller coolant ports function as either inlet or outlet. The performance of the system is not impacted by which controller coolant port is used for inlet or outlet. The temperature of the coolant going to the controller must not exceed 60°C to achieve full performance (reference the flow rates in ICD drawing and Table 4.2).

The coolant fittings on the controller are intended for a ¾" hose. The coolant must have a minimum flow of 10 LPM.

⚠	***CAUTION***	*Never allow the controller to operate unless the coolant is flowing at a minimum coolant flow rate of 10 LPM.*

There is no restriction on the maximum coolant flow; however, the system is designed for a maximum operating pressure of 30 PSI.

2.2.2 Routing the Controller Cables

The signal cable from the motor to the controller is necessary for operation and care must be taken to ensure the integrity of these signals. Please exercise care with the routing of these cables to prevent them from being damaged, cut, scraped, shorted, unplugged, or disturbed by high voltage noise fields. *Do not* route this cable near any DC power cables or the motor phase cables. The signals in this cable contain information about the position of the rotor, and the controller depends on that information to properly control the motor.

The user interface connector carries the 12 V (or 24 V) power for the internal power supplies of the controller. Without this power, the controller will not operate and cannot communicate. This line should be switched like the ignition system of a typical vehicle, and fused. UQM recommends a 10 amp automotive style fuse in this line. The 12 V (or 24 V) must be capable of 10 amps at start-up and 7 amps continuous.

2.2.3 Applying Voltage

For the PP HD system, the controller must have the 12 V (or 24 V) system powered up before high voltage is applied. Once CAN communications are established, you can apply the high voltage. The 12 V (or 24 V) power must remain on as long as high voltage is applied.

The user interface connector also contains the CAN signals and an RS-232 serial connection. The CAN signals are required for communication to the controller. The serial connection is only needed for diagnostics of the controller with the UQM Diagnostic Software.

See the **UQM CANbus Interface Manual** for the CAN message definitions.

2.3 Installing the Motor

The interface dimensions and tolerances of the PowerPhase® HD motor can be found on the ICD drawing. This section describes the preferred method for coupling the motor shaft. Please discuss any other methods with UQM Engineering before implementing.

Transmission to Motor Interface Coupling

In the preferred installation, the motor mounts to a transmission via a bell housing adapter and a coupling. The coupling adapter interfaces the spline on the motor and also interfaces the input spline on the transmission. See Figure 2.1 below.

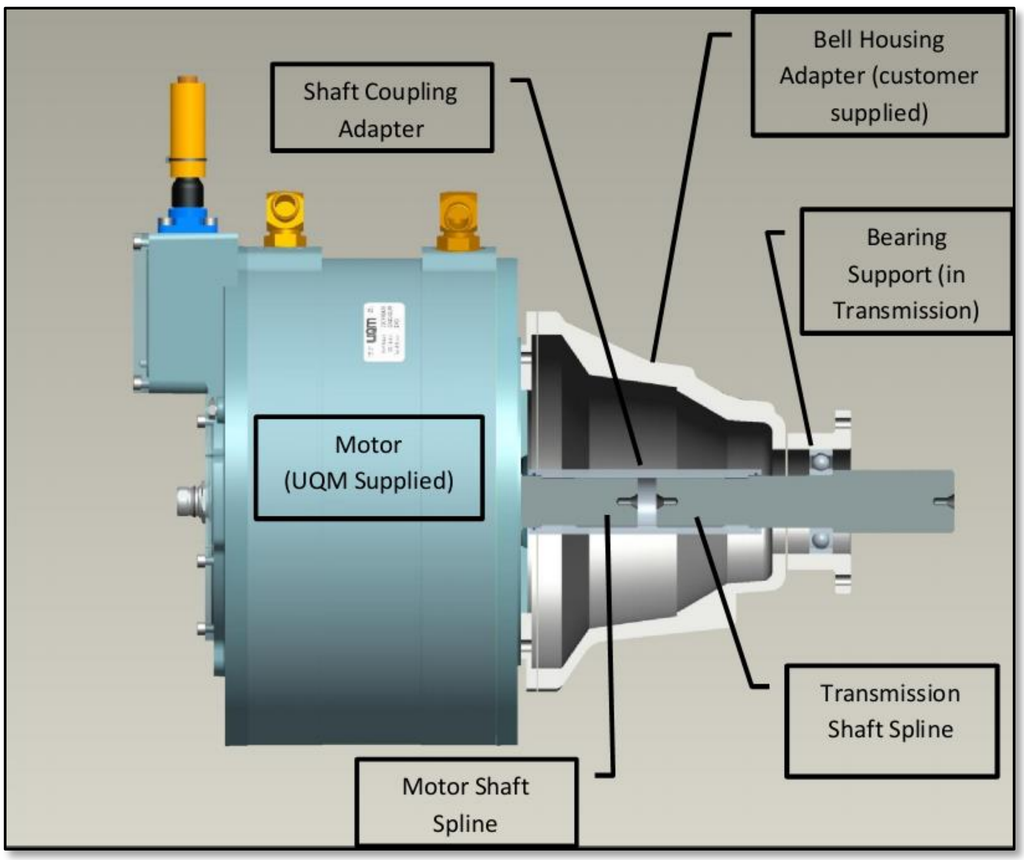


Figure 2.1: Preferred Motor to Transmission Coupling

In this type of mounting configuration, there are two spline interfaces (between the motor spline and coupling, and between the coupling and transmission spline). In this configuration, the locating pilot feature on the motor can normally be used to center the motor to the transmission shaft. The accuracy of this centering feature is disclosed in the notes of the ICD drawing (see Position tolerance at the spline pitch diameter in the ICD drawing notes).

The user must perform the tolerance stack-up that determines the maximum misalignment between the pitch diameter of the motor shaft spline and the pitch diameter of the transmission shaft spline. The user must also determine if the clearance between both splines in the coupling can take up the maximum misalignment based on the worst case tolerance stack-up for shaft misalignment. This tolerance analysis must be performed to ensure there cannot be radial interference due to misalignment, which will induce a radial load onto the coupled shafts. Some types of compliant couplings are advertised to take up misalignment; however, note that the compliant materials in these couplers still impose a load on the shafts, even if operating within their rated amount of allowable misalignment. In addition, the user must check the axial tolerance stack-up of the coupling, shafts, and adapter components to ensure that there is not a possible interference condition that would induce an axial load on the motor shaft.

Note that if a transmission is not used in the application, the same coupling configuration can be accomplished with a support bearing holding the opposing shaft.

⚠	***WARNING***	*Loads on the motor shaft induced by the coupling system can result in premature motor failure. Users of the motor MUST ensure the motor shaft is not improperly loaded.*

Shaft Loading

See the motor ICD drawing for the maximum radial and axial loads that can be applied to the shaft while maintaining the intended design life. The maximum loads on the interface drawing are assumed independent, i.e. maximum radial load assumes no axial load and maximum axial load assumes no radial load. Contact UQM for bearing life prediction at specific load requirements or combinations of radial and axial loading. Shaft loading should only be attempted if it can be accurately measured and controlled using features such as a belt tensioner. UQM is not responsible for damage due to shaft loading from radial or axial interference as described above.

Shaft Spline Lubrication

To prevent wear at the spline interface, ensure the entire surface of the shaft spline is lubricated with high quality grease. UQM recommends AeroShell Grease 22, which achieves Mil Spec: MIL-PRE-81322F; Grade: NLGI-2.

Shaft Spline Lubrication Containment

The motor shaft provides a sealing surface for lubrication containment that can be utilized with an O-ring groove and O-ring in the coupling. UQM highly recommends using this method or a similar method of lubrication containment. UQM is not responsible for premature wear caused by a spline joint that has lost adequate lubrication.

2.3.1 Mounting the Motor

The pattern of threaded holes on the shaft-side of the motor is the primary interface for mounting the motor. Utilize all of these mounting holes with an appropriate fastener when mounting the motor. The user must apply proper bolted-joint design for the loads imposed during operation in the specific application.

The threaded holes on the other side (lead exit side) of the motor can be used in conjunction with the primary mounting holes as a secondary mounting surface in applications with heavy loading. The fasteners on the secondary mounting surface cannot be used without all of the fasteners present on the primary mounting surface (see the ICD drawing). The ICD drawing also provides the maximum recommended torque for the threaded holes. The user is responsible for specifying the minimum torque as well as the bolt length and grade needed for the bolted joint in the application. Do not allow the bolts to bottom out in the mounting holes. Thread engagement should be at least 1.5 times the bolts' major diameter.

⚠	***WARNING***	*The motor housing is not a structural member and is not intended to bear structural loads.*

UQM's motor is designed for maximum allowable shock load as specified and tested to SAE J1455 specification. This is the maximum shock rating for survivability only. The motor is not intended to handle multiple shock cycles at this level. This shock rating is valid when the motor is mounted using the primary interface fasteners and supported at the plane indicated as Datum A on the ICD drawing.

The motor and transmission assembly must be supported at a point close to the plane indicated by Datum A. However, if the ideal support system is not possible, calculations must be performed to ensure that the loads imposed on the motor housing do not exceed the loads imposed when the motor is mounted using the primary mounting interface, supported at the plane indicated by Datum A, and subjected to the SAE J1455 shock specification. Please contact UQM Motor Engineering and provide us with the specific mounting locations, transmission weight, and Center of Gravity, to verify that the load profile is acceptable. Figure 2.2 illustrates the generally preferred mounting and support locations as well as the incorrect mounting configuration that should be avoided.

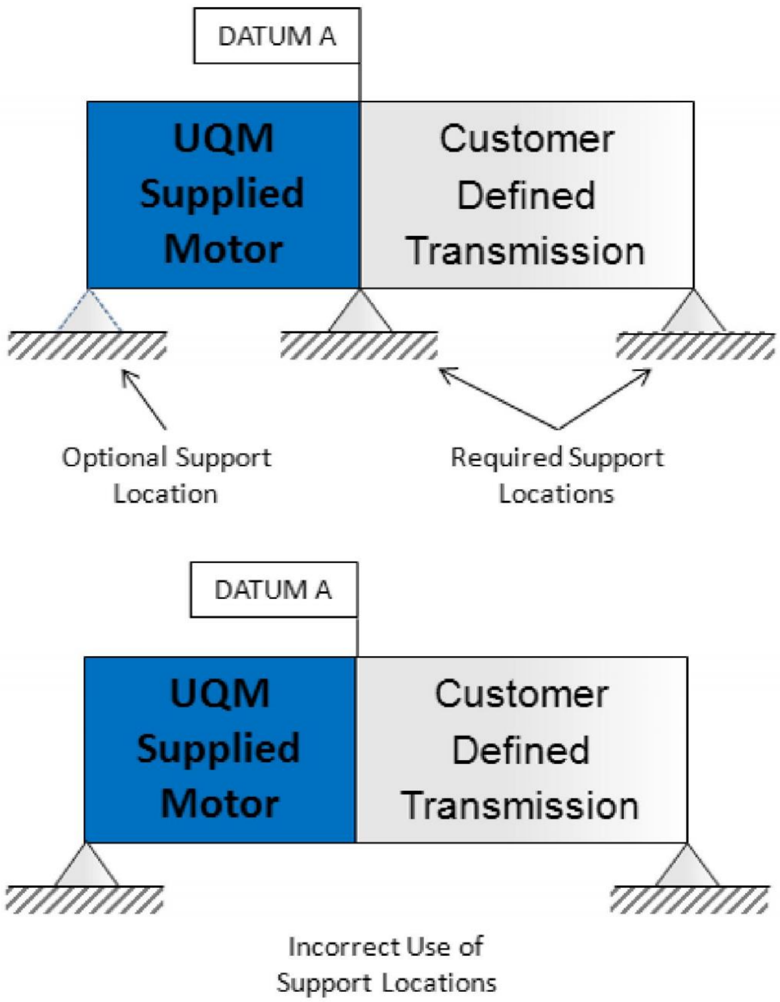


Figure 2.2: Correct and Incorrect Use of Support Locations

⚠	***WARNING***	*Exercise care when mounting the motor to ensure that moving parts are not constrained and proper clearances are observed. All drive mechanisms mounted to the motor shaft must be properly secured.*

⚠	***WARNING***	*A separate ground wire must connect the motor case to the controller housing. High Voltage lines (positive or negative) must not be tied to the chassis, or the motor and controller/inverter cases. Please see Section 3.4 for more information on grounding requirements.*

2.3.2 Coupling to an Internal Combustion Engine (ICE)

Coupling the UQM motor/generator to an IC engine requires special considerations that are specific to the IC engine that is selected and the method of coupling. UQM must review the installation and engine parameters before approving an engine coupled application.

⚠	***WARNING***	*Coupling the motor to an Internal Combustion Engine could result in premature motor damage.*

2.3.3 Coolant Connections

The coolant fitting location, hose size, and the inlet and outlet designation of the coolant fittings on the motor are referenced on the ICD drawings. Also reference the ICD drawing for the volume of coolant contained within the motor housing. The angular orientation of the coolant fittings can be changed by loosening the nut on the coolant fitting, rotating it to the desired angle, and tightening the nut to the torque specification on the ICD drawing. More details for making the coolant connections can be found in Section 4.

NOTICE	*The preferred orientation for the cooling ports is upward, to allow for natural air removal from the coolant system. However, any orientation of the coolant ports is acceptable with an adequate air bleeding procedure.*

2.4 Electro-Magnetic Interference and Compatibility

UQM has tested the system for Electro-Magnetic Interference (EMI), susceptibility, and electrostatic discharge (ESD). The drive system has a built in EMI filter and comes with shielded phase leads to help in reducing the level of electromagnetic emissions generated. However, please note that due to application-specific routing of the wires and shielding required for installation into a vehicle, UQM cannot guarantee compliance with vehicle level testing that must occur.

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

- Keep the controller and the drive motor as close as possible to one another in the installation. This reduces the power conductor length, thus reducing the length of the radiating antenna.
- Keep all of the high-power, motor phase leads as close together as possible in the routing from the controller to the motor. This reduces the open loop area of the radiating element.
- When routing the high power DC conductors, run them side-by-side. This reduces the loop area and length, and thus reduces emissions.
- Most importantly, 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 emissions from these wires. Use proper grounding and shielding techniques when building a vehicle.

2.4.1 CAN and Serial Shielding

- For the CAN connection on the user interface connector, use a high quality, insulated, shielded, twisted pair cable, and terminate the shield on the user interface connector to the CAN_COM pin. Do not allow the shield to touch the motor or controller housing.
- For the Serial cable, you can also use the same type of shielded, twisted, pair cable used on the CAN, and use the shield for the Serial_COM pin connection.
- When using CAN, ensure that you have a ground connection on the user interface connector CAN_COM to the same source as the CAN signal, using the CAN shield or a separate ground connection. The CAN circuits within the UQM controller are isolated from the 12 V system as well as the high voltage. Providing the ground connection from CAN_COM to a ground of your upper level controller allows the CAN signal reference to be the upper level controller ground.

3 Electrical Connections

The motor and controller electrical connections are shown in Figure 1.1. The 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.

⚠	**DANGER**	*Dangerous voltages, currents, and energy levels exist in this product. Exercise extreme caution in the application of this equipment. Only qualified individuals should attempt to install and set-up this equipment.*

3.1 Power Cables

Figure 3.1 shows an exploded view of the controller connections. Before connecting any cable to the controller, remove the terminal housing cover.

⚠	***WARNING***	*Ensure that the power is off before connecting the power cables.*

⚠	***WARNING***	*Ensure that the phase cables and DC cables are routed and restrained to prevent insulation damage.*

3.1.1 Phase Cables (3 Phase AC cables)

Install the phase cable housing to the controller housing using the included M6x1x16 socket head cap screws (SHCS), and tighten to the torque indicated in the ICD drawing. The phase cable housing is keyed to the controller housing so it can only be installed in the correct orientation. After installation, the holes in the ring lugs at the end of the phase cables should line up with the threaded holes at the terminals of the controller. Install three of the included M8x16 flanged head bolts through the ring lug holes, and thread them into the hole in the controller terminal. Tighten to the indicated torque in the ICD drawing. See components in the exploded view in Figure 3.1.

3.1.2 DC Cables

Install the DC cable housing to the controller housing using the included M6x1x16 socket head cap screws (SHCS), and tighten to the torque indicated in the ICD drawing. The DC cable housing is keyed to the controller housing so it can only be installed in the correct orientation. After installation, the holes in the ring lugs at the end of the DC cables should line up with the threaded holes at the terminals of the controller. Install two of the included M8x1.25x16 flanged head bolts through the ring lug holes, and thread them into the hole in the controller terminal. Tighten to the indicated torque in the ICD drawing. See components in the exploded view in Figure 3.1.

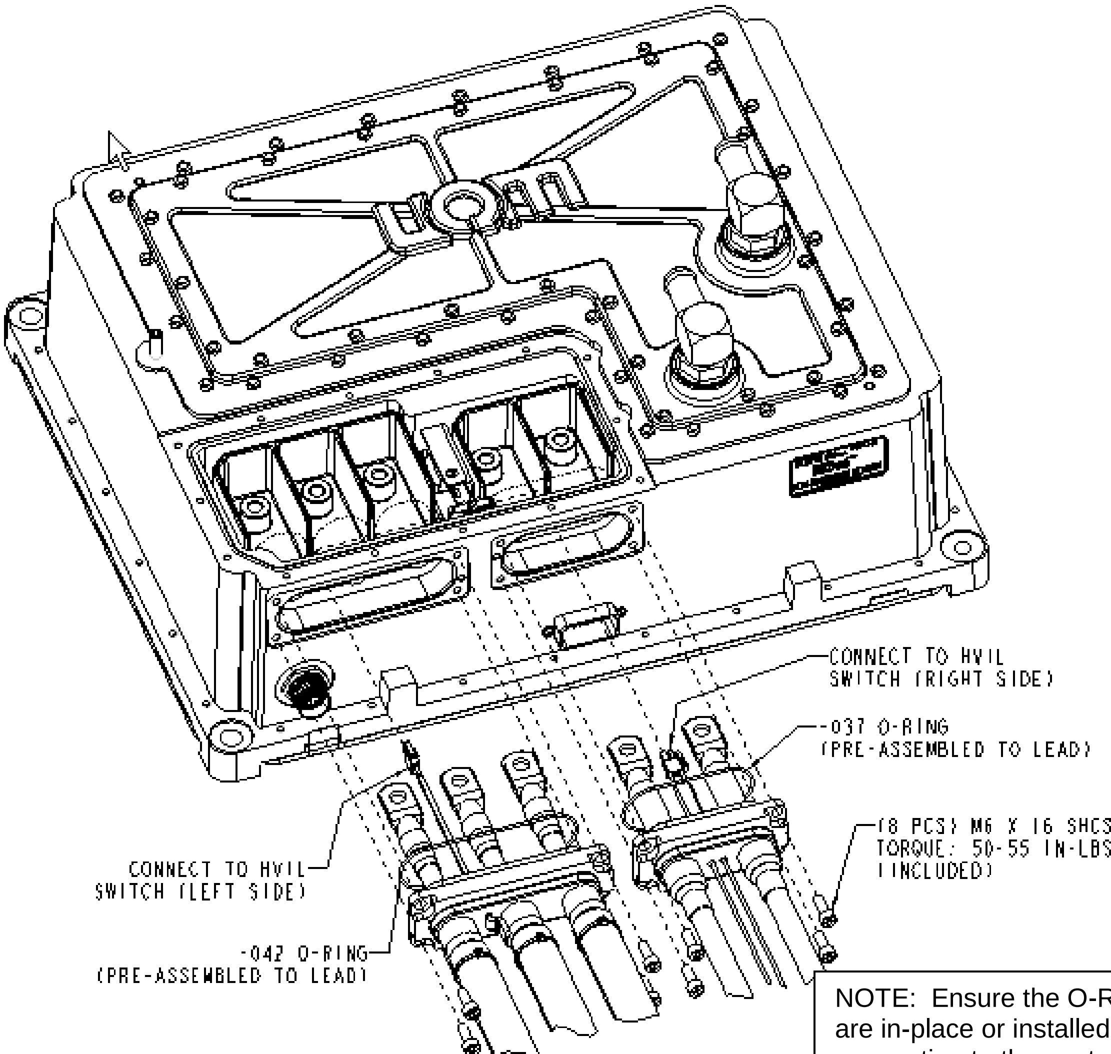


Figure 3.1: Controller Connections

NOTE: Ensure the O-Rings are in-place or installed before connection to the controller. Ensure the O-Rings are not pinched or nicked during installation.

3.1.3 HVIL Connection

The following HVIL connections must be made for the system to operate. Connect the motor HVIL connector from the phase cables (3 cable side) to the HVIL card located between the phase and DC termination connectors on the controller. Connect the DC HVIL connector from the DC cables to the HVIL card located between the phase and DC termination connectors on the controller.

Removal of the motor termination cover or the controller termination cover will open the HVIL circuit. If either the controller or motor termination covers are open, the UQM HVIL connections provide a signal to the vehicle system indicating that high voltage is exposed. It is the user's responsibility to take appropriate action with the UQM HVIL circuit when either termination cover is open.

⚠	**CAUTION**	*The user is responsible for proper HVIL actions and for disabling the DC high voltage power when the HVIL circuit is open.*

3.1.4 Termination Cover Installation

To seal the controller, place the O-ring (Item 6 in the ship kit) into the rectangular grove on the controller housing. Then, place the termination cover, making sure the O-ring remains within the grove. Install the terminal cover screws, M5 x16 HHCS (Item 7), into the 14 holes in the cover. Torque the screws to the torque specified on the ICD drawing.

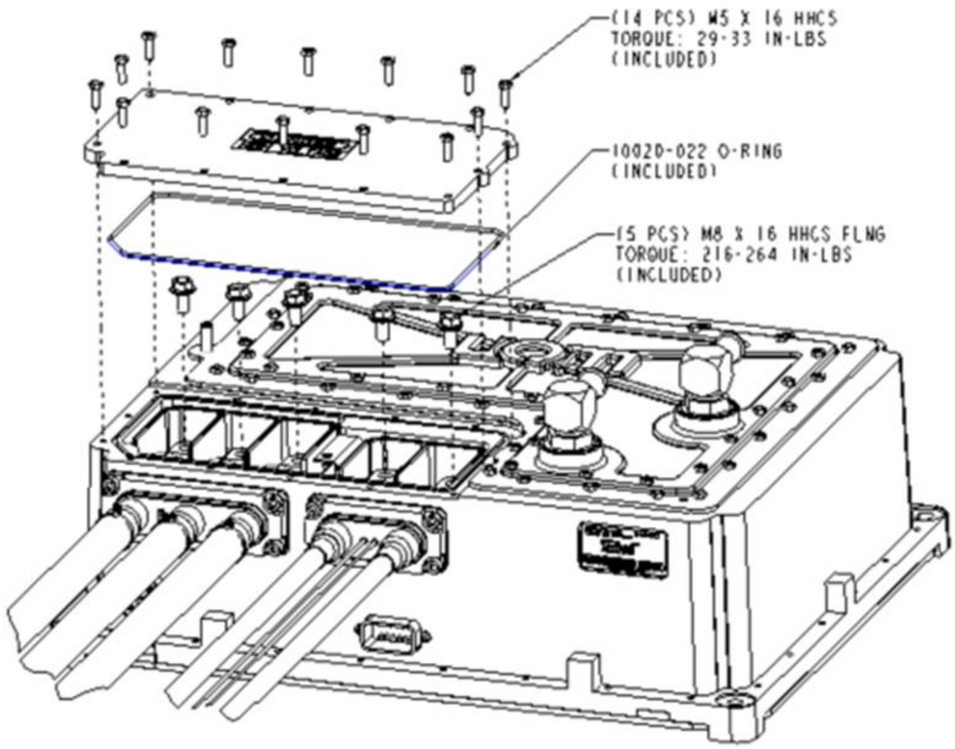


Figure 3.2 Exploded View of the Controller Connections

3.1.5 Phase Cable and DC Cable Routing and Air Flow Requirement

Take care in routing and attaching the Phase cables and DC cables such that there is no rubbing and abrasion of the outer insulation. The customer is responsible for securing the cables to avoid insulation damage. In addition, it is recommended that the Phase and DC cables be routed such that air flow is directed over the cables for cooling. The maximum outer jacket of cable temperature must be maintained below 130°C (for example a maximum rise of 80°C above an ambient temperature of 50°C is permitted). Application testing in maximum thermal conditions must be completed to ensure the cable temperature does not exceed this maximum cable jacket temperature. The cable temperature rise will depend on many factors including, but not limited to: the average or RMS current flowing through the cables, (which will be determined by the vehicle drive cycle), air flow over the cables or thermal isolation of the cables in the application. See the applicable motor ICD drawing for minimum recommended air flow across the phase cables (this recommended air flow also applies to the DC cables).

When connecting the Phase cables and the DC cables, ensure that the O-Rings are installed on the cable housings before attaching to controller as shown in Figure 3.1. These O-Rings may be already attached the cable housings or shipped as part of the ship kit. Ensure the O-Rings are in-place or installed before connection to the controller. Ensure the O-Rings are not pinched or nicked during installation.

3.2 Signal Cable

The signal cable is the small shielded cable with a 17-pin Amphenol M23 style connector. Some of the wires in this cable are used for the rotor position signals. Others are used to send stator and rotor thermal information to the controller.

This is the most critical and sensitive cable within the drive system and it must be protected from any potential damage.

⚠	***WARNING***	*Do not attempt to lengthen or shorten the cable in any way. Contact UQM if the cable is too short or too long for the application.*

⚠	***WARNING***	*Do not bundle the signal cable with the motor power leads. This may cause a controller failure.*

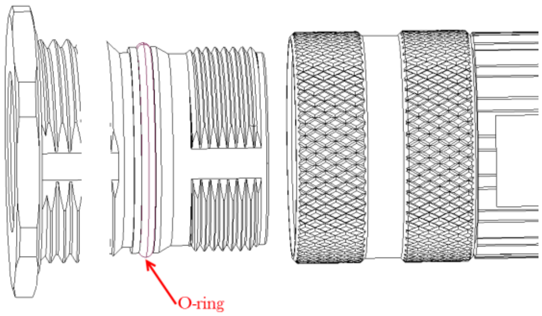
Connect the signal cable from the motor to the controller. Connectors are keyed to require one orientation, and must be tightened as specified below.

⚠	***CAUTION***	*Do not over-tighten the signal cable connector.*

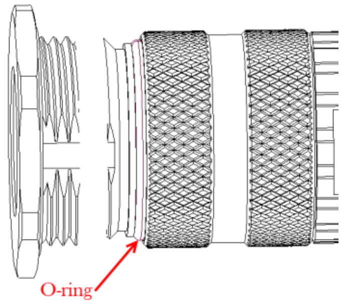
Signal cable connector assembly instructions

Note: These assembly instructions are only needed for the M23 screw type connector and not needed if your system has the Bayonet type connector.

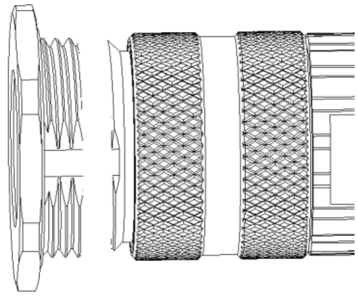
1. Orient rotor position cable connector to the mating connector on the motor or the controller and rotate cable until key way allows insertion.



2. Screw knurled connection nut clockwise. At about 3 turns some resistance will be felt. This is the nut coming into contact with the sealing o-ring. The connector is not fully seated.



3. Continue to tighten knurled nut until o-ring is covered, and increased torque is required, (about 2 turns) this is the point when the cable connector is fully seated to the mating connector.



4. Torque the mated connector to 20-30 in lbs. This is about 2-3X the torque that can be achieved by hand.

3.3 User Interface Connection

The user interface connector is a 12-pin Deutsch connector. The input/output signal descriptions are listed in Table 3.1 for the pins used on the 12-pin connector.

The low voltage power can be either 12 V or 24 V DC.

This system requires that you provide 12 V for the internal power supplies within the controller. This 12 V supply is likely the same source that provides power for other auxiliaries on the vehicle. UQM recommends that this supply be switched and fused using an automotive rated 10 amp fuse. We also recommend that the switch be in some way controlled by the operator of the vehicle. Treat this 12 V supply as you would the 12 V ignition source for a gasoline powered vehicle. Use 16 gauge wire to avoid a voltage drop in the wire supplying LV to the controller.

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.

Table 3.1: List of User Interface Control Signals

Name	**Signal**	**I/O port**	**Pin # of 12-Pin Deutsch connector**
+12V BAT	+12 VDC (or 24 VDC)	INPUT	1
Reserved	N/C		2
Reserved	N/C		3
CAN_H	CAN High	CAN_H	4
CAN_L	CAN Low	CAN_L	5
CAN_COM	CAN_COM		6
Serial	Transmit	USER-TxD	7
Serial	Receive	USER-RxD	8
Serial_COM	Serial_COM		9
ENABLE	Hardware Enable +12 VDC	INPUT	10
Reserved	N/C		11
12V RTN BAT	12 V return	INPUT	12

⚠ ***WARNING***

*CYCLING THE **+12V** OR **ENABLE** SIGNALS WHILE THE MOTOR IS IN MOTION SHOULD BE AVOIDED IF AT ALL POSSIBLE. Cycling either of these signals will cause the inverter CPU to shut down and restart – which may result in unpredictable current surges.*

3.3.1 Traction Battery Power Connection

DANGER	*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 must be connected to the controller terminals on the positive and negative terminals under the termination cover of the controller. Refer to the ICD drawing and markings on the cables for polarity. Observe the correct polarity when making connections.

At rated peak power of the PPHD system at the nominal voltage (both stated in the specific product specification sheet available through UQM sales), the UQM controller can draw over 650 Amps from the traction battery. Internal impedances inside the customer's battery can drop the voltage supplied to the UQM controller.

DANGER	*Do not connect either the positive or negative high voltage bus to the chassis, motor cases, or controller. Catastrophic damage will occur. Provide sufficient insulation on all power terminals for safety.*

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

Before applying input high voltage, ensure that the shaft, and anything connected to the shaft, has sufficient area for rotation. Also make sure that the motor is secured to something that can handle the reactionary torque from the motor. As the rotor accelerates, the motor case attempts to torque in the opposite direction. Always disconnect input high voltage before making or removing any connections.

Due to the high inrush current of charging the controller's internal capacitors, the customer *must* ensure that the high voltage system has proper fusing and contactor configuration to ensure proper system start-up. UQM recommends some type of "soft start" circuit, which is the responsibility of the user and/or high voltage battery pack manufacturer.

NOTICE	*A soft start circuit is recommended for input voltages above 100 V High Voltage DC.*

3.4 Grounding Requirements

The housings of the controller and motor must be wired together with large gauge copper wire (4 gauge or larger, stranded or braided is recommended) to ensure proper electrical ground. There is a stud on the coolant port side of the controller where the ground strap should be connected. The motor has a boss on the lead exit end bell for the ground strap connection. The motor and/or controller are typically in contact with the metal chassis of the vehicle, but this metal contact is not enough to provide the proper grounding path for the system.

WARNING	*The user is responsible for providing and installing a ground strap from the motor to the controller. Without a ground cable, erratic operation can occur.*

4 Liquid Cooling

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

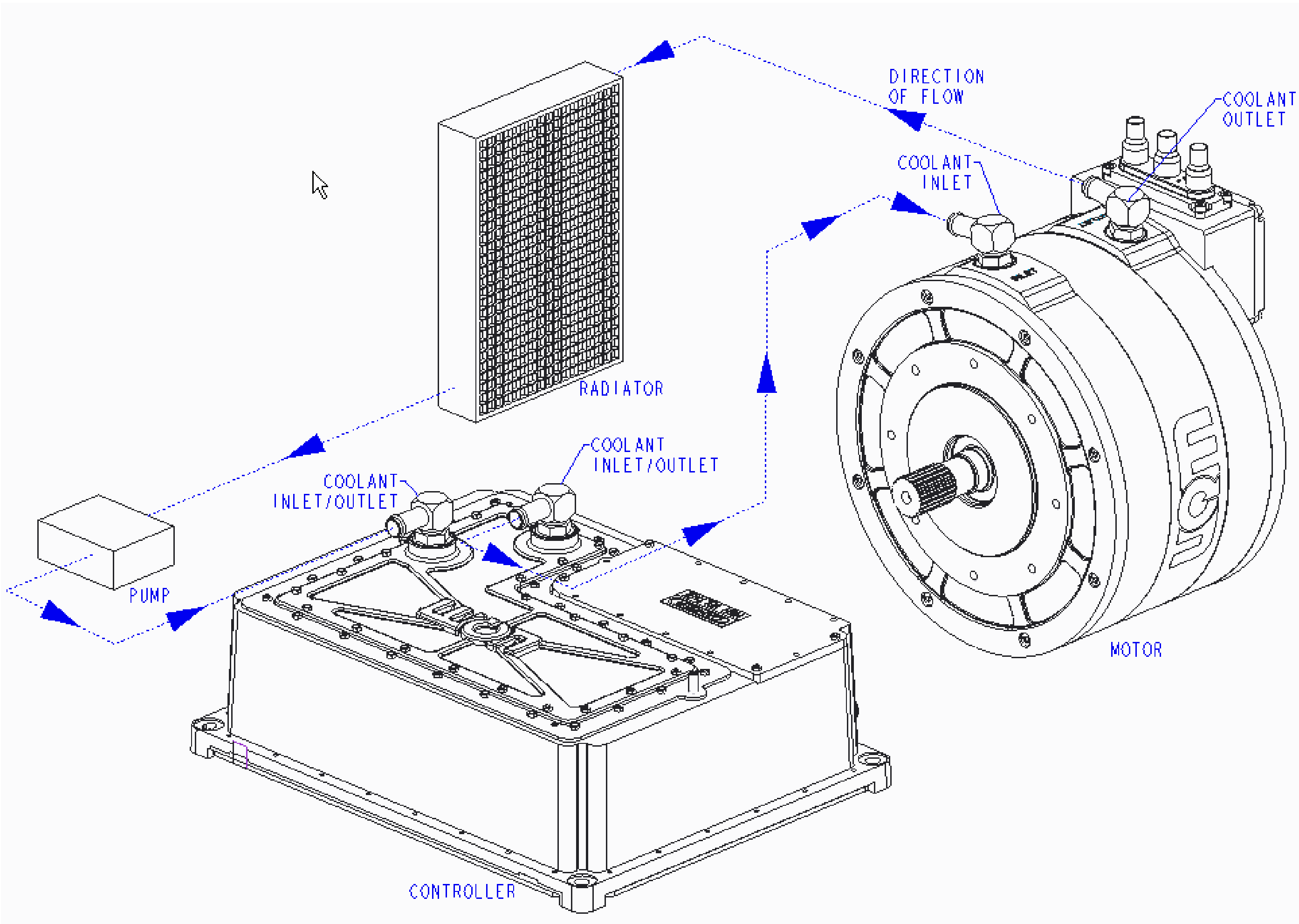


Figure 4.1: Recommended Liquid Cooling Setup

4.1 Coolant Loop Requirements

⚠ **CAUTION**	*The coolant should never run in parallel paths. The coolant hoses between the controller and the motor should be in series, as the thermal algorithms used in the software depend upon the coolant flowing at the same rate through both components.*

The coolant for the UQM system must be designed and specified by the user or vehicle integrator. The heat rejection for the system is dependent upon the drive cycle; therefore, the customer must size the coolant system based on the drive cycle power requirements in the application. The losses can be determined from the efficiency maps for the propulsion system.

The motor and controller coolant fittings are attached to the respective devices via an O-ring port specified by SAE J1926-10. The controller and motor have 90° elbows that adapt to the hoses and rotate to meet with the particular application. The coolant fittings can be unscrewed and changed to meet the requirements of the application. Many different fittings are available that fit the SAE J1926-10 O-ring boss.

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

Table 4.1: Liquid Cooling System Requirements

Requirement	Specification
Coolant Type	50/50 water to glycol
Maximum Inlet Coolant Temperature (full performance)	60° C
Minimum Coolant Flow Rate	10 liters per minute (LPM)

Coolant volume for the controller and motor can be found on the ICD drawing or by contacting UQM.

A coolant flow rate of 10.0 liters per minute will have a pressure drop of approximately 8.5 kPa total from just the controller and motor. This does not include additional fittings, valves, or plumbing.

Note in Figure 4.1 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. The controller is more heat sensitive than the motor, and needs the coolant to be as cool as possible. While the system can operate at maximum rated coolant temperatures, the operating life of the controller will be extended if the coolant is kept below the maximum operating temperature.

To make loading the coolant into the system easier, make sure the radiator fill port is higher than the motor and controller, which allows air to flow out of the coolant system more easily.

4.2 Flow Rate vs. Pressure Drop

The total pressure drop in the system is the summation of the pressure drop across the controller, motor, and all customer installed hosing and fittings. The table below shows flow rate data for 50/50 water glycol coolant at 32° C in the PPHD System.

Table 4.2: PPHD Coolant Flow Rates

PP220 Coolant Flow Rates (50/50 mix water to glycol)					
		Controller		Motor	
Flow Rate		Pressure Drop		Pressure Drop	
GPM	LPM	PSI	kPa	PSI	kPa
2.0	7.6	0.35	2.41	0.35	2.41
2.5	9.5	0.60	4.14	0.55	3.79
3.0	11.4	0.80	5.52	0.70	4.83
3.5	13.2	1.45	10.00	1.15	7.93
4.0	15.1	1.95	13.44	1.75	12.07
4.5	17.0	2.35	16.20	2.30	15.86
5.0	18.9	2.90	19.99	2.70	18.62
6.0	22.7	3.80	26.20	3.60	24.82
7.0	26.5	5.00	34.47	4.90	33.78
8.0	30.3	6.25	43.09	6.15	42.40
9.0	34.1	7.65	52.74	7.65	52.74

If the Flow rates and pressure drops are identified on the ICD drawings, the ICD drawings overrule this table and need to be used as the latest information.

5 Communications

This section covers the CAN communications required for normal motor operations and serial communications required by the diagnostic software.

5.1 CAN Communications

The user is responsible for connecting the CAN communication from the UQM controller to the Vehicle Control Module. Refer to the pinout on the 12-pin Deutsch connector in Table 3.1.

Please follow the typical CAN setup procedures according to J1939. The controller includes 120 ohm terminating resistors internally therefore the CAN is terminated inside the controller.

5.2 Serial Communications

The UQM Motor Diagnostic Software communicates to the motor system through the serial communication port of the 12-pin Deutsch connector.

Connect the serial pins from the 12-pin Deutsch connector to a 9 pin D-sub connector compatible with the three wire RS232 serial interface specification (See Table 3.1 for the Deutsch connector pinout).

Mate the RS232 cable from the Deutsch connector to the RS232 port of the user's computer. If the user's computer does not have an integral RS232 serial port, an appropriate RS232 to USB converter (user supplied) may be used.

The user must ensure that pin 7 (Transmit) of the Deutsch connector is properly routed to pin 2 (Receive) of the computer's 9 pin connector, that pin 8 (Receive) of the Deutsch connector is properly routed to pin 3 (Transmit) of the computer's 9 pin connector, and that pin 9 of the Deutsch connector (Serial_COM) is properly routed to pin 5 of the computer's 9 pin connector (Signal Ground).

6.1 Electric Vehicle System Overview

The UQM system is the main drive component of an Electric Vehicle System. The major items are shown below.

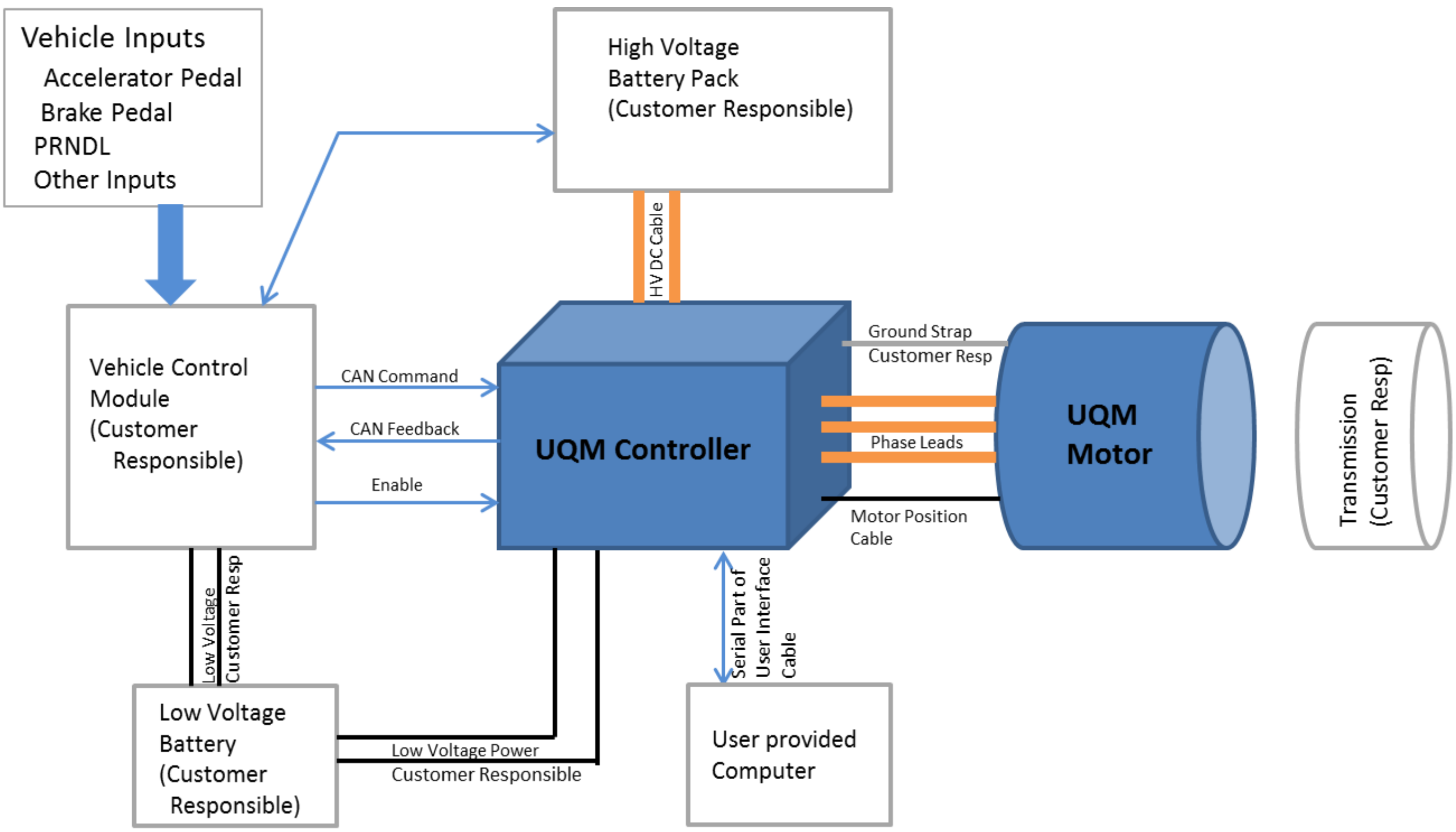


Figure 6.1: Block Diagram of Electric Vehicle Drive System

The customer must supply the Vehicle Control Module. Typically, it performs the following functions:

- Monitors the accelerator, brake pedal, and PRNDL inputs
- Monitors the High Voltage Battery
- Sends a Hardware Enable signal to the UQM controller
- Sends valid CAN torque commands to the UQM controller as appropriate for the accelerator, brake pedal, PRNDL gear selector, and High Voltage Battery inputs

⚠ ***WARNING***	*DO NOT FLAT TOW the vehicle. While towing the vehicle, the drive wheels MUST NOT ROTATE, or damage will result when the motor system is not operational.*

⚠	***WARNING***	*DO NOT RE-ENABLE BATTERY VOLTAGE TO A MOVING VEHICLE.* It is strongly recommended that if a condition occurs which requires power cycling the system, the vehicle should be at a full stop before battery power is enabled. Applying battery voltage while the motor is moving may result in serious damage to the system.

6.2 Valid Control Modes via CAN

The only Control Mode in the UQM Motor System is CANbus Control. Control commands are issued to the controller via the CANbus. Three types of control, Torque, Speed, and Voltage, are possible with this system, including the ability to switch between the control types dynamically.

6.2.1 Torque Control

Torque control is the most common operational mode for the motor. The desired torque is communicated as a requested torque value through the Universal Command. The speed limitation is included in the same command message. See the **UQM CANbus Interface Manual** for details.

6.2.2 Speed Control

In the operational mode of speed control, the controller tries to keep its spinning rate and direction matching the requested speed level. The desired speed is communicated as a requested speed value through the Universal Command. The torque limitation is included in the same command message. See the **UQM CANbus Interface Manual** for details. See Section 1.4.1 regarding use of the speed control mode.

6.2.3 Voltage Control

⚠	***WARNING***	*UQM Motors in Voltage Control require that the controller's voltage bus must have a separate UQM capacitor box attached to it for safe 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 7.4).

Alternatively, if in CANbus Control, then the voltage is commanded as a requested voltage value through the Universal Command with current limits. See the **UQM CANbus Interface Manual** for details. You can limit the execution through current limits in the Universal Command, and through the voltage ramp in the System Configuration (see Section 7.4 for more details).

Voltage Control ignores the CANbus enable bit.

6.2.4 Control Security

The UQM Motor System has available a number of CANbus control security features. All are built around the CANbus Watchdog, a timer that monitors the frequency of valid control commands received by the inverter on the CANbus. When the CANbus Watchdog times out because a valid command did not arrive in time, the inverter either drops to zero torque requested if in Torque Control, or drops to zero speed requested with very limited torque if in Speed Control.

These security features include a variable timeout period defined through the System Configuration (see section 7.4 for details) which can be set from 40 milliseconds up to 1 second. There is also support for the requirement of a rolling counter within the control command, a feature that causes identical repeated messages to be rejected as valid control commands. Lastly, two different commands, the control command and the heartbeat command, can be required to occur within the watchdog timeout period, or timeout will occur.

6.3 Special Features

The UQM controller has a number of special features which can simplify vehicle control, improve system efficiency, and help with electric vehicle ride comfort. In this section, friction compensation, acceleration limits, active damping, dynamic motor tuning, and Regen Switch control will be discussed.

6.3.1 Friction Compensation

The UQM controller automatically compensates for the electric motor's friction, and the friction value used increases as a function of speed to account for the motor bearings' responses. This allows the controller to correct its output and its torque measurements so that they better match torque requests.

In addition, a static friction value can be specified through the System Configuration as a torque value representing the amount of friction the UQM motor encounters in the vehicle drive train. The UQM controller will then use this value to further correct its output and its torque measurements. (See Section 7.4 of this manual for further information about the System Configuration.)

⚠ ***CAUTION***	*Increasing the friction compensation to account for drive train friction could cause motoring at zero torque when the motor is disconnected from that drive train.*

Note that these friction values are zeroed when the system is disabled through the CANbus control command. (See the **UQM CANbus Interface Manual** for details.)

6.3.2 Acceleration Control

While fast acceleration is desirable, too much acceleration can cause poor riding comfort and excessive mechanical stress. All vehicles have a natural maximum acceleration limit due to the mechanical systems themselves and their environment. In addition, some applications have mandated limits to the acceleration experienced by vehicle riders. UQM's Acceleration Limit feature attempts to control the acceleration of the electric motor to a user-defined level, allowing simplification of the vehicle control algorithms during terrain changes. With the same command sequence, more torque can be used going uphill and less torque be used going downhill, providing the vehicle occupants with identical experiences in both cases.

The Acceleration Limit is set dynamically through a CANbus command (see the **UQM CANbus Interface Manual** for details). It is also possible to set a default acceleration limit through the system configuration (see Section 7.4 of this manual). In addition, a Surge Limit is set dynamically through the same CANbus command. It sets how many RPM the acceleration controller can surge while it brings the acceleration under control.

When in **Speed Control**, the Acceleration Limit causes the UQM controller to accelerate at the requested rate when the desired speed request changes. For example, if an Acceleration Limit of 150 RPM/sec is set and a 1200 RPM speed request is issued to the UQM controller while the motor is at rest, then the speed controller will smoothly ramp the speed from zero to 1200 RPM over an 8 second period. A further speed request to 1500 RPM will be accomplished over a 2 second period, and a subsequent speed request to 300 RPM will cause the speed to lessen smoothly over another 8 seconds. If the motor's available torque is not enough to maintain the desired acceleration rate, it will naturally accelerate at the slower rates arising from the limited torque. In CAN control, the available torque is affected by the torque limits within the Universal Command.

When in **Torque Control**, the Acceleration Limit causes the UQM controller to use less torque if motor acceleration exceeds the user-defined level. Note that it can only *remove* torque. It does not try to maintain the acceleration rate unless too much torque is requested. Thus, a controlled deceleration requires a negative torque request, and a controlled acceleration requires a positive torque request. For example, if an Acceleration Limit of 150 RPM/sec is set and a full torque request is issued to the UQM controller while the motor is at rest, then the UQM controller could deliver up to full torque to get the motor spinning. As the motor begins to spin, the controller will lessen the torque delivered to maintain an acceleration of 150 RPM/sec. The controller maintains this acceleration *while the torque request is too great*. If the torque request drops to zero, torque will immediately be removed. If a negative torque request is issued at this point, the UQM controller will deliver the requested regeneration torque (or less) in order to maintain a 150 RPM/sec deceleration.

When in **Voltage Control**, the UQM controller ignores any acceleration limit set in the system configuration. There is a voltage change rate controller (see Section 7.4 for more details), but motor acceleration rates are not managed.

6.3.3 Active Damping

⚠	***CAUTION***	*Enabling Active Damping with added torque allowed may violate torque security strategies. The customer is responsible for addressing any regulatory requirements. See Section 1.4.1.*

Resonances in drive trains are caused by elasticity and gear play; these are mitigated by dampers. Drive trains with combustion engines are usually equipped with dampers because of the high torque pulses of the engine. Contrarily, electrically driven trains are often weakly damped because of the smooth torque delivery of electric motors. However, they still experience the drive train's mechanical resonances, which at low speeds can cause uncomfortable vehicle shudders. UQM's Active Damping feature, when activated through the system configuration (Section 7.4), determines a small corrective torque signal and adds it to the driver's requested torque, mitigating the oscillations quickly. See figure 6.2 to see active damping in action.

When enabled, the Active Damping Control monitors the acceleration experienced by the electric motor's rotor, and if the acceleration exceeds the limit defined in the system configuration, the controller will insert the corrective torque signal. The amount of authority given to the Active Damping Control can be set through the system configuration (Section 7.4). This authority is limited to increasing the desired torque by 10% of the maximum torque supported by the motor and decreasing the desired torque to zero torque.

Please note that Active Damping requires an acceleration limit. When Active Damping is turned on, Acceleration Limit is also active. Therefore, you must define a desired maximum acceleration rate, and your torque requests will be lessened if the measured acceleration exceeds this desired value. The UQM Motor Diagnostic Software reports this measured acceleration in both its Data Acquisition and Logging files (see Section 7.5 in this manual).

Since the acceleration limit can be set dynamically through CANbus command, active damping also reacts differently as that acceleration limit is changed. It is also disabled when the Acceleration Limit is disabled through the CANbus Universal Command.

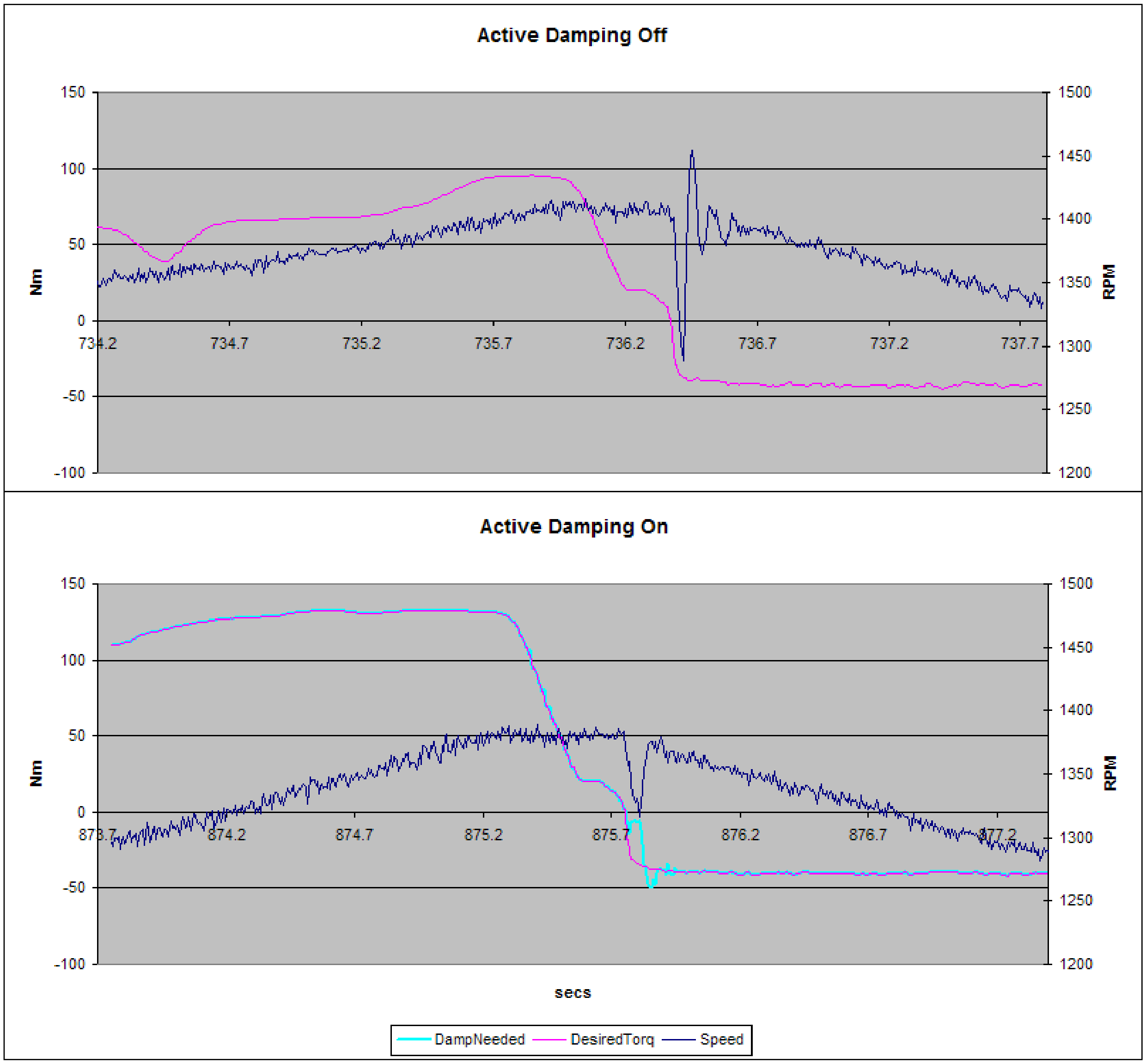


Figure 6.2 Active Damping Control Results

6.3.4 Dynamic Adjustment of Motor Parameters

A valuable feature in the UQM controller is its ability to dynamically adjust the vital motor parameters it is using to more closely match the actual motor it is controlling, thereby improving torque delivery and efficiency. These parameters are the raw voltage produced in the stator of the motor when its rotor spins (called Back EMF), and the position of the rotor in relation to the stator (called Position Offset).

These adjustments are fit in during normal operation when conditions meet the requirements for the adjustments (speeds in the 1200-1800 RPM and the speed is steady, and less than 5% torque requested steadily). The Position Offset adjustment takes a total of 5-20 seconds, and the Back EMF adjustment takes a total of 15 seconds.

6.3.5 Regen Switch Control

Vehicle battery systems can be sensitive to too much voltage or too much charging current coming from the electric motor. A new feature in version 4.11 of the UQM controller is the ability to choose lower voltage and current trigger points causing the Regen Switch to open. These values are stored in the System Configuration, and define the voltage level and the negative current level when the switch disconnects the inverter from the battery bus.

Note that it is filtered measurement values that are used for these triggers in order to prevent measurement noise from causing false triggers. Because of this it is important to choose trigger levels that have a safety margin to allow for the filtering delay. A sudden change in the voltage measurement of 200V is delayed 12 milliseconds, and a 400A change in the current measurement is delayed 42 milliseconds.

NOTICE	The Regen Switch is closed when the UQM controller measures the external voltage and its internal capacitors voltage and finds they are within 25V of each other.

6.4 Safety Features

The UQM motor system provides built-in features to minimize hazardous conditions, like over motor current, over/under battery voltage, or over motor speed, with values selectable by the customer. It also has features to protect against battery disconnect, conditions causing stall, and hardware failures. These are discussed in the sections below, beginning with an explanation of limits. In general, these safety features are provided through limits that regulate the command torque when a problem is detected.

6.4.1 Limits

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%. The limit values are also available through the CANbus message “Limited Torque Percentage.” The limitations can take away significant amounts of the deliverable torque of the system. The following table shows the conditions and the maximum limit that can occur to motoring torque requests and regeneration torque requests.

In Table 6.1 below, the **Limp Home Mode** limits are defined by the **Limp Home Percentage** in the **Torque Profile** tab of the **System Configuration**. For further details, see Section 7.4.2.

Table 6.1: Potential Limitations

Cause	Maximum Motoring Limits	Maximum Regeneration Limits
Motor velocity over Customer Speed	0% *or* -100%[1]	
Coolant loss detected	0%	0%
No CAN communication	0%	0%
Over temperature (Inverter/Stator/Rotor)	0%	0%
Position bad	0%	0%
Power supply out of specification	0%	0%
System halted	0%	0%
Torque producing current too noisy	0%	0%
Bus current too noisy	0%	0%

Cause	Maximum Motoring Limits	Maximum Regeneration Limits
Raw bus current too large	0%	0%
Unreliable bus current measurement	0%	0%
Redundant torque mismatch[2]	0%	0%
Redundant current mismatch[3]	0%	0%
Bus Voltage over Safety Voltage		1%
Bus Voltage over Customer Battery Max		2%
Bus Voltage under Customer Battery Min	3%	
Stall conditions	10%	10%
Bus current over Positive Current	26%	
Bus current under Negative Current		24%
Current Transducer Fault	Limp Home Percentage	Limp Home Percentage
Disconnected Temperature Sensor	Limp Home Percentage	Limp Home Percentage
Inverter Fault	Limp Home Percentage	Limp Home Percentage
Bad controller calibration	Limp Home Percentage	Limp Home Percentage
Bad switch safety	Limp Home Percentage	Limp Home Percentage
Invalid Sensor voltage	Limp Home Percentage	Limp Home Percentage
Error with leg current sensors	Limp Home Percentage	Limp Home Percentage
Incorrect position offset	Limp Home Percentage	Limp Home Percentage
Motor Leg current Over Current	Limp Home Percentage	Limp Home Percentage
Apparent Rotor Movement	Limp Home Percentage	Limp Home Percentage
Over Positive Phase Advance limit	Limp Home Percentage	Limp Home Percentage
Under Negative Phase Advance limit	Limp Home Percentage	Limp Home Percentage
Variable Back EMF saturated high	Limp Home Percentage	Limp Home Percentage
Variable Back EMF saturated low	Limp Home Percentage	Limp Home Percentage

1. If the "Allow Braking" box in the System Configuration is checked, the system will be able to apply regeneration torque to slow down the motor. Otherwise, the limit will be 0%. For more details, please refer to in Section 7.4.4.
2. Redundant torque mismatch = torque calculated using bus current does not match expected torque.
3. Redundant current mismatch = measured bus current does not match expected bus current.

When more than one limiting factor is present, the lowest limitation dominates. The most serious motoring limitation is Over Speed. If configured to do so, this limitation can actually cause motor regeneration in order to slow down the speed. (See Section 7.4.) 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.

6.4.2 Forced Voltage Control

Forced voltage control ensures the bus voltage of the inverter does not exceed the limits of the inverter's components. This condition may occur if the high voltage path is suddenly removed, for example, if a battery contactor opens.

If the motor is regenerating when the high voltage path is suddenly removed, then the bus voltage experienced by the inverter can rise very rapidly, endangering inverter components. This is detected as a **Disconnected Battery Event**. It will occur if, over a 2 millisecond period, the bus current is very small but the voltage change indicates that significant currents are flowing into the inverter's capacitors.

If the motor is motoring when the high voltage path is suddenly removed, the bus voltage experienced by the inverter can fall very rapidly, threatening a power device shutdown. This is detected as a **Low Forced Voltage Event**. It will occur if all of the following are happening: bus current is small, the bus voltage is less than the minimum allowed battery value and dropping fast, and the inverter is seeing large motor currents OR the speed is above base speed.

UQM inverters monitor for these conditions and enter the control mode "Forced Voltage Control" in order to control the bus voltage by motoring or regenerating rapidly. While in control, Forced Voltage Control maintains the voltage 10 V below the maximum battery voltage defined in the System Configuration. Note that if the regen switch is open then it will control the voltage to a higher value. This control mode is only allowed to use 10% of the motoring and regeneration capabilities of the UQM motor. The mode releases control within 128 milliseconds if conditions indicate that the battery is still connected. This condition is reported through the Diagnostic Software described in Section 7 of this manual, and also through the CANbus message "System Status."

6.4.3 Stall

If the motor's rotor does not move when high torque is commanded, the result is a stalled condition in the motor. A rotor locked in this way can cause the current through the inverter to exceed safe limits. If unchecked, these high currents will cause the failure of an IGBT power device in the inverter. To protect against a prolonged stall condition (locked rotor); UQM controllers contain a complex algorithm to deliver the requested torque for as long as possible without damaging the power devices. The amount of time is variable and contingent on the amount of torque requested. It can range from many seconds down to 600 milliseconds. Once this time has elapsed, the Stall Limit will report a stall condition and limit the torque to 10% for 30 seconds. This condition is reported through the Diagnostic Software described in Section 7 of this manual, and also through the CANbus message "System Status."

Under most conditions, stall can be avoided by selecting a low value for the variable PWM frequency (Figure 6.3). The lower PWM frequency only applies to low motor speeds. Below 200 rpm, the selected PWM frequency is always used. There is a hysteresis band between 200 and 1000 rpm. During acceleration, the PWM frequency shifts from the selected frequency to the high speed frequency of 12 kHz at 1000 rpm. During deceleration, the shift from the high speed frequency to the selected frequency occurs at 200 rpm.

Note that the lower PWM frequency may result in a significant increase in audible noise that will be most noticeable when decelerating to a stop. When deciding the best frequency to select, the user should evaluate the tradeoff between the system's audible noise level and the likelihood of encountering the stall condition.

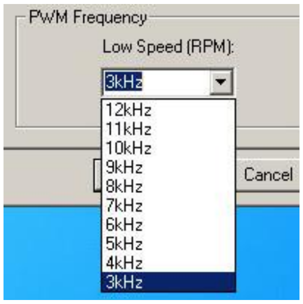


Figure 6.3: PWM Frequency Selection

6.4.4 Forced Open Loop

In normal operation, the controller uses measured values from the motor to tune and improve control. In the case of detected measurement failure, control is managed with open loop values. The conditions that cause this include Invalid Sensor voltage, Error with leg current sensors, Current sensors appear disconnected, and bad controller calibration. Each significantly limits torque output, but the motor is allowed to operate in a “limp-home” mode. This condition is reported through the Diagnostic Software described in Section 7 of this manual, and also through the CANbus message “System Status.”

6.4.5 Software Watchdog Timer

In addition to all limit protections 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.

6.5 Vehicle responses to UQM’s CAN Status and Error Messages

The customer and/or vehicle integrator is responsible for proper responses to the UQM CAN Status and Error Messages (see the UQM CAN Manual). The Vehicle Control Unit/Module will need to determine the appropriate actions to these messages. UQM is providing the status and error messages so that appropriate actions are taken at the vehicle level. UQM assumes no liability if the vehicle does not respond to our status and error messages. For a typical electric vehicle application, the following actions should be considered as part of the vehicle integration:

Table 6.2: System Error Flags

System Error	Time period before reacting	Typical Vehicle Controller Unit (VCU) Expected Action
Not Enabled	X	Nothing, typical occurrence
Over Leg Current	X	Nothing, only occurs in highly dynamic situation
Over Bus Current	X	Customer dependent - over customer's limit
Over Phase Advance	X	Nothing, if error lasts under 10 seconds (See Notice below for persistent occurrences of this error).
Under Voltage Warning	X	Customer dependent - under customer's limit
Rotor Over Temp	X	Bit set at 130 deg C, Read in actual rotor temperature, if over 136 deg C then amber over temp light, if over 146 deg C, then red over temp light
Stator Over Temp	X	Bit set at 150 deg C, Read in actual stator temperature, if over 156 deg C then amber over temp light, if over 166 deg C, then red over temp light
Inverter Over Temp	X	Bit set at 90 deg C, Read in actual inverter temperature, if over 93 deg C then amber over temp light, if over 98 deg C, then red over temp light
Over Speed Warning	X	Customer dependent - over customer's limit or UQM upper limit
Over Voltage Warning	X	Customer dependent - over customer's limit or UQM upper limit

System Error	Time period before reacting	Typical Vehicle Controller Unit (VCU) Expected Action
Over Speed Alarm	X	Customer dependent - over customer's limit or UQM upper limit
Over Voltage Alarm	X	Battery fuse blown or contactor opened? High voltage battery problem? Regen switch will open.
ADC Calibration Problem	Long	Check engine light
Limp Home Mode	Immediate	Check engine light
Inverter Fault Latched	Immediate	Check engine light
Inverter Fault	Immediate	Check engine light

NOTICE

If **Over Phase Advance** is persistently detected over time, contact UQM for a motor specific QSC file (Section 7.4). UQM will require the serial number of the motor and a copy of the current QSC to process this request.

The QSC is for the specific motor. If the motor is replaced, revert to the original QSC or load the QSC for the replacement motor

Table 6.3: System Status

System Status	Time period before reacting	Typical Vehicle Controller Unit (VCU) Expected Action
Forced Voltage Control	X	Battery fuse blown or contactor opened? High voltage battery problem? Regen switch will open.
CAN Limits Active	X	Nothing, typical occurrence
System Disabled In Motion	Short	Customer dependent - Is customer enabling the UQM drive?
ABC Phase Order	X	Nothing, typical occurrence
Regen Switch Open	Short	Customer dependent, only react if high voltage is applied and if it is then check engine light
Current Transducer Fault Ileg/Ibus	Long	Check engine light
Acceleration Limited	X	Nothing, typical occurrence
Using Raw Speed	X	Nothing, typical occurrence
Turbo Mode	X	Nothing, typical occurrence
Forced Open Loop	Long	Check engine light
Motor Stalled	Long/X	Customer dependent - hill too steep for motor torque and vehicle weight - UQM delivering 10% torque for 30 seconds
Phase Current Sensor Error	Long	Check engine light
Bad Position Signal	Long	Check engine light
Bad Switch	Long	Check engine light
Invalid Power Supply	Long	System inoperable
Power Switches Off	Immediate	System inoperable

Table 6.4: Error Response Delay Time

Length of time period before reacting	Typical Vehicle Controller Unit (VCU) Reaction Time
Immediate	0 seconds
Short	0.3 seconds
Long	1.0 seconds
X	Don't react

7 Motor Diagnostic Software

UQM Technologies Inc. provides diagnostic software with their systems. This software runs on Microsoft Windows XP/Windows 7, 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 the functionality of the diagnostic software.

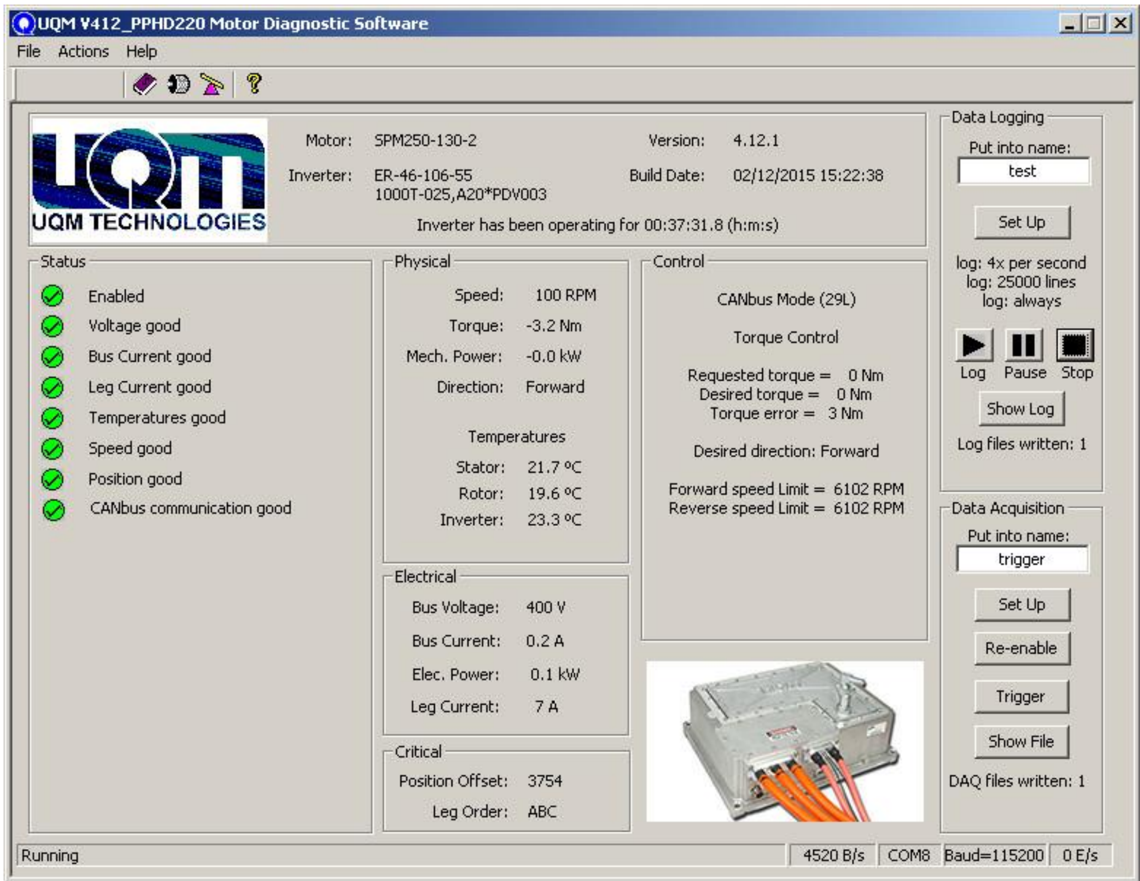


Figure 7.1: UQM Motor Diagnostic Software Front Panel

7.1 Setting Up the Software

UQM Motor Diagnostic Software requires 10 Megabytes of hard disk space on a Microsoft Windows XP/Windows 7 Computer with a COM port. A USB to Serial Converter can be used to connect the COM port, but it must be installed before the UQM Motor Diagnostic Software.

Table 7.1: Components of a UQM Motor Diagnostic Software Installation

Start Menu Label	Description
UQM Motor Controller	The main diagnostic software described in this section of the manual. Connects to a UQM motor controller via a serial cable and provides an environment to monitor and record the motor system conditions. It also allows you to change motor system configuration settings.
QscReader	A helper application that allows the user to examine, edit, and compare QSC files without being connected to a UQM motor controller. QSC files are UQM Motor System Configuration files that store a particular motor controller configuration.
UQM User Guides	User Guides to the various UQM systems (e.g.: this manual)
UQM CANbus Manual	The manual describing the CANbus operation of UQM motor controllers.

7.2 Starting Up the Software

After launching the UQM Motor Diagnostic Software, you are prompted (Figure 7.2) for the COM port number (near the serial cable connection on the controller), as well as for the fastest baud rate you desire. Using the default top speed of 115200 is recommended. The software negotiates the baud rate with the controller each time it is started and finds the fastest baud rate that can be maintained, so it will not necessarily operate at 115200 baud. You can, however, constrain it to a lower rate by setting that rate in the COM Port dialog box (Figure 7.2). Typically, this dialog box only appears the first time you launch the software. It stores these settings and uses them each time it is launched.

NOTICE	If the UQM Motor Diagnostic Software always asks you to choose a COM Port then it is unable to store the information. Move the UqmMotor directory to a location on your disk where the operating system allows the user to write.

If you want to change COM port or baud rate settings later, select **Actions > Choose COM Port** from the menu.

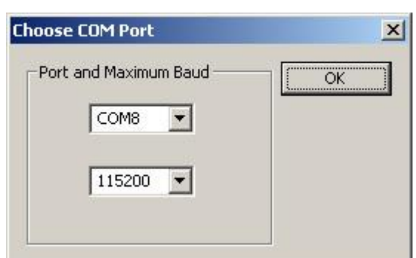


Figure 7.2: Choose COM Port Dialog Box

NOTICE	*UQM recommends that you save the original system configuration to a QSC file for each motor when you launch your software with that motor for the first time. This allows you to return to the configuration of your original shipped state at any time. See "Save to file" in Table 7.6 of this manual.*

7.2.1 Multiple Motor Operations

If your PC supports more than one COM port, you can launch multiple instances of the UQM Motor Diagnostic Software to view multiple motor systems at the same time.

If you plan to use this capability, UQM recommends that you make a copy of the complete UqmMotor directory with a different name. Each executable file then retains the knowledge of which COM port it "owns" and communicates only with the motor connected to that COM port.

7.2.2 Status Bar

As the UQM Motor Diagnostic Software starts, it contacts the controller via the COM port. The Status Bar (Figure 7.3) at the bottom of the application window communicates all the details of the serial communication. It displays status messages, the current bytes-per-second rate, the COM port, the baud rate, and the current errors-per-second rate.

Figure 7.3: Status Bar

Table 7.2 (below) shows the communication messages that occur in the Status Bar (Figure 7.3).

When errors occur, the software provides additional information through message boxes or other dialog boxes. For example, if the software encounters a device that uses an older version of firmware, the software informs you and inquires if you wish to update or just run the application. Alternatively, if communication is not possible, the software either exits or returns to the "Choose COM Port" dialog box.

Table 7.2: Status Bar Communication Messages

Message	Description
Communication down, continuing to try...	Communication between the PC and the device has not yet been established or has failed. The PC will continue to try to establish communication every five seconds until you stop it via the "Choose COM Port" Action.
Have gotten the COM port	First message during initial 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.

Message	Description
Fetching DAQ data	A DAQ trigger has occurred, and data is being moved from the device into a file.
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.
Cannot operate	An unrecoverable error has occurred.
Error count exceeded allowed. Letting go of COM port	Too many errors have occurred in the serial communication channel. The software is ending communication.

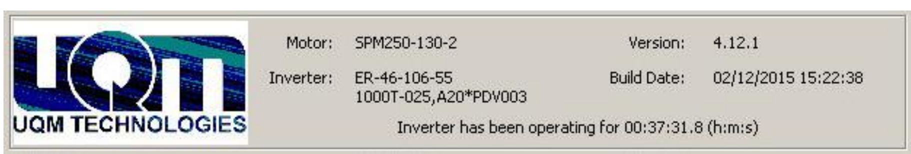
In normal operation, the software initializes the serial interface and retrieves the device's initialization information, negotiates the baud rate, reads the EEROM, checks to see if the firmware can be upgraded, and then begins operation. These activities do not disturb the normal operation of the UQM controller as it manages its electric motor. You can connect the diagnostic software to a UQM controller at almost any time.

We recommend that you save your system configuration to a file as soon as you begin using the software—this allows 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 7.6 for further details on saving system configurations.

7.3 Diagnostic Software Operation

The UQM Motor Diagnostic Software consists of a front panel with menu, toolbar, and status bar. The status bar is described in Section 7.2.2 above. Table 7.3 gives general descriptions of each group on the front panel. Figure 7.1 shows each of these groups.

Table 7.3: Front Panel Group Descriptions

General	Shows the motor, controller, build version, and date of the firmware in the controller. It also shows the the elapsed time since the last controller power-up of the controller in hours:mins:secs. 
Status	Shows the current 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 7.4. Indicates proper operation Indicates a cautionary or questionable situation Indicates a severely-limited or non-operation situation
Physical	Reports measurements for speed, torque, mechanical power, motor direction, and component temperatures. Any problem measurements are noted in the Status Group.
Electrical	Reports 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 if the motor is wired incorrectly to the controller.
Control	Reports the current control mode and control parameters of the motor system. Control mode options include: `CANbus Control` The modes are selected via the System Configuration (see further information in Section 7.4.)
Data Logging	Data logging controls the 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. 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 occurred. Significant time is required for extraction of the DAQ data from the controller. Details on DAQ are located in Section 7.3.

7.3.1 Measurement Update Speed

In normal operation, the front panel (Figure 7.1) 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, slow down the measurement rate to approximately 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. One exception is if Data Logging at 4x per second is occurring. DAQ file retrieval is not maximized so that the requested logging rate is maintained. Front panel measurements are updated normally in this case.

7.3.2 Status Group

The status group is an important area of the front panel because it shows the status of the motor system at that moment. Conditions are monitored and problems are reported that are currently affecting the normal operation of the motor system. Whenever a red light is showing in the status group, the controller could be severely limited in operation. Table 7.4 shows the conditions that can cause red and yellow lights in the status group.

Table 7.4: Status Group Problems

RED LIGHT	
EEROM failed	The persistent memory on board the controller has failed or is not programmed. The controller cannot operate.
Bad System Configuration	The system configuration information in the persistent memory is unusable. The controller cannot operate.
Unit not Calibrated	The calibration data in the persistent memory is not present. The controller is severely limited in operation.
Bad ADC Calibration	The calibration values are out of specification. Default calibration values are being used, and the controller is severely limited in 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 controller is severely limited.
Inverter Faulted	One or more inverter/controller modules are presently faulted. This is normal when high voltage is not present. However, if high voltage is present, the controller is severely limited.

RED LIGHT	
Untrusted Voltage	The two measurements of voltage made by the controller have diverged unexpectedly. The controller cannot operate.
Over Voltage	Bus voltage is over the allowable limit. The controller is likely to have gone into forced voltage control to bring this condition under control. The controller 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 controller imposes limitations on its output during this condition.
Leg Current too large	The motor's phase currents are exceeding limits. The controller is limiting torque.
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 controller 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) Switch(es)	The controller has detected a problem on one or more of the three motor phases (A, B, or C) and assumes one or more IGBT switches are bad for the controller module in question. The controller imposes limitations on its output.
Phase limited	In high speed operation, the controller's phase adjustment has reached its allowable limit. The controller imposes limitations on its output during this condition.
Inverter/Stator/Rotor Temperature Disconnected	The inverter/controller has detected a disconnected temperature sensor. The controller imposes limitations on its output during this condition.
Inverter/Stator/Rotor/ Over Temperature	The temperature measurement is over the allowable limit. The temperature limits are given on the "About UqmMotor" dialog box. The controller imposes limitations on its output during this condition.
No position signal	There are no position sensor inputs detected. Ensure that the position signal cable is connected properly. The controller cannot operate.
Rotor movement	The controller has detected a condition that often indicates that the rotor or the position-sensing equipment has moved. The controller imposes limitations on its output.
Position signal is bad	The position signal is bad. The controller cannot operate and must be reset. Ensure that the position cable is properly connected.
Position error too large	The amplitude of the error on the position signal has become too large so the position signal itself is suspect. The controller cannot operate.
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 continually occurring.
Forced Open Loop	The controller is operating in forced open loop control and is limited in capability. This can occur because of bad sensor measurements.
CANbus communication error	The CANbus communication has ceased and the controller is disabled. This is the CANbus watchdog error and must be reset via the heartbeat command through CAN. See the **CANbus Manual** for further details.
IBus CT Fault / ILeg CT Fault	The measurement sensors are untrustworthy and the system cannot operate.

RED LIGHT	
Limp Home happening	Indicates that the inverter has detected a condition that causes it to limit system torque to that specified by the **Limp Home Percentage**
Power switches off	Indicates that the inverter has detected a condition that causes it to shut down the IGBT Switches

YELLOW LIGHT	
Disabled	The controller 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 controller modules has faulted and the fault was cleared. The controller is limited in operation.
Motoring limited to x%	This caution appears whenever motoring ability has been limited to less than 100%. Besides the conditions outlined throughout this table, motoring can also be limited by a CANbus command.
Regen limited to x%	This caution appears whenever the motor's generation ability has been limited to less than 100%. Besides the conditions outlined throughout this table, generation can also be limited by a CANbus command.
Power close to or over limit	Electrical power is close to or over the allowable limit of the motor system. The controller will experience regeneration limitations.
Voltage Warning	Bus voltage is nearing its allowable limit. The controller will experience regeneration limitations.
Under Voltage	Bus voltage is too low to operate normally. Motoring is limited.
Voltage causing torque limitation	Bus voltage is below the nominal voltage for system operation. Maximum motoring and regen will be limited accordingly.
Speed Warning	The motor speed is near the allowable limit. Motoring will soon be 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.
Inverter/Stator/Rotor/ Temperature warning	The temperature measurement is approaching the allowable limit. The temperature limits are given on the "About UqmMotor" dialog box. The controller 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 controller is in CANbus control but no CANbus communication has yet been detected. The controller is disabled.
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 periodically limited in output to prevent damage to the controller 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 controller limit, which would damage the hardware. The controller drops out of forced voltage control automatically when the battery is re-connected.
Leg current separation occurring	The motor's phase legs have some current separation (vertical displacement from one phase to another). No limitation occurs with this message.

YELLOW LIGHT	
Direction mismatch	The desired direction in the 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.
Torque matching problem	If this condition persists, the controller is indicating that it is unable to control the motor to the desired torque. This could be because the motor has partially demagnetized.
Limiting acceleration	Torque is being limited due to the acceleration limit in force.
Actively Damping	The Active Damping Control is altering the torque to damp out a drive train oscillation. See Section 7.4.1 for more information.
Regen disabled	The Regen Switch is open and regeneration power is impossible. The switch will close when the internal and external voltage measurements close to within 25V of each other
System Halt	The system is not operational. Voltage must rise to the minimum battery level before the system becomes operational.
ManuInfo invalid	The manufacturing information present in the inverter is invalid. This may mean that there is a problem with the inverter's EEROM.
Event Log disabled	The Event Log is inoperable. This does not affect motor operation.

7.3.3 Menu Bar and Toolbar

The diagnostic software has a menu and toolbar to access other functionality beyond condition and measurement information. Table 7.5 describes the menu's choices and shows those that have Toolbar buttons.

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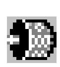
Figure 7.4: Menu Bar and Toolbar

Table 7.5: Menu and Toolbar Descriptions

Menu Choice		**Button**	**Description**
File	Recent Files		Shows the four most recent log or DAQ files written by the software.
	Exit		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. Only one marker is allowed per day.

Menu Choice		Button	Description
	System Configuration		Opens a pop-up 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.
	DAQ Configuration		Opens a pop-up menu with multiple DAQ configuration options. See DAQ, Section 7.6 for more details.
	Change COM port		Closes communication to the controller through the serial port and brings up the "Change COM Port" dialog box. Canceling this dialog box causes the diagnostic software to exit. See Section 7.2 for more details.
	Show CAN tests		Shows the CANbus Test dialog box. This dialog box generates and sends CANbus errors and status condition messages, so you can test whether your connecting software is responding correctly. See the **UQM CANbus Interface Manual** for more details.
	Allow PWMs at Stop		Normally, the pulse width modulation (PWM) the UQM controller 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 controller 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	User Manual		Shows the **UQM Motor System User Manual**. This is a PDF file.
	CAN Manual		Shows the **UQM CANbus Interface Manual**. This is a PDF file.
	About UqmMotor		Opens the "About UqmMotor" dialog box, showing the application's version number and the attached controller's temperature limits.

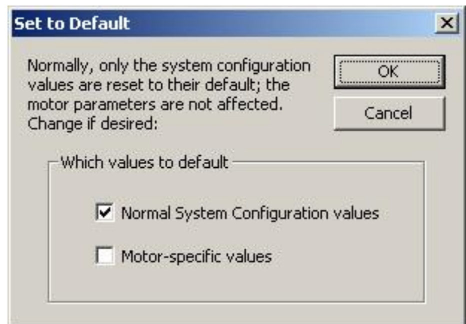
7.4 System Configuration

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, a 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.*

System Configuration is accessed via the menu: **Actions > System Configuration**. Table 7.6 describes the choices found in the pop-up menu accessed from this point.

Table 7.6: 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 populated 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 you saved on arrival to return to YOUR defaults. This menu choice does not return the motor-specific parameters to default unless requested.  Figure 7.5: Set To Default
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 the default values 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 different controllers while still allowing each motor to have its specific parameters untouched.
Load QSC file as motor		Acts like “Load QSC file,” but loads all motor-specific parameters as well as the template portion of the chosen QSC file. Use this method if you are moving a controller from one motor to another. This method causes the controller’s motor-specific parameters to be reloaded with the new motor’s numbers. *Verify that you are loading the correct motor’s parameters.*
Load ONLY motor data		Acts like “Load QSC file”, but loads ONLY motor-specific parameters, without the template portion of the chosen QSC file. Use this method if you are moving a controller from one motor to another, and would like to maintain the template portion of the System Configuration already saved in the controller. This method causes the controller’s motor-specific parameters to be reloaded with the new motor’s numbers. *Verify that you are loading the correct motor’s parameters.*

The System Configuration dialog box is tabbed to provide access to the system parameters. Tabs are listed in Table 7.7.

Table 7.7: System Configuration Tabs

Tab Choice	Description
Control	Provides access to the Control modes and the settings affecting those modes.
Torque Profile	Provides access to the torque profile that limits the torque/power output of the motor.
CANbus Settings	Provides access to the digital control CANbus parameters like baud, style, and frequency of information.
System Parameters	Provides access to the parameters describing the entire system, like the battery, friction, and speed.

NOTICE *Changes to the system only take effect at system startup. If changes are made when the motor is not moving, the controller will reset itself, and the changes will take effect immediately. If changes are made while the motor is in motion, the changes will be stored and will take effect the next time power is applied to the controller.*

7.4.1 Control

The Control tab, shown in Figure 7.6, provides access to the control modes of the UQM motor system, and the settings affecting those modes.

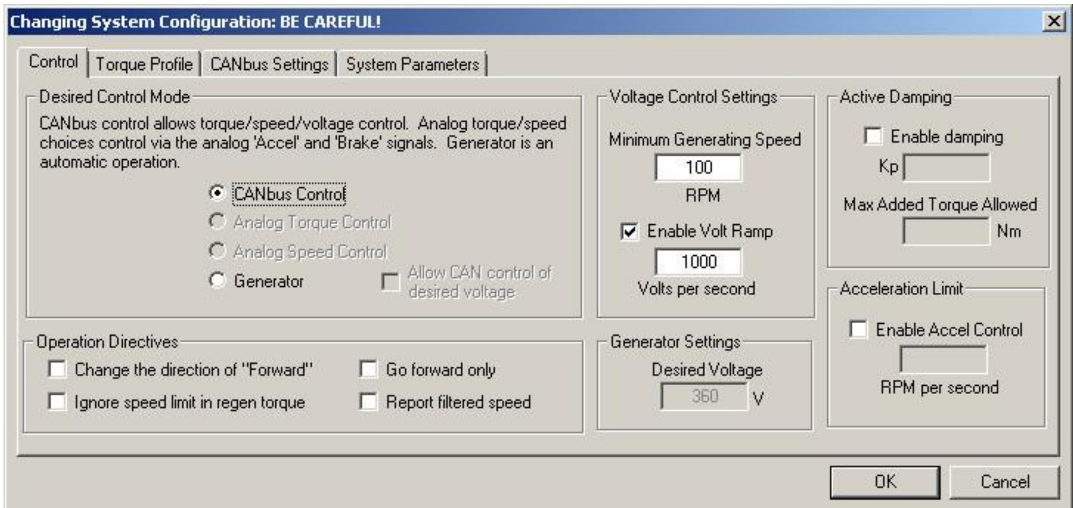


Figure 7.6: Control Tab

Desired Control Mode

The **Desired Control Mode** (Figure 7.7) determines how the motor is controlled.

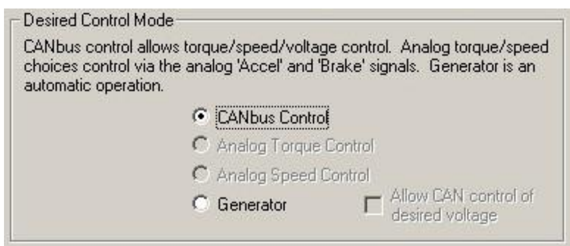
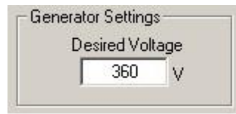
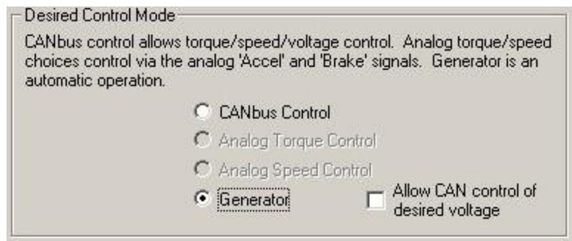
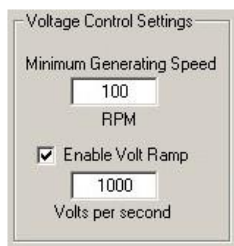


Figure 7.7: Desired Control Mode Selection Box

Table 7.8 : Desired Control Modes/Generator Settings

Control	Description
CANbus Control	The **CANbus Control** radio button allows control of the system via CAN bus messages. Further details about CANbus Control can be found in Section 7.4.1 of this manual.
Analog Torque Control	This control mode is unavailable on the PP HD systems.
Analog Speed Control	This control mode is unavailable on the PP HD systems.

Control	Description
Generator	The **Generator** control mode is intended for certain applications in which the system functions solely as a generator. In this mode, the controller starts in Voltage Control at power-up, and it attempts to maintain the bus voltage level specified in the Desired Voltage box (Figure 7.8).  Figure 7.8: Generator Settings If your generator application requires the ability to change the Desired Voltage setting via CAN commands during operation, you can check the “Allow CAN control of desired voltage” box (Figure 7.9).  Figure 7.9: Desired Control Mode Note that the controller in generator mode will not attempt to generate power if the motor is spinning too slowly. This minimum speed threshold can be specified in the Minimum Generating Speed box (Figure 7.10).  **Figure 7.10: Voltage Control Settings** The Volt Ramp setting (shown above) allows the user to set a slew rate limitation on the generated bus voltage. Please note that many generator applications require more flexibility and should should use **CANbus Control** instead of **Generator** mode. For example, in many starter/generator applications, the UQM motor first spins an internal combustion engine to start it, and afterwards functions as a generator. In such an application, a CANbus Speed Control command would spin the motor to start the engine, and then a CANbus Voltage Control command would specify the desired voltage level, causing the controller to function as a generator.

Operation Directives

The **Operation Directives** (Figure 7.11) allow you to tune very specific settings affecting operation, listed below in

and Table 7.9.

Figure 7.11: Operation Directives

Table 7.9: Operation Directives Settings

Control	Description
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 to switch the direction names, so that controller changes the direction it calls ‘forward,” check or uncheck this selection. When unchecked, “forward” corresponds to leg order “A-B-C” in the Critical group of the Diagnostic Software front panel. When checked, “forward” corresponds to “C-B-A.”
Ignore speed limit in regen torque	Previous versions of the UQM controller firmware “ignored” (i.e., assumed zero RPM for) the speed limits in the CANbus Torque Control commands when regneration torque was requested; the speed limits only affected motoring torque requests. However, by default, the current version of the firmware does NOT ignore these speed limits for regeneration torque commands. The purpose of this box is to allow backwards compatibility; check this box if your application requires the old behavior. If unsure, leave this box unchecked, which is the default.
Go forward only	Check this box to take away the motor’s ability to go in reverse. Note that the “reverse” definition is your choice.
Report filtered speed	Normally, the unfiltered speed measured by the UQM controller is reported through the CANbus and the diagnostic software. This speed shows changes in rotor speed quickly, but has inherent noise as well. Checking this box changes the speed reported to a filtered speed that significantly lessens the noise but causes an 80 millisecond delay in showing changes in speed.

Active Damping Setting and Acceleration Limit

CAUTION *Enabling Active Damping with added torque allowed may violate torque security strategies. The customer is responsible for addressing any regulatory requirements. See Section 1.4.1.*

The **Active Damping Setting** and **Acceleration Limit Setting** allow you to access the acceleration control features of the UQM controller. Active Damping can help mitigate vehicle drive train oscillations, and Acceleration Limit defines a maximum allowable acceleration for the UQM motor. See Figure 7.12, Figure 7.13, Table 7.10, and Table 7.11.

Figure 7.12: Active Damping

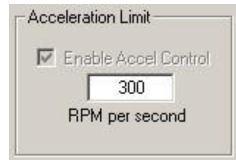


Figure 7.13: Acceleration Limit

Table 7.10: Active Damping

Control	Description
Enable Damping	This checkbox/edit box manages the Active Damping feature. No active damping will occur until the checkbox is checked. If checked, this safety will take away torque to reduce the oscillations. Note that an Acceleration Limit must be specified when Active Damping is enabled.
Kp	No active damping will occur until the checkbox is checked. Once checked, the Kp = 1 by default. A Kp = 2 doubles the corrective damping signal. A Kp = 0.5 halves the amount of corrective torque.
Max Added Torque Allowed	The amount of torque the safety is allowed to exert beyond the CAN requested torque in either motoring or regeneration. It is limited to 10% of the maximum torque. If set to 0, then the safety is only allowed to take away torque.

Table 7.11: Acceleration Limit

Control	Description
Enable Accel Control	This checkbox/edit box manages the maximum desired acceleration rate of the UQM motor.
RPM per second	This value can be set to the maximum expected rate of acceleration in the motor's application, and the system automatically reduces torque if this acceleration limit is exceeded (for example, if a vehicle is slipping on ice).

Active Damping and Acceleration Limit are discussed in greater detail in Sections 6.3.2 and 6.3.3 of this manual.

7.4.2 Torque Profile

The torque profile tab, shown in Figure 7.14, controls 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 regeneration the motor can do.

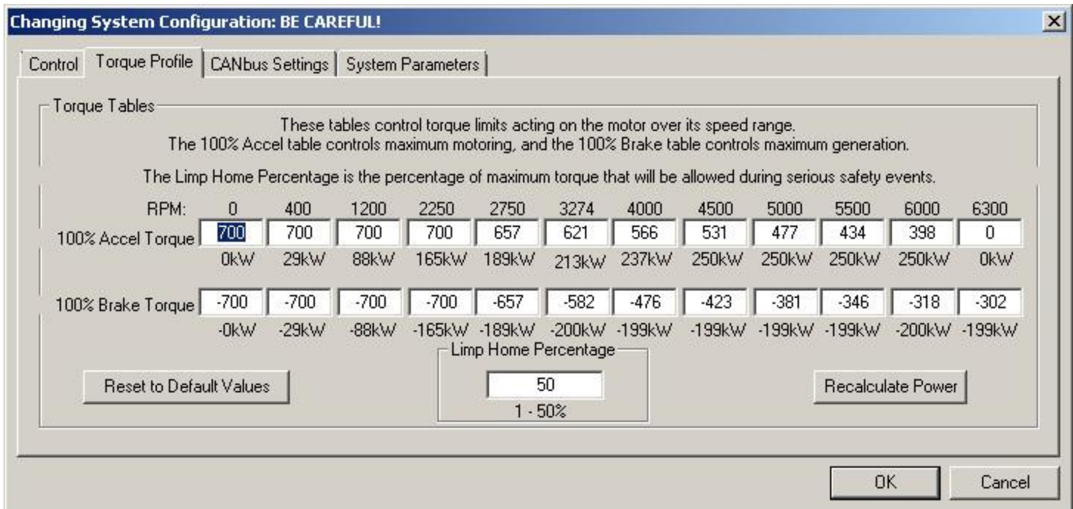


Figure 7.14: Torque Profile Tab

Speed/Torque values between each point on the table are linearly interpolated. In CANbus control, these torque profiles limit the absolute amount of torque available at each speed point. (Torque control is also described in Section 7.4.1.)

Note that for some generator systems, the listed values in the Brake Table can exceed the rated power of the system. This listed power is the calculated mechanical power for that speed and torque level. After taking losses into account in regeneration, the electrical power will be less than the mechanical power at the same speed and torque. This system has a maximum regeneration current allowed, which limits the electrical power as a function of voltage, and is less than the rated motoring power.

The **Reset to Default Values** button resets both the Acceleration and Brake tables back to the default settings for the system. The **Recalculate Power** button re-calculates the power values displayed in the dialog, if the torque values have been changed.

Here are two situations in which torque profiles 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 600 Nm, then the 100% Acceleration Table would contain 600 Nm for entries 0 RPM through 3274 RPM, and all other entries would remain unchanged.
- **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 Nm before the critical speed. In the system illustrated in Figure 7.14, if the drive train component were limited to 4000 rpm, then all values above this speed on the 100% Acceleration Table would be set to 0 Nm.

Limp Home Percentage

Limp Home Percentage (Figure 7.15) is the percentage of max torque at current speed the system is allowed to produce while in the **Limp Home** mode.

E.g.: for the displayed system (Figure 7.14) the torque limits are +700 to -700 Nm from 0 to 2250 rpm and decrease to 398 to -318 Nm at 6000 rpm. If the system is in the **Limp Home** mode and the **Limp Home Percentage** is set to 50, those limit will decrease to +350 to -350 Nm from 0 to 2250 rpm and 199 to -159 Nm at 6000 rpm with proportional decreases in the values between 2250 and 6000 rpm.

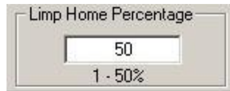


Figure 7.15: Limp Home Percentage

7.4.3 CANbus Settings

The CANbus is the UQM motor system's digital control mechanism. This tab, shown in Figure 7.16, provides access to the communication parameters like baud, style, and frequency of information. (See the **UQM CANbus Interface Manual** for complete details of CANbus control functionality.)

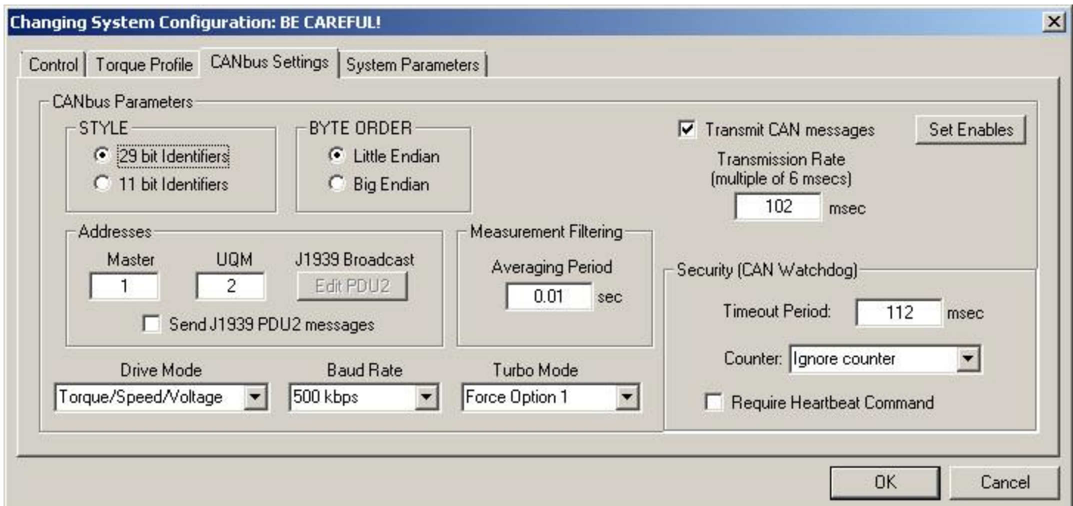


Figure 7.16: CANbus Tab

The functionality of each section of this tab is described in the following paragraphs.

Style

Select the CANbus communication style desired (Figure 7.17). 29-bit identifiers are used in CANbus Standard 2B, and 11-bit identifiers are used in CANbus Standard 2A.

Figure 7.17: Style

Byte Order

Select the byte order of the data sent over the CANbus (Figure 7.18). In Little Endian mode (the default mode), all 16-bit values are broadcast LSB/MSB; whereas in Big Endian mode, all 16-bit values are broadcast MSB/LSB. Note that all 8-bit values and single-bit fields are unchanged by this setting.

Figure 7.18: Byte Order

Addresses

When in 29-bit style, **Addresses** (Figure 7.19, Figure 7.20, and Table 7.12) configures the CANbus message addressing scheme.

Figure 7.19 Addresses

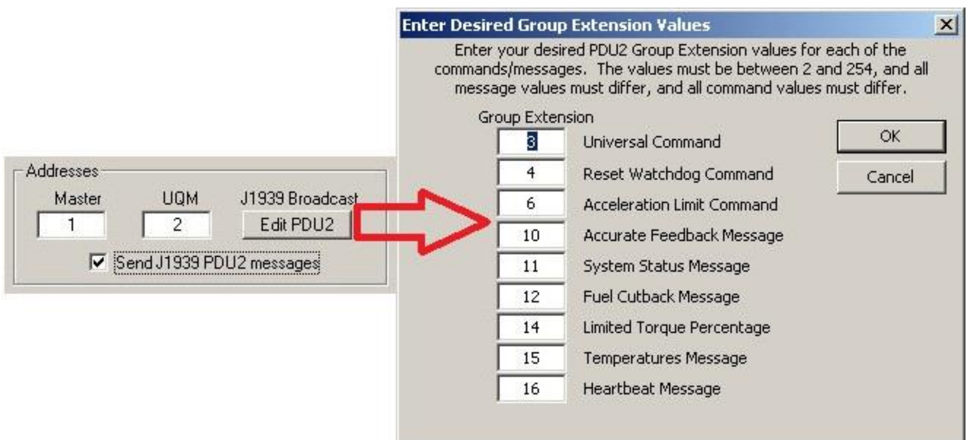


Figure 7.20: Enter Group Extension Values

Table 7.12: CANbus 29 bit addressing

Control	Description
Master	CANbus address of the master that will be commanding the UQM controller.
UQM	CANbus address of the UQM controller.
Send J1939 PDU2 messages	Configure the UQM controller to use the J1939 PDU2 addressing format. Selecting the checkbox will cause the **Enter Desired Group Extensions** popup to appear to allow the user to configure the message group extensions. Note that the UQM controller uses the J1939 PDU1 addressing format by default.

Control	Description
J1939 Broadcast	When the **Send J1939 PDU2 messages** checkbox is enabled, clicking this button will cause the **Enter Desired Group Extensions** popup to appear to allow the user to configure the message group extensions.
Enter Desired Group Extensions	This popup allows the user to configure the J1939 PDU2 message extensions.

Drive Mode

The UQM motor can be constrained to support only one control mode (either torque or speed), or it can be allowed to support both at once (Figure 7.21).

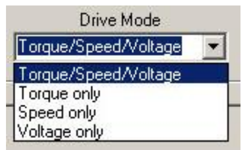


Figure 7.21: Drive Mode

Turbo Mode

Turbo Mode (Figure 7.22) gives the most amount of power possible at the highest efficiency possible. However, it also creates additional audible harmonic content inside the motor. The user can trade off efficiency and auditory noise through three options for transitioning into and out of Turbo Mode (See Table 7.13). The wake-up choice can be selected here in System Configuration. If the Use CAN Value option is selected, then the CANbus Universal Command will determine the selection. If any of the **Force Option** choices are selected, that option cannot be changed by the Universal Command Control Parameters bytes. UQM recorded datasheet information and performance testing with Force Option 1.

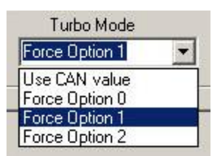


Figure 7.22: Turbo Mode

Table 7.13: Turbo Mode Options

Option	Action
USE CAN Value	Options 0, 1, and 2 are set via the **Turbo Mode** field of the **Universal Command** CAN message. The modes perform as stated below.
Option 0	The system transitions in and out of Turbo Mode based on operating speed and voltage. There is a 200 rpm hysteresis band to ensure Turbo Mode is not entered and exited repeatedly.
Option 1	The system is defaulted to Force Option 1.This option increases the speed range over which Turbo mode operates. The transition occurs at a lower speed compared to any of the other options. When compared to Option 0, the result is higher system efficiency between the Option 1 and Option 0 transition speeds. The audible noise of the system is higher between these speeds.

Option	Action
Option 2	This mode restricts the Turbo mode to a small range, transitioning at a higher speed than any of the other options. The efficiency leading up to the transition speed, therefore, is lower than any of the other options. This is also the quietest mode, with the lowest audible noise at speeds leading up to, and including, the transition speed.

See the **UQM CANbus Interface Manual** for full details of these options.

Baud Rate and Transmission Rate

The CANbus baud rate (Figure 7.23) applies to all messages. The frequency at which the UQM controller should transmit the accurate feedback messages is controlled through Transmission Rate (Figure 7.24).

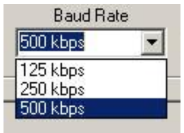


Figure 7.23: Baud Rate

Figure 7.24: Transmission Rate

Transmit CAN Messages

The Transmit CAN Messages checkbox (Figure 7.24) controls whether the messages are transmitted or not. If the master checkbox is selected, then the UQM controller transmits the individual messages that are checked within the dialog box brought up by the Set Enables button (Figure 7.25).

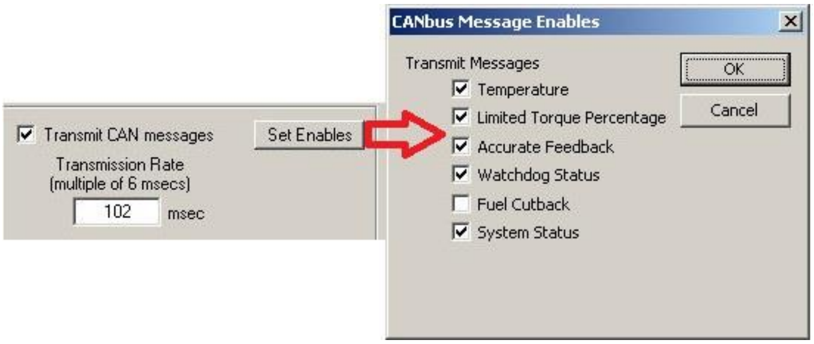


Figure 7.25: CANbus Message Enables

Security (CAN Watchdog)

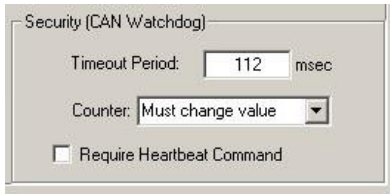


Figure 7.26: Security (CAN Watchdog)

Control security is provided through the CANbus Watchdog (Figure 7.26), a timer that monitors the frequency of valid control commands received by the inverter on the CANbus. When the CANbus Watchdog times out because a valid command did not arrive in time, the inverter either drops to zero torque requested if in Torque Control, or drops to zero speed requested with very limited torque if in Speed Control.

Timeout Period

Defines the time period within which a valid command must arrive. It can be set from 40 milliseconds up to 1 second. The default Timeout Period is 100 milliseconds.

Counter

Determines the level of security required of the rolling counter in the Universal Command. The rolling counter essentially makes it harder for a received command to be judged as valid. There are three levels of security:

Ignore counter is the default, and means that no counter security is enabled. Every validly built command will be judged valid. If a repeater is in the system and keeps sending the same command over and over, they will be judged valid and the CANbus Watchdog will not complain.

Must change value means that the counter cannot freeze in value, but as long as it has changed value within each subsequent command received, the command will be considered valid.

Must count in order means that the counter must count from zero to 15 (and repeat) in order within each subsequent command received. Any command that does not follow in that order will not be a valid command, and if it continues for the timeout period a CANbus Watchdog event will occur.

Require Heartbeat Command

Adds another level of security by requiring two different commands be received by the UQM controller within the timeout period. The Universal Command is ALWAYS required, but checking this box means that the Heartbeat Command must also arrive regularly.

7.4.4 System Parameters

The System Tab (Figure 7.27) provides access to the parameters describing the entire system, such as the battery parameters, the system friction, or the maximum speeds.

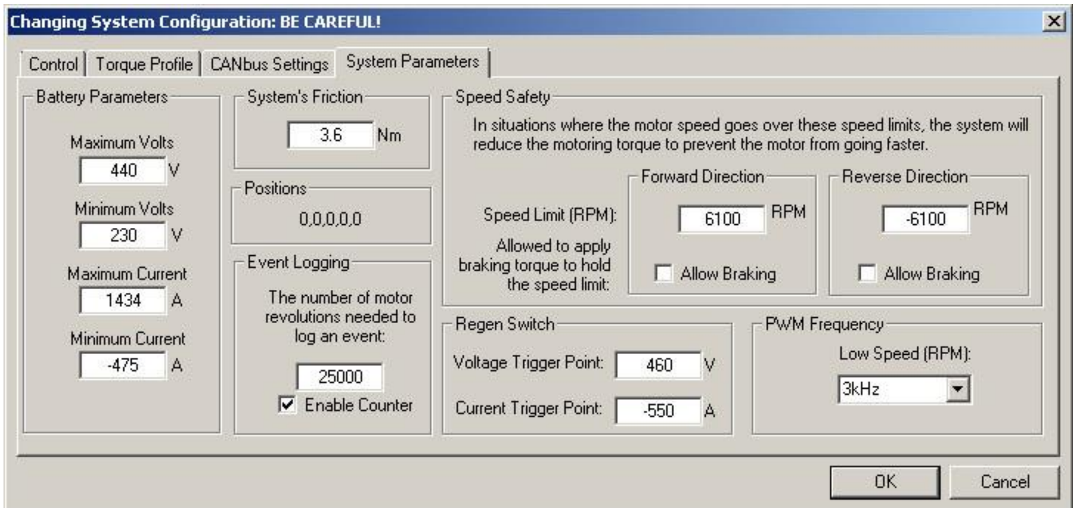


Figure 7.27: System Configuration Tab

The functionality of each section of this tab is described in the following paragraphs.

Battery Parameters

The **Battery Parameters** (Figure 7.28) allow you to specify the Over and Under Voltage and Current settings that cause output limiting by the UQM motor system when they are approached.

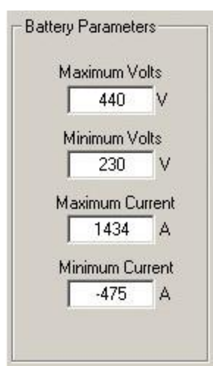


Figure 7.28: Battery Parameters

Please note that the parameters shown in Figure 7.27 are for the PPHD220 system. Other systems in the PP HD family may have different limits.

Table 7.14: Battery Parameters

Control	Description
Maximum Voltage	The controller limits regeneration when the voltage is above this setting.
Minimum Voltage	The controller limits motoring when the voltage is below this setting.
Maximum Current	The controller limits motoring torque when this bus current is reached.
Minimum Current	The controller limits regeneration torque when this bus current is reached.

System Friction

The **System's Friction** (Figure 7.29) is a torque value of the amount of friction the UQM motor encounters in your system. The UQM controller uses this value to correct its output and its torque measurements so that they better match your requests.

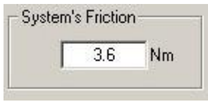


Figure 7.29: System's Friction

Positions

The **Positions** area (Figure 7.30) normally shows five zeroes, but if your UQM system is tuned for the particular motor it is attached to, position correction values are shown here. These values aid in efficiency. This field is not used in the PPHD220, PPHD250, and PPHD950T systems.

Figure 7.30: Positions

Event Logging

The **Event Logging** value and enable checkbox (Figure 7.31) controls the motor revolutions counter. When enabled, an event is written to the event log when the number of motor revolutions specified in the edit box has passed. When Event Logging is disabled, no revolution count events are logged. See Event Log, Section 7.7, for more information.

Figure 7.31: Event Logging

Speed Safeties

The **Speed Safeties** (Figure 7.32 below) 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. If the motor speed goes over the speed limit threshold, the system reduces the motoring torque to prevent the motor from going faster.

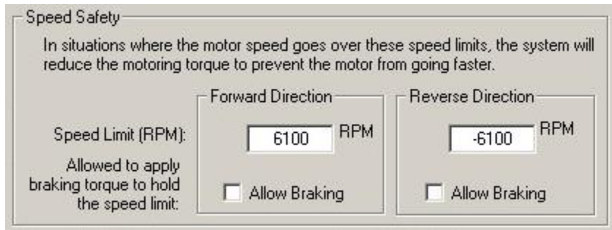


Figure 7.32: Speed Safety

Table 7.15: Speed Safeties Options

Control	Description
Speed Limit (RPM)	The RPM speed is where you want the limit. The torque begins to be limited at this speed.
Allow braking	Check this box to allow the system to apply braking (regeneration) torque to maintain the speed limit. This is useful in situations in which the vehicle is moving down a hill, and removing all the forward (motoring) torque is not enough to prevent the vehicle from speeding up. On the other hand, if this box is NOT checked, the controller will be restricted to removing forward torque in attempt to reduce speed, and it will not apply any braking torque, even if the speed is increasing past the specified limit.

Regen Switch

Figure 7.33: Regen Switch

The **Regen Switch** (Figure 7.33) section allows you to lower the voltage and current points where the Regen Switch will open in order to protect your battery system. By default they are set to the maximum values possible.

NOTICE	*The Voltage Trigger Point must be at least 20V greater than the Maximum Voltage in the Battery Parameters, and the Current Trigger Point must be 20A lower than the Minimum Current in the Battery Parameters.*

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 quarter-second to multiple-second rates. The diagnostic software can log data at these rates indefinitely, only limited by the disk drive space of your computer.

Log files are located and named via the logging set up dialog box. The files are numbered so that each name is unique and no data is lost. The naming convention includes the date. For example, two files taken on June 21st, 2013 with default settings would be named:

`20150318LOG_test00.csv`

`20150318LOG_test01.csv`

Note that the Data Logging feature also automatically saves a file with the extension "`.uqm`". This file contains additional log data that UQM can use in diagnosing issues. If you are experiencing problems, we usually request that you e-mail both the "`.csv`" log file and the "`.uqm`" file to UQM.

Logging is controlled via the right top corner of diagnostic software's front panel. Figure 7.34 Figure 7.34 and Table 7.16 show details of these controls.

Figure 7.34: Front Panel Components of Logging

Table 7.16: Front Panel Logging Group Components

Label	Description
Put into name	The edit box is a shortcut to setting the name portion of a logging filename. Normally, this name is set in the logging Set Up, but it is sometimes more convenient to change the filename without going into the Set Up dialog box.
Set Up	Opens the Logging Set Up dialog box. This functionality is described in detail later in this section.
Log	Starts the logging of data into the log file. If a file is already logging, it closes that file and opens a new file. If a logging file is paused, it continues logging into the paused file.
Pause	Pauses the logging of data into the log file.
Stop	Stops logging and closes the log file.
Show Log	Starts your spreadsheet program with the last closed data log file. This feature will only work if you have a spreadsheet program has the file type associated for the CSV (comma-separated values) file format.

7.5.1 Logging Set Up

The Logging Setup dialog box controls where and how data logging occurs. Figure 7.34 illustrates this dialog box, invoked via the “Set Up” button in the Data Logging group. Table 7.17 describes each component of this dialog box.

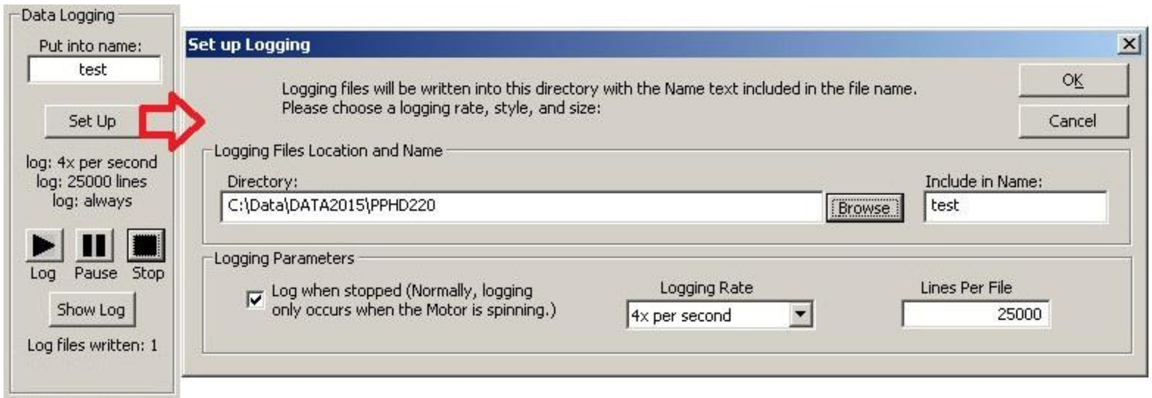


Figure 7.35: Logging Set Up Dialog Box

Table 7.17: Logging Set Up Components

Label	Description
Directory: Browse button	Enter the directory where Log 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 log filename. It includes the date, this text, and an incrementing number.
Log when stopped	Normally logging only occurs when the motor is spinning. If you want data to be logged at all times, then select this box.
Logging Rate	Select the rate that you want data logged.
Lines Per File	Enter the number of rows you want in each logging file. The diagnostic software will open a new file (incremented name) when this number of rows has been stored into a logging file.

In general, Data Logging stores one snapshot of measurement data every second or at an integer multiple of seconds. The fastest rate that data can be logged is four times a second. If you need faster data acquisition, then you should use the data acquisition feature of the UQM Motor System (see Section 7.6).

NOTICE *Logging at a four or two times per second rate will slow down the extraction of a data acquisition file.*

This data is stored in a spreadsheet file, with a snapshot of data measurements forming one row in the spreadsheet. The file format used is the comma-separated values (CSV) format. You can control the size of these files using the logging setup and the **Lines Per File** setting. By default, 25,000 rows of data are stored per file. Once a file is full, it is closed, and the next incremented file name is opened.

Data logging of measurements can be paused and continued into the same file using the **Pause** button. It is not possible to reopen a file and continue logging into it if that file has been closed. If you click on the **Log** button while the diagnostic software is actively logging, then the current log file is closed, and a new file is opened.

NOTICE	*Normally, the diagnostic software logs data into the file only when the motor is spinning. This means that you can start a log and have an active log file even when no data is being logged because the motor is quiescent. It begins automatically logging data when the speed reported by the motor is non-zero. If you want to log data even when the motor is motionless, open the Set Up dialog box and select the "Log when stopped" check box.*

One row of data contains the measurements shown in Table 7.18.

Table 7.18: Logging and DAQ Measurement Columns

Column Label	Description
General	A column containing the motor and controller 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 displays the controller'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 show what has happened since the file was opened. Note that this field is present only in Data Logging files, not in DAQ files.
System Error	The controller's System Error word in decimal format. See the **UQM CAN Manual** for further details.
Operating Time(secs)	This is the controller's operating time: the number of seconds since the controller 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.
FilteredSpeed	The filtered output of the motor speed, in revolutions per minute. This number multiplied by the value in the Motor Direction column is a signed speed value.
Actual Torque (Nm)	The torque in Newton meters, as calculated by the controller.
Friction (Nm)	The friction amount, in Newton meters, being used by the controller in its control calculations to overcome system friction. See Section 7.4 System Configuration to change the system friction.
Mech Power (W)	The mechanical power in watts, as calculated by the controller from the actual torque and speed.
Motor Direction	The direction of the motor. 1 is "Forward" and –1 is "Reverse." This value multiplied by either Speed or FilteredSpeed provides signed speed values like those available through CANbus.
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 controller at its cooling block in degrees Celsius.
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 controller from the bus voltage and current.
Leg Current (A)	The measured envelope of the current motor's phase legs.

Column Label	Description
Acceleration (RPM/sec)	The calculated rate of acceleration of the UQM motor. The maximum acceleration rate can be specified in the System Configuration (Section 7.4).
Stall Percentage	The stall percentage value counts up from 0 to 100 as the motor approaches stall conditions. When the count reaches 100, a stall condition is detected, and the motor will limit torque to 10% of rated output for 30 seconds. For more information on stall conditions, please refer to Section 6.4.3.
RevCounter	Positive integer number of motor revolutions since the inverter was power up
AngularDistance	Total angular distance the motor has traveled since the inverter was powered up (1 count = 3.75°). Travel in the Forward direction is positive. Travel in the Reverse direction is negative.
Desired Direction	The requested direction of the motor. A 1 is "Forward" and –1 is "Reverse."
Requested Torque (Nm)	This is the amount of torque requested by the user, in Newton meters. The values reported in this column come directly from the received CAN torque commands. This is useful in debugging because it allows the user to check whether the CAN commands contained the correct values and were received by the controller. In contrast, the *Desired Torque* column reports the torque that the controller intends to produce, after applying safeties and limits to the requested torque.
Desired Torque (Nm)	This is the amount of torque, in Newton meters, that the controller intends to produce. This column may differ from the *Requested Torque* column due to CAN limits or safety limitations. For example, if the user requests a large value of forward torque, but the motor is already spinning at its forward speed limit, the desired torque will be reduced to avoid exceeding the speed limit. Furthermore, the value in the *Desired Torque* column may differ slightly from the value in the *Actual Torque* column because the desired torque is the amount of torque that the motor intends to produce, whereas the actual torque is determined from measurements and best reflects the torque that the motor is truly producing.
Requested Speed (RPM)	This is the speed requested by the user, in revolutions per minute. The values reported in this column come directly from the received CAN speed commands. This is useful in debugging because it allows the user to check whether the CAN commands contained the correct values and were received by the controller. In contrast, the Desired Speed column reports the target speed of the controller, after applying safeties and limits to the requested value.
Desired Speed (RPM)	This is the speed that the controller aims to maintain, in revolutions per minute. If the controller is not in speed control, this number is meaningless. This column may differ from the *Requested Speed* column due to CAN limits or safety limitations. For example, if the torque limits in the CAN speed command are too restrictive, the controller will be unable to maintain the desired speed, and as a result the desired speed would be less than the requested speed. Note that the *Speed* and *FilteredSpeed* columns report the actual, measured speed of the motor, whereas *Desired Speed* reports the controller's target speed.
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 is a value below 100%.
Regen Limit (%)	If any limits are acting on any regeneration torque demand, this is a value below 100%.

Column Label	Description
HighestTorqAllowed (Nm)	The maximum motoring torque allowed at this moment. This value is affected by many limits (voltage, temperature, etc.) and command limits. Those limits are reflected by the Motoring Limit percentage.
LowestTorqAllowed (Nm)	The maximum regeneration torque allowed at this moment. Affected by many limits (voltage, temperature, etc.) and command limits. Those limits are reflected by the Regen Limit percentage.
Highest Power Allowed (kW)	The maximum motoring power allowed at this moment.
Lowest Power Allowed (kW)	The maximum regeneration power allowed at this moment
Accel Limit (RPM/sec)	The acceleration limit value that has been set as of this moment. It is the maximum expected rate of acceleration (in RPM per second) for the motor's application. The system will automatically reduce torque if this acceleration limit is exceeded.
Accel Surge (RPM)	The acceleration surge value that has been set as of this moment. It is the speed difference range (in RPM) that the motor's acceleration might be surging above the acceleration limit as the inverter tries to bring the acceleration under control.
Damping Torque (Nm)	The Active Damping corrective torque signal in Newton meters. See Section 6.3.3 for further description of Active Damping.
TorqueMatchingProblem	Displays a 1 if the desired and actual torque of the UQM motor are consistently not matching due to motor demagnetization or other factors. A 0 is displayed if it is matching consistently.
SwitchesOff	False (0) when power switches are active. True (any non 0 value) when power switches are not active.
RegenSwitchOpen	If there is a Regen Switch in the system, this would indicate that it is open with a 1.
Position Noise Level	Rate of noise on the position signal. 0 = No noise. Any non zero value indicates that there is noise on the position signal. 5 = max measurable noise level.
Noisy Positions	The count of noisy position events that have occurred since wake-up.
CAN Comm	A 1 indicates that CAN communication is active. A 0 indicates that it is not.
CAN Limiting	A 1 indicates that a CAN limit is in effect. A 0 indicates this is not the case.
Enabled	A 1 is displayed if the controller in enabled. A 0 indicates it is not.
Turbo Mode	A 1 is displayed if the controller is in Turbo Mode, a 0 if it is not. Turbo Mode is UQM's proprietary control algorithm that produces outstanding power and efficiency at high speeds.
Torque Control	A 1 is displayed if the controller is in torque control, a 0 if it is not.
Speed Control	A 1 is displayed if the controller is in speed control, a 0 if it is not.
Voltage Control	A 1 is displayed if the inverter is in voltage control, a 0 if it is not.
Forced Voltage Control	A 1 if the controller has entered forced voltage control (a safety response to dangerous voltage levels), a 0 if it is not.
Forced OL	A 1 if the controller is in forced open loop, a 0 if it is not.
Stalled	A 1 if the controller is responding to stall conditions, a 0 if it is not.
Accel Limiting	A 1 if the motor acceleration is being limited by the maximum acceleration safety; a 0 if it is not.
Bad Switch	If non-zero, indicates that a IGBT Switch error is occurring. A upper=32, A lower=16, B upper=8, B lower=4, C upper=2, C lower = 1

7.6 Data Acquisition

UQM's data acquisition (DAQ) feature is a powerful diagnostic tool for your system design. The UQM Motor System measures 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 triggering event has occurred.

Significant time is required to extract the DAQ data from the UQM controller. The amount of time is dependent on the baud rate and whether Data Logging is also occurring. If your connection speed is 115200 baud and you are not logging, then a download takes approximately 50 seconds. If you are Data Logging at a four times per second rate, then an additional 20 seconds is added to the extraction time. Files take several minutes to extract when running at a baud rate of 19200.

The measurement data taken and stored in a data acquisition file is identical to the data stored in a data-logging file; it is simply taken at a faster rate and has a controlled length. See Table 7.18 for details of the measurements in a data acquisition file. In addition, a diagnostic UQM file is generated, useful to the UQM factory when advanced diagnostics are required.

DAQ Configuration is accessed via the menu choice **Actions > Daq Configuration**. Choices found in the pop-up menu accessed from this point are described in Table 7.19.

Table 7.19: DAQ Configuration Menu

Menu Choice	Button	Description
Edit Settings		Shows the Data Acquisition Set-up dialog box. See and Table 7.20: Front Panel DAQ Group Components for more details.
Edit Levels		Shows the DAQ trigger levels dialog box. See Figure 7.38 and Table 7.21: DAQ Trigger Descriptions for more details.
Save to file		Saves the current DAQ configuration settings to a QDC file.
Load from file		Loads a DAQ configuration file into the UQM Motor controller.

In addition to menu access, complete Data Acquisition functionality is accessible from the lower right corner of the Diagnostic Software front panel itself. Figure 7.36 (below) and Table 7.20 illustrate these Data Acquisition group components.

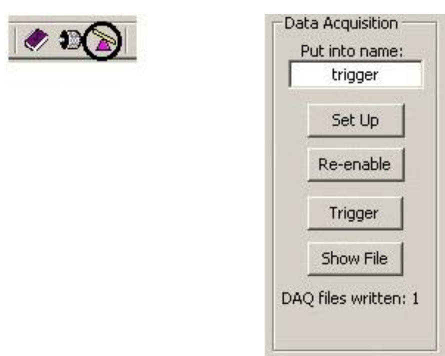


Figure 7.36: Front Panel Components of DAQ

Table 7.20: Front Panel DAQ Group Components

Label	Description
Put into name	This edit box is a shortcut 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 > Daq Configuration > Edit Settings**. It brings up 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. They can be automatically re-enabled as well.
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 into the PC, this button’s label changes to “Cancel.” Clicking on it cancels the upload and clears the buffer. 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 values) 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 7.21 lists the triggers available.

Table 7.21: DAQ Trigger Descriptions

Trigger	Description
Absolute value of leg current exceeds specified level	Set an amperage level, and the trigger occurs when the composite leg current exceeds that level.
Acceleration exceeds trigger level	Set an acceleration level, and the trigger occurs when the UQM motor’s acceleration exceeds that level.
Bus current reaches trigger level	Set an amperage level, and the trigger occurs when the bus current passes through that level from either direction.
Bus voltage reaches trigger level	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’s control mode (torque or speed) changes through the CANbus.
Desired Torque becomes dynamic	A trigger occurs when a significant change in desired torque is detected.
Desired Torque becomes steady state	A trigger occurs when no significant change in desired torque is detected over a period of time.
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	Set a wattage level, and the trigger occurs when the electrical power passes through that level from either direction.
Forced voltage control occurs	A trigger occurs when the controller is in forced voltage control, which is a safety mode entered only when bus voltage reaches a dangerous level.

Trigger	Description
Inverter fault occurs	A trigger occurs when any controller module faults. Over current and over temperature problems can cause these modules to fault when they are switching power. A drop in the 15 V supplying the modules also triggers a controller fault. It is also possible for a false trigger to occur when the bus voltage drops below the necessary level for controller module operation. This trigger is a default trigger.
Leg current exceeded within 16ms of bad position	A trigger occurs if a bad position signal event and an over leg current event occur within 16 milliseconds of each other.
Mechanical Power reaches trigger level	A mechanical power level is set, and a trigger occurs when the UQM motor's mechanical power exceeds this level.
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 signal is searching	A trigger occurs if the position signal had been lost and the controller is attempting to re-sync to the position signal.
Position signals are noisy	A trigger occurs when electrical noise is detected on the position sensor signals.
Regen is limited below trigger level percentage	A percentage level is set, and the trigger occurs when the limit acting on the regeneration torque is below that level.
Regen switch changes	A trigger occurs when the state of the regen switch changes from open to closed or from closed to open.
Speed reaches trigger level	A 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.
Stall conditions occur	A trigger occurs when the controller begins limiting its output because it has detected stall conditions (also called locked rotor, when large torques are requested but the motor is not spinning).
Stall conditions stop	A trigger occurs when the controller begins limiting its output because it has detected stall conditions. See **Stall conditions occur** above.
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.
Limp home mode occurring	A trigger occurs when the inverter detects a condition that required it to enter **Limp Home Mode**
Power switches off permanently	A trigger occurs when the inverter detects a condition that requires it to shut down the IGBT Switches

In addition to these triggering capabilities, DAQ allows you to specify the percentage of the data that is recorded on either side of the trigger event. By moving the slider in Figure 7.37 towards the left, the amount of data recorded before the trigger event is decreased, and the amount of data recorded after the trigger event is increased. The opposite can be achieved by moving the slider to the right. There are also six different sampling rates, from 80 microseconds to 6 milliseconds, allowing for a wide range of time windows.

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 June 21st, 2013, would be named:

`20150318_inverterFault00.csv`

`20150318_inverterFault01.csv`

Note that the DAQ feature also automatically saves a file with the extension “`.uqm`”. This file contains additional log data that UQM can use in diagnosing issues. If you are experiencing problems, we usually request that you e-mail both the “`.csv`” log file and the “`.uqm`” file to UQM.

7.6.1 DAQ Set Up

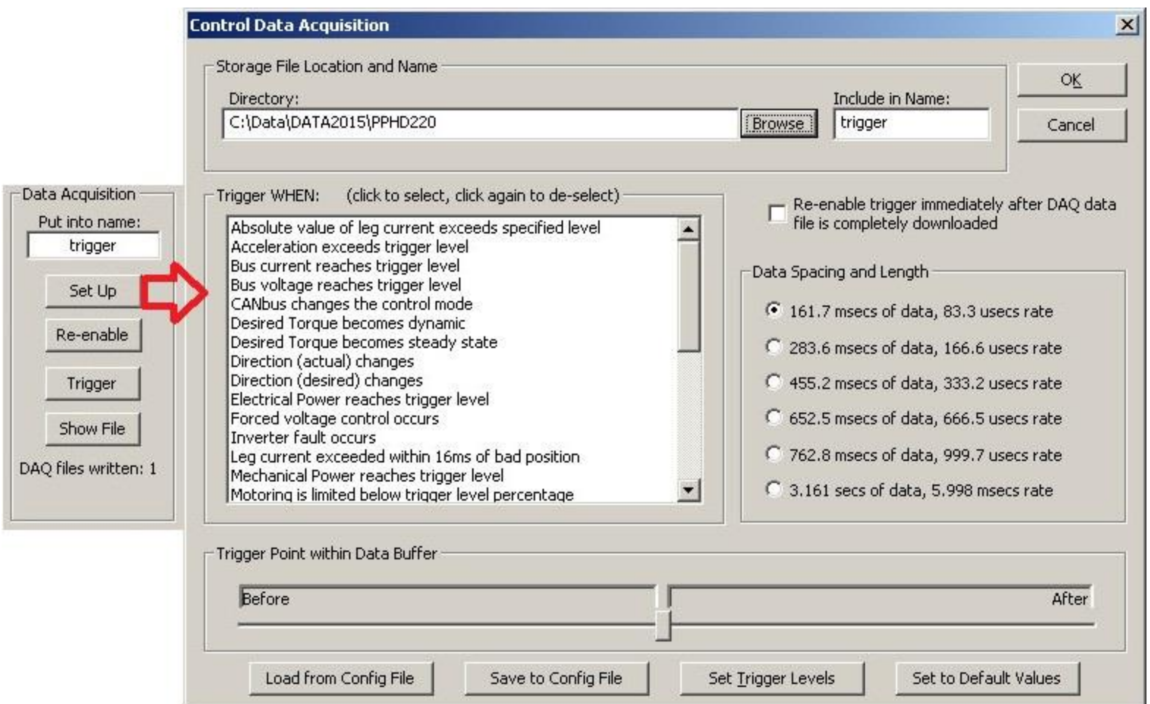


Figure 7.37: DAQ Setup

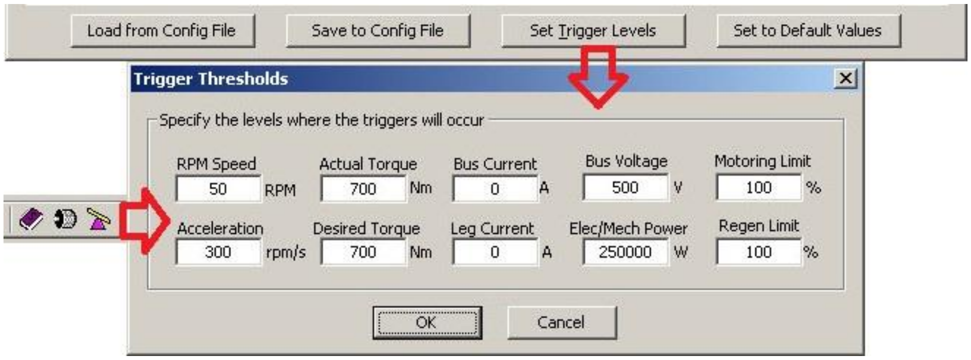


Figure 7.38: DAQ Trigger Thresholds

You must 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 7.37 shows this dialog box, and Table 7.22 lists the set up components with descriptions.

Note that the DAQ trigger settings and data spacing settings do not persist between resets. In other words, if you power cycle the inverter, you will have to enter your DAQ settings again. Fortunately, the Save/Load to Config File ("`.QDC`" file) feature makes it easy to restore settings. Please refer to the example in Section 7.6.2 for details.

Table 7.22: 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.
Re-enable trigger	Re-enables the trigger immediately after a DAQ data file has been completely downloaded. **NOTICE** You must ensure that the triggers selected are not still active when the re-enable occurs. For example, a trigger of "Position signal is bad" if re-enabled immediately will also immediately cause another file to be gathered. This will continue until you manually cancel or until your disk is full.
Data Spacing and Length	Select the sampling rate from 80 microseconds, to 6 milliseconds. This also selects the total amount of time that data is collected, from 140.2 msec to 3.625 sec.
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.
Load from Config File	This button is the equivalent of the menu choice **Actions > Daq Configuration > Load from File**. It loads a QDC configuration file into the dialog box.
Save to Config File	Button is the equivalent of the menu choice **Actions > Daq Configuration > Save to File**. It saves the current configuration to a QDC file in the location you specify.
Set Trigger Levels	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 > Daq Configuration > Edit Levels**. Figure 7.38 shows this dialog box.
Set to Default Values	Button resets all DAQ Configuration settings to their default values.

The “Trigger Thresholds” dialog box (Figure 7.38) sets the levels at which several triggers will occur. Note that the RPM Speed trigger is a SIGNED trigger level. If the motor is rotating in reverse, a positive trigger value can never cause a trigger.

7.6.2 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, if 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 would set a trigger on the event of the voltage bus value reaching 250 V. You want several seconds of data, taken mostly after the triggering event occurs. To use the DAQ system to capture this event, perform the following steps:

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.
6. Enter 250 in the Bus Voltage box, and select **OK** to close the Trigger Thresholds dialog box.
7. Select the last radio button in the “Data Spacing and Length” area that is labeled “3.625 secs of data, 6.240 msecs rate.”
8. 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 5% of the buffer).
9. Select **OK** on the DAQ Set Up dialog box.

You are now ready to begin the soft-start procedure. Once the bus voltage reaches 250 V, UQM’s DAQ system triggers and captures the event. The data is 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 (at the bottom of the front panel) shows the progress. Data extraction takes approximately one minute when running at 115200 baud rate. Once the file is finished, the **Show File** button becomes available. Clicking on it starts your spreadsheet program, opening 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 record over less time.) Select **OK** to close the dialog box and re-initiate the event in your system. Again, when the voltage reaches 250 V, data is captured, and a new file is written in the same directory with the same name, except for an incrementing number. It does not overwrite old data.

We recommend saving the useful DAQ configurations you have set up to a QDC file. With a QDC file, you can return the UQM Motor system to particular settings at any future time.

7.7 Event Log

Another helpful diagnostic tool in UQM Motor Systems is the Motor Event Log. The UQM controller tracks and stores all the system error events that occur and when they occurred into persistent memory. The diagnostic software provides access to this information through the “Event Log” dialog box illustrated in , which is available through the menu choice **Actions > Show Event Log**, or its toolbar button.

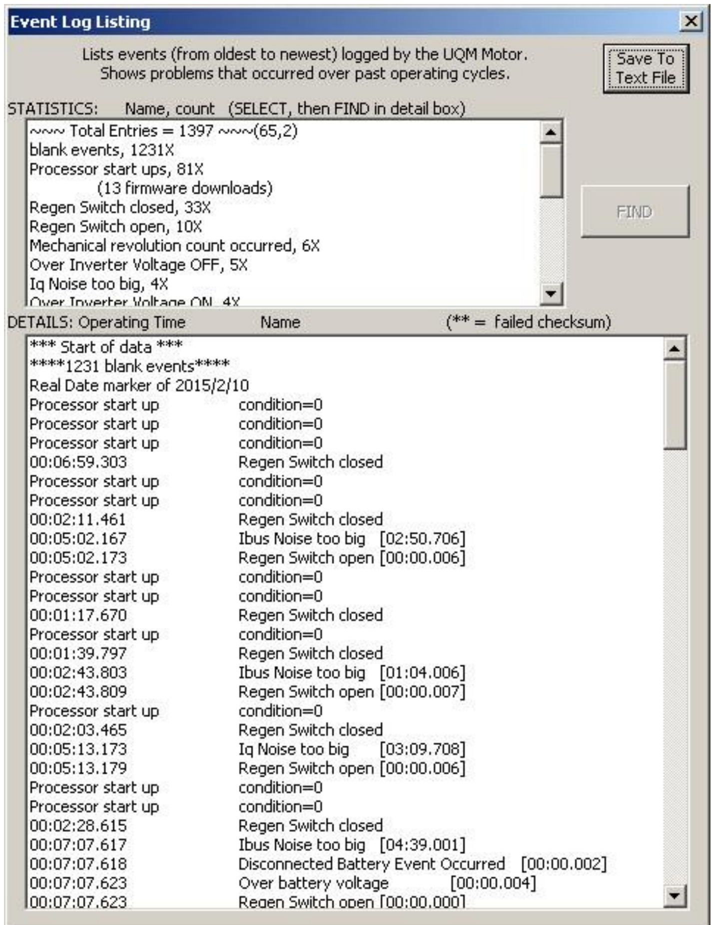


Figure 7.39: Event Dialog Box

The Event Log shows when error events occurred during operating time. It also logs the wake up condition of the controller. Table 7.23 lists the possible logging entries.

The dialog box consists of two lists: the event statistics and the event details. The statistics show which events have happened and how many times they have happened. The details show the order of the events from oldest to newest, and when they happened relative to controller turn-on. A line item in the statistics list can be used to find one entry in the details list by selecting it and pressing the **Find** button.

One feature specific to the Event Log is the revolution counter event. This feature logs an event into the Event Log representing that a user configurable number of motor revolutions have occurred. This can be thought of as a "mileage counter" when the number of revolutions equates to a distance. See Section 7.4: System Configuration to set the number of revolutions that are counted on each event.

Table 7.23: 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 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 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.
Real Date marker of **Real Time marker of**	These mark the point when a date marker or a time marker were inserted. It shows the date in year/month/day format, and the time in hours:minutes:seconds format.
Inverter Fault ON **Inverter Fault OFF**	These events mark when an inverter fault occurred that affects the inverter's power switches. Over large motor phase currents or high temperatures can endanger the power switches.
Forced open loop ON **Forced open loop OFF**	These events mark when the controller has had to go into forced open loop because of sensor 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** **Under battery voltage**	These events mark when bus voltage problems occurred. Over inverter voltage means the inverter had to enter forced voltage control.
Untrustworthy voltage measurement occurred	The bus voltage measurement is suspect and the inverter shut down.
Sensor voltage invalid **Sensor voltage good**	These events mark when the voltage that powers the controller's sensors is not at an acceptable level and subsequently when the voltage has become good again.
CTFault safety ON	This event marks when a problem was detected with the current sensors of the controller.
Leg sums not zero **Over Leg Current** **Leg significantly over current** **Leg dangerously over current** **Leg Current Separation ONCE**	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.
Bad rotor temperature occurred	The rotor temperature sensor is suspect.
Inverter Temp Shutdown **Rotor Temp Shutdown** **Stator Temp Shutdown**	These events mark when temperatures exceeded limits, causing the power switches of the inverter to shut down.

Entries	Description
Over Positive Phase Advance ONCE **Under Negative Phase Advance ONCE**	These events mark when the controller has encountered the phase limits of the motor.
Position signal is bad **Position signal has come good** **Position error is too large** **Apparent rotor movement occurred**	These events mark a problem or the resolution of a problem with the position sensor signals. Either a cable was removed or the position offset is suspect.
Mechanical revolution count occurred	The user configurable number of motor revolutions has occurred. This entry will be made each time that counter counts this number of revolutions.
CANbus watchdog occurred	CANbus commands ceased. This is sometimes seen benignly because the vehicle controller is powered off and is no longer communicating, but the motor controller has not yet been powered off.
Torque matching problem	The controller found that it was unable to control the motor to the desired torque. If this occurs regularly, this could be because the motor has partially demagnetized.
Back EMF saturated high **Back EMF saturated low**	The dynamic motor tuning control could not find the motor's Back EMF. Indicates that the wrong motor is connected.
Low Forced Voltage Control Occurred	The controller went into forced voltage control because of dangerous low voltage conditions.
Disconnected Battery Event Occurred	The controller detected conditions that indicated no power supply connection. This condition often results in forced voltage control.
Noisy position < 1 Hz **Noisy position < 150 Hz** **Noisy position < 250 Hz** **Noisy position < 350 Hz** **Noisy position > 350 Hz**	Electrical noise occurred on the position signals. This is a potentially dangerous condition because it could cause motor miscommutation if this rate is greater than 150 Hz.
Regen Switch closed **Regen Switch open**	Indicates the state of the 7th power switch in the inverter, called the Regen Switch. It isolates the inverter when high voltage or high regeneration current occurs.
Stalled OFF **Stalled ON**	These events mark when the controller severely limited torque while the motor could not spin.
In Limp Home mode	The system torque is limited to the **Limp Home Percentage**
Iq Noise too big **Ibus Noise too big** **Ibus Raw too big**	Indicated that system current is operating outside of expected parameters
Redundant torque mismatch **Redundant current mismatch**	Indicated that system torque is operating outside of expected parameters
Phase A switch problem **Phase A switches problem** **Phase B switch problem** **Phase B switches problem** **Phase C switch problem** **Phase C switches problem** **Bad switch occurred** **Bad switches occurred**	Indicates IGBT switch failure

Entries	Description
Torque Desired Osc warning ONCE **Active Damping Osc warning ONCE**	Indicates that Active damping and/or Torque Desired are oscillating due to rapid changes in torque requests
Unreliable bus current measurement occurred	The bus current sensor value is not consistent with the expected value for existing operating conditions.

The word “ONCE” in an event log entry indicates that the event was logged the first time that the event occurred, but further such events will not be logged until the controller is reset.

The Event Log dialog box has a **Save to Text File** button that allows you to save a listing of the events to a text file. It is a good idea to save one of these text files occasionally. 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 with a “.txt” extension. A text file saves automatically if a firmware download is initiated.

Each time after completing an examination of the Event Log, you may want to mark the Event Log with the date. Since the Event Log is a circular buffer, older events disappear with time. An Event Log date marker will assist you on your next examination to know which events have occurred since your last examination. The Event Log data marker is available via the menu choice **Actions > Date Into Event Log**. Only one date entry is allowed per day.

Figure 7.40 Mark Event Log with Today’s Date dialog box

8 Glossary

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.

Brushless Permanent Magnet (PM) Motor: A synchronous electric motor that uses permanent magnet excitation.

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) shape, 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.

Regen Switch: The 7^{th} switch in the inverter which provides electrical separation between the inverter and the connected system when voltage grows too high or charging current too great.

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.

8.1 Abbreviations

CSV: Comma-separated values format

DAQ: Data Acquisition

ESD: Electrostatic Discharge

IGBT: Insulated-gate bipolar transistor

LPM: Liters per Minute; unit of volume equal to 1 cubic decimetre (dm^3)

VDC: Voltage direct current

9 Safety Notices

These safety notices are contained in the body of the document and are repeated here as a quick reference. If there are any questions about one or more of these notices, the appropriate section of this document should be reviewed.

Section 1

DANGER	*Dangerous voltages, currents, and energy levels exist in this product. Exercise extreme caution in the application of this equipment. Only qualified individuals should attempt to install, set-up, and operate this equipment.*

DANGER	*Incorrect motor and controller wiring can cause catastrophic failure. Proper connection of motor cables, signal cable, and DC cable are necessary for safe operation. Do not swap motor windings to reverse direction.*

Section 1.2

DANGER	*Exposure to high voltage can cause shock, burns, and even death.* *Technicians with special training and knowledge are required to service the high voltage components in the vehicle.* *High voltage components are identified by labels. Do not remove, open, take apart, or modify these components.* *High voltage cable or wiring has an orange covering. Do not probe, tamper with, cut, or modify high voltage cable or wiring.*

Section 1.3

WARNING	*Both the motor and controller are very heavy! Be careful while removing the products from packaging to avoid dropping the components and potentially damaging the products.*

CAUTION	*The motor is bolted to the bottom of the plywood crate to ensure it is not damaged during shipment.*

CAUTION	*Dropping the motor on the shaft will cause damage to the motor.*

Section 2.1

WARNING	*Do not modify, or cut and re-solder, the Signal cable length. If you need an alternate length, contact UQM.*

WARNING	*Do not modify, or cut and re-solder, the Phase cable length. If you need an alternate length, contact UQM.*

WARNING	*The DC cable length can be shortened if necessary. The customer is responsible for the termination to the battery system and for ensuring proper termination of the shielding is achieved.*

WARNING	*Ensure that the motor shaft will remain unobstructed during acceleration.*

WARNING	*Do not open the controller or motor housings.*

CAUTION	*Ensure that there is sufficient liquid cooling and flow rate of coolant.*

Section 2.2

CAUTION	*The customer must secure the phase cables, DC cable, and signal cables to ensure the sealing interfaces are not stressed during operation.*

CAUTION	*Never allow the controller to operate unless the coolant is flowing at a minimum coolant flow rate of 10 LPM.*

Section 2.3

WARNING	*Loads on the motor shaft induced by the coupling system can result in premature motor failure. Users of the motor MUST ensure the motor shaft is not improperly loaded.*

WARNING	*The motor housing is not a structural member and is not intended to bear structural loads.*

WARNING	*Exercise care when mounting the motor to ensure that moving parts are not constrained and proper clearances are observed. All drive mechanisms mounted to the motor shaft must be properly secured.*

⚠	***WARNING***	*A separate ground wire must connect the motor case to the controller housing. High Voltage lines (positive or negative) must not be tied to the chassis, or the motor and controller/inverter cases. Please see Section 3.4 for more information on grounding requirements.*

⚠	***WARNING***	*Coupling the motor to an Internal Combustion Engine could result in premature motor damage.*

Section 2.4

⚠	***DANGER***	*Dangerous voltages, currents, and energy levels exist in this product. Exercise extreme caution in the application of this equipment. Only qualified individuals should attempt to install and set-up this equipment.*

Section 3.1

⚠	***WARNING***	*Ensure that the power is off before connecting the power cables.*

⚠	***WARNING***	*Ensure that the phase cables and DC cables are routed and restrained to prevent insulation damage.*

⚠	***CAUTION***	*The user is responsible for proper HVIL actions and for disabling the DC high voltage power when the HVIL circuit is open.*

⚠	***CAUTION***	*The user is responsible for proper HVIL actions and for disabling the DC high voltage power when the HVIL circuit is open.*

Section 3.2

⚠	***WARNING***	*Do not attempt to lengthen or shorten the cable in any way. Contact UQM if the cable is too short or too long for the application.*

⚠	***WARNING***	*Do not bundle the signal cable with the motor power leads. This may cause a controller failure.*

⚠	***CAUTION***	*Do not over-tighten the signal cable connector.*

Section 3.3

WARNING	*CYCLING THE **+12V** OR **ENABLE** SIGNALS WHILE THE MOTOR IS IN MOTION SHOULD BE AVOIDED IF AT ALL POSSIBLE*. Cycling either of these signals will cause the inverter CPU to shut down and restart – which may result in unpredictable current surges.

DANGER	*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.*

DANGER	*Do not connect either the positive or negative high voltage bus to the chassis, motor cases, or controller. Catastrophic damage may occur. Provide sufficient insulation on all power terminals for safety.*

Section 3.4

WARNING	*The user is responsible for providing and installing a ground strap from the motor to the controller. Without a ground cable, erratic operation can occur.*

Section 4.1

CAUTION	*The coolant should never run in parallel paths. The coolant hoses between the controller and the motor should be in series, as the thermal algorithms used in the software depend upon the coolant flowing at the same rate through both components.*

Section 6.1

WARNING	*DO NOT FLAT TOW the vehicle. While towing the vehicle, the drive wheels MUST NOT ROTATE, or damage will result when the motor system is not operational.*

WARNING	*DO NOT RE-ENABLE BATTERY VOLTAGE TO A MOVING VEHICLE.* It is strongly recommended that if a condition occurs which requires power cycling the system, the vehicle should be at a full stop before battery power is enabled. Applying battery voltage while the motor is moving may result in serious damage to the system.

Section 6.2

WARNING	*UQM Motors in Voltage Control require that the controller's voltage bus must have a separate UQM capacitor box attached to it for safe control.*

Section 6.3

⚠	***CAUTION***	*Increasing the friction compensation to account for drive train friction could cause motoring at zero torque when the motor is disconnected from that drive train.*

⚠	***CAUTION***	*Enabling Active Damping with added torque allowed may violate torque security strategies. The customer is responsible for addressing any regulatory requirements. See Section 1.4.1.*

Section 7.4

⚠	***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, a 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.*

⚠	***CAUTION***	*Enabling Active Damping with added torque allowed may violate torque security strategies. The customer is responsible for addressing any regulatory requirements. See Section 1.4.1.*