UQM TECHNOLOGIES INC.
CAN Document
Version 4.05 February 2009
Referring to firmware versions 4.05 and above

CAN COMMUNICATION SUMMARY

This brief description should be used in conjunction with the User's Manual. Note that throughout this documentation a positive current is defined as current flowing into the inverter. A negative current is defined as current flowing out of the inverter.

All the information in this document is preliminary and is subject to change.

Overview:

The CAN system is capable of commanding three modes of operation:

- Torque control/speed limit
- Speed control/torque limit
- Voltage control/current limit

All three modes are commanded through the *Universal Command.* Note that voltage control requires that the controller's voltage bus have a separate UQM capacitor box attached to it for safe control. Not all controllers are enabled to allow voltage control, and the command will be ignored in these cases.

Note: In order for the user to switch between these three control modes on the fly, the feature must be enabled; refer to section '**Dynamically Switching Control Modes**' (Section **1b**) for details on enabling it.

The CAN protocols are based on the SAE J1939-21 specification. Please refer to this document for more detailed information. This protocol specifies the following:

- Extended (XTD) 29-bit identifier
- Protocol Data Unit (PDU format) for all proprietary messages is 239 (0xEF)
- Priority 0 is the highest priority and 7 is the lowest

The 29-bit identifier consists of the following fields:

	Priority	0	0	PDU Format (PF)	PDU Specific (PS)	Source Address (SA)
Bit 31-29	*Bit 28-26*	*25*	*24*	*Bits 23-16*	*Bits 15-8*	*Bits 7-0*

The Parameter Group Number (PGN) for the CAN messages can be calculated using the formula:

$$256_{10} * PF + PS$$

For the proprietary PDU format of 239, the PDU specific is the same as the Destination Address (DA) (i.e. address of the intended message recipient node). Hence, the PGN should be configured as:

$$61184_{10} + 218_{10} = 0xEF00_{16} + 0x00DA_{16}$$

The CAN communication is configurable to any one of the following baud rates: 125 Kbps, 250 Kbps, 500 Kbps, and 1 Mbps. Appendix 3 lists the detailed CAN parameters. All messages sent or received by the UQM controller are in **LITTLE ENDIAN** format.

The master controller of the user's system controller is configurable to any J1939 CAN network address of 0-255. The UQM system CAN network address is configurable to any address 0-255.

The UQM Motor Controller Diagnostic Software allows the user to program each UQM controller to a different CAN address, baud rate, and command type. See the user's manual or perform the following steps:

1. Select *Actio*ns → *System Configuration* → *Edit Current* from the inverter diagnostic software menu
2. Select the *General* tab in the System Configuration dialog
3. Select the *CANbus Control* radio button
4. Select the *Digital/CAN* tab in the System Configuration dialog
5. Select the Drive Mode (described in Section 1)
6. Enable the *Transmit CAN messages* option
7. Enable individual messages to be transmitted (described in Section 2)
8. Enter desired *Master* and *UQM Address (CAN network address)*
9. Select desired CAN baud rate and message transmission rate

Note: Ensure that the inverter has been disabled using the analog enable input before making any configuration changes.

Note: Each UQM system on the same CAN bus must have a unique CAN network address. For more detailed information on UQM CAN messages see the Appendix in Section 2 located at the end of this document.

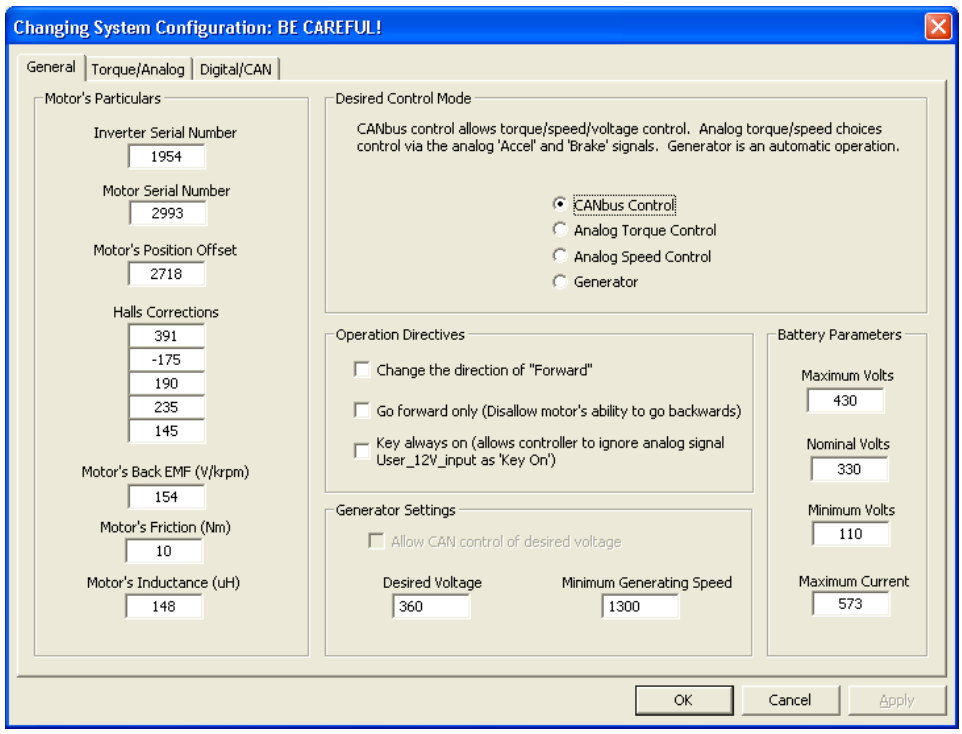


Figure 1. System Configuration *General* tab

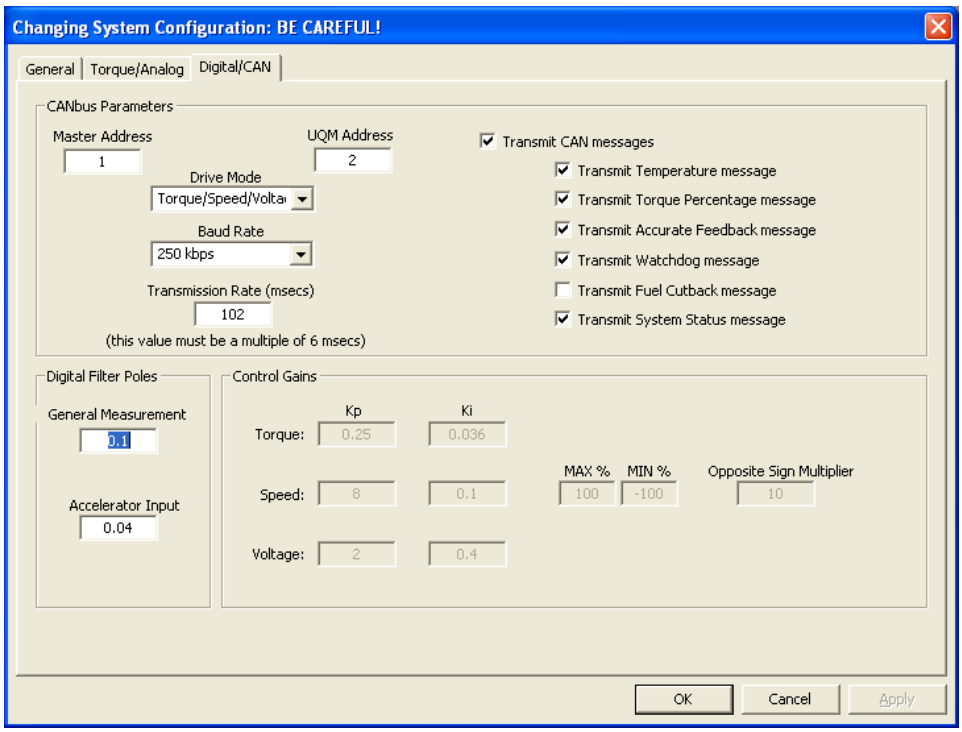


Figure 2. CAN Configuration Menu

1. CAN COMMAND MESSAGES

A single message packet is used for receiving control commands from the system controller. This is called the *Universal Command.* The address assignment protocol is shown by the following example. Assume the UQM's CAN address has been specified to 10 (0x0A) and the system controller is 1 (0x01). After specifying the CAN address, the hardware calculates a corresponding XTD identifier using a J1939 convention of [RXNODE], [TXNODE] → In this case the final 2 bytes in the XTD identifier are [$0A01_{16}$].

Identifier "0x14EF*rrss*" where *rr* is the receiving node address and *ss* is the sending node address.

Therefore, in this example the complete command identifier is: **"**0x14EF0A01**"**, where the CAN address on the UQM system was set to 10 (0x0A).

Bits 28, 27, and 26 of the identifier indicate the priority of this message (Bit 0 = LSB, Bit 2 = MSB). The above example shows a binary 101_2 or priority 5.

1 a) Universal Command

The CAN software is capable of receiving three command modes through the *Universal Command* whose first byte is the command byte:

- [0x01] Torque control/speed limit
- [0x02] Speed control/torque limit
- [0x03] Voltage control/current limit

The priority of this message is 5. (Priority 5 Identifier "0x14EF*rrss*") The message contains 8 bytes: the first byte is the command byte and the second byte contains control bits. The last 6 bytes contain the requested value and desired limits.

<u>Torque Control Command</u> [0x01]
The byte following the command byte contains control bits. It is used to send an enable command (bit 4, where the LSB is bit 0) and direction control (bit 3, where the LSB is bit 0). If bit 4 is set to zero, the system is considered as disabled and will control to zero torque. If bit 4 of this byte is set to one, then the system is considered as enabled and ready to control to the requested torque.

Note: The enable bit is coupled with the analog enable bit. You need both the CAN enable bit and the analog enable bit to be ON in order to request an enable of the system.

Bit 3 of the byte following the command byte is the direction bit. If bit 3 is set to 1, the motor will go in the forward direction. If it is set to 0, the motor will go in the opposite direction. This bit is coupled with the direction bit in the configuration menu. In the configuration menu, the user is allowed to define whether '1' defines a clockwise rotation of the motor or a counter clockwise rotation. To change the direction of rotation, follow these steps (refer to Figure 1):

1. Select *Actio*ns → *System Configuration* → *Edit Current* from the inverter diagnostic software menu
2. Select the *General* tab in the System Configuration dialog.
3. Toggle the *Change Direction of "Forward"* selection

Following the control bits, bytes 3 & 4 contain the requested torque value. The range is -3212.8 to 3212.8 Nm with a 0.1Nm delta. The actual range is dependent on the motor specification. Note that, even though torque requests can be made in 0.1 Nm increments, there is no guarantee that the control will react to these steps.

Following the requested torque value, bytes 5 & 6 contain the maximum speed allowed in the forward direction to achieve the desired torque, and bytes 7 & 8 contain the maximum speed allowed in the opposite direction to achieve the desired torque.

The message details are listed in the Appendix in Section 2.3.

Speed Control Command [0x02]
The byte following the command is used to send an enable command. If bit 4 (where the LSB is bit 0) is set to zero, the system is considered as disabled and will control to zero torque. If bit 4 of this byte is set to one, then the system is considered as enabled and ready to control to the requested speed.

Note: The enable bit is coupled with the analog enable bit. You need both the CAN enable bit and the analog enable bit to be ON in order to request an enable of the system.

Following the control bits, bytes 3 & 4 contain the requested speed value. The range is -16064 to 16064 rpm with a 0.5 rpm delta. The actual range is dependent on the motor specification. Note that, even though speed requests can be made in 0.5 rpm increments, there is no guarantee that the control will react to these steps.

Following the requested speed value, bytes 5 & 6 contain the maximum motoring torque allowed to achieve the desired speed, and bytes 7 & 8 contain the maximum generating torque allowed to achieve the desired speed.

The message details are listed in the Appendix in Section 2.3.

Voltage Control Command [0x03]
The byte following the command is used to send an enable command. If bit 4 (where the LSB is bit 0) is set to zero, the system is considered as disabled and will control to zero current. If bit 4 of this byte is set to one, then the system is considered as enabled and ready to control to the requested voltage. Note however, that if the speed is very slow (typically 200rpm or lower), then voltage control is not possible and the motor is controlled to a zero torque value until the speed goes above 200 rpm.

Note: The enable bit is coupled with the analog enable bit. You need both the CAN enable bit and the analog enable bit to be ON in order to request an enable of the system.

Following the control bits, bytes 3 & 4 contain the requested voltage value. The range is -3212.8 to 3212.8 V with a 0.1V delta. The actual range is dependent on the motor specification. Note that, even though voltage requests can be made in 0.1 V increments, there is no guarantee that the control will react to these steps.

Following the requested voltage value, bytes 5 & 6 contain the maximum motoring current allowed to achieve the desired voltage, and bytes 7 & 8 contain the maximum generating current allowed to achieve the desired voltage.

The message details are listed in the Appendix in Section 2.3.

1 b) Dynamically Switching Control Modes

The user may switch between torque control, speed control, and voltage control modes dynamically by sending the appropriate CAN commands to the system. To enable this feature do the following (Refer to
Figure 2):

1. Ensure CANbus control is enabled on the *General* tab of the *System Configuration* dialog.
2. Set *Drive Mode* (on tab *Digital / CAN*) to *Torque / Speed / Voltage*

Now the system will switch between these three control modes depending on the command mode of the *Universal Command* message it receives.

1 c) CAN Watchdog Commands

CAN Watchdog Commands [0xA5]
The priority of this message is 7.
Priority 7 Identifier "0x1CEF*rrss*", CAN Watchdog Command

The CAN watchdog command is both received and transmitted by the UQM system (the sender and receiver addresses are swapped depending on whether the message has been received or transmitted). Bytes 1 & 8 should be used by the master controller to detect a watchdog error condition while bytes 1, 2 & 3 must be used by the master controller to prevent / clear an error condition.

Once communication has been established with the UQM controller, it is required that a valid command be received by it no slower than one transmission every 1 second. The valid commands that must be sent every second depend on the CAN drive mode (see note below) of the UQM controller. If the drive mode is set to *torque control mode* then only torque commands are valid, if in *speed control mode* then only speed commands are valid, if in *voltage control mode* then only voltage commands are valid, and if in *automatic mode* then any of the three commands are valid. In addition, a *reset CAN watchdog timer* message is always valid irrespective of the CAN drive mode. If a valid CAN message is not received then the UQM system will issue a watchdog error condition, and the desired torque will be set to zero.

A *reset CAN watchdog timer* message should be sent to the UQM controller if the user wants to ensure a watchdog error condition does not happen and the user is not sending one of the other valid commands. To send a *reset CAN watchdog timer* message, byte 2 of the CAN Watchdog Command should be set to 0xA5.

If a watchdog error condition occurs, it is assumed that there is a problem with the physical CAN layer. The UQM controller will immediately zero the torque output. Once a CAN watchdog error condition occurs, there are two ways to reset it. One method is to power down the high voltage bus, disconnect the 12V power supply, fix the physical CAN problem, and then reapply 12V and high voltage. If there is no physical CAN layer problem, then another method of resetting the watchdog is to send a 0x5A command in byte 3 of the CAN Watchdog Command after sending a valid drive command.

The message details are listed in the Appendix in Section 2.4.

Note: To set the CAN drive mode perform the following steps:

1. Select *Actio*ns → *System Configuration* → *Edit Current* from the inverter diagnostic software menu
2. Select the *Digital/CAN* tab in the System Configuration dialog
3. Select the desired drive mode from the *Drive Mode* dropdown menu.

2. CAN STATUS MESSAGES

Multiple identifier packets are used to send status messages from the UQM controller. These are detailed below. The address assignment protocol is shown by the following example. Assume the UQM controller's CAN address has been specified to 10 (0x0A). The system controller is assigned address 1 (0x01). After specifying the CAN address, the hardware calculates a corresponding XTD identifier using a convention of ([RXNODE][TXNODE]). In this case the final 2 bytes in the XTD identifier are [$010A_{16}$]. Note that this is reversed from the received packet described above.

The seven transmitted messages are as follows:

- Priority 1 Identifier "0x04EF*rrss*", Accurate Feedback
- Priority 2 Identifier "0x08EF*rrss*", System Status Message
- Priority 3 Identifier "0x0CEF*rrss*", Emergency Fuel Cutback
- Priority 4 Identifier "0x10EF*rrss*", Reserved
- Priority 5 Identifier "0x14EF*rrss*", Limited Torque Percentage
- Priority 6 Identifier "0x18EF*rrss*", Drive Temperatures
- Priority 7 Identifier "0x1CEF*rrss*", CAN Watchdog Status

If CAN transmission is enabled, these status commands will be sent at regular intervals once the controller is in normal operation.

In order to enable CAN transmission has to be enabled, perform the following steps (refer to

Figure 2).

1. Select *Actio*ns → *System Configuration* → *Edit Current* from the inverter diagnostic software menu
2. Select the *Digital/CAN* tab in the System Configuration dialog
3. Enable the *Transmit CAN messages* option
4. Enable the desired messages to be transmitted by the inverter.

2 a) Priority 1 Messages

Accurate Feedback Message
Priority 1 Identifier "0x04EF*rrss*", Accurate Feedback

This message provides the master controller with high-resolution measurements for torque, voltage, current, and speed. Note that, even though the measurements are reported at a high resolution, the actual resolution will be lower and the accuracy is typically 5% of Full Scale. Full Scale will depend on both the motor type and inverter type.

Bytes 1 & 2 contain the signed torque feedback. Its range is -3212.8 to 3212.8 Nm with a 0.1 Nm delta.

Bytes 3 & 4 contain the signed voltage feedback. Its range is -3212.8 to 3212.8 V with a 0.1 V delta.

Bytes 5 & 6 contain the signed current feedback. Its range is -3212.8 to 3212.8 A with a 0.1 A delta.

Bytes 7 & 8 contain the signed speed feedback. Its range is -16064.0 to 16064.0 A with a 0.5 RPM delta.

The message details are listed in the Appendix in Section 2.1.

2 b) Priority 2 Messages

System Status Message
Priority 2 Identifier "0x08EF*rrss*", System Status Message

Bytes 1 and 2 contain the System Error. This will inform the user why the control is limiting the output power of the system.

Byte 7 contains the system status bits. The LSB bit shows the force voltage control mode status. This bit is set by the UQM system when it enters this mode. (It automatically drops out of this mode when the causal high voltage condition stops.) The 2nd LSB bit shows if the limits from the Universal Command are in effect. This bit is set if the system hits the limits set by the Universal Command. The 3rd LSB bit warns that the system is disabled but the motor is in motion.

The message details are listed in the Appendix in Section 2.7.

2 c) Priority 3 Messages

Emergency Fuel Cutback (Derate/Shutdown) Message
Priority 3 Identifier "0x0CEF*rrss*", Emergency Fuel Cutback

This message is used to signal error conditions to the master controller and advise it to either reduce its power output demand from the system or shut it down completely depending on the severity of the problem. Typically the master also has control over an external device that is spinning the UQM system (i.e. internal combustion engine or ICE).

This message will work as described only if the system is in voltage control. It is assumed that as a voltage controller, the machine is spun externally as a generator. In this case, the generator system cannot self-limit without going out of voltage regulation. Instead of self-limiting and going out of regulation, the system will send a Derate/Shutdown message.

Derate (recoverable conditions) is used for conditions where normal operation is expected to resume after reducing the speed to the generator or reducing the power out of the generator. The Derate conditions are:

a. Over temperature
b. Under voltage warning (below Minimum Battery Voltage)
c. Over voltage warning (above Maximum Battery Voltage)
d. Over positive/under negative bus current
e. Over leg current
f. Over speed alarm/warning
g. Over positive/under negative phase
h. Over maximum power

Shutdown (non-recoverable conditions) is used for conditions where normal operation is not expected to resume. The Shutdown conditions are:

a. Inverter fault or fault occurred
b. Over voltage alarm – voltage went above the maximum inverter voltage (400V on a D*x*_40_*xxx* controller and 450V on a D*x*_45_*xxx* controller). Sends both Derate and Shutdown messages. The Shutdown condition is latched and the system has to be reset to clear it.
c. Broken wire safety: leg current, bus current or +/-15V supply. Sends both Derate and Shutdown messages. The system has to be reset to clear it.
d. Controller Board was not calibrated.

To aid in debugging the system, the user should examine the system status of the System Status Message. This will help determine the source of the Derate or Shutdown message.

This message is sent every 500 ms periodically, but the system also transmits this message immediately if a change in the error condition occurs. Byte 1 is reserved, the LSB bit (bit 0) of byte 3 is the Derate status bit and bit 1 of byte 3 is the Shutdown status bit. To verify that the master controller is correctly responding to these messages, a test message is available and is described in Section 2.1.

The message details are listed in the Appendix in Section 2.6.

2 d) Priority 4 Messages

Priority 4 Identifier “0x10EF*rrss*”, Reserved

2 e) Priority 5 Messages

Limited Torque Percentage
Priority 5 Identifier “0x14EF*rrss*”, Limited Torque Percentage

This status contains the maximum motoring and regen percentages allowed by the system at that instant. The system may be limiting the motoring (high bound) or regen (low bound) torque requested by the user for a variety of reasons.

Byte 1 is reserved. Byte 2 has the High Bound Percentage, where 100% is no limiting (full torque and power are available) and 0% is complete limiting (no torque and power are available). Byte 3 has the Low Bound Percentage, where 100% is no limiting (full torque and power are available) and 0% is complete limiting (no torque and power are available). Byte 4 has the Accel Analog Input voltage. Byte 5 has the Brake Analog Input voltage. Byte 6 has the Accel_2 Analog Input voltage. Bytes 7 and 8 are reserved.

The rate of this message is the same as the Priority 1 Message, Accurate Feedback.

The message details are listed in the Appendix in Section 2.5.

2 f) Priority 6 Messages

Electric Drive Temperatures
Priority 6 Identifier "0x18EF*rrss*", Drive Temperatures

This message contains the temperatures for the inverter heat sink, rotor, and stator. This command is sent every 1 second.

The message details are listed in the Appendix in Section 2.2.

2 g) Priority 7 Messages

CAN Watchdog Commands [0xA5]
Priority 7 Identifier "0x1CEF*rrss*", CAN Watchdog Status

This message should be monitored constantly to detect whether the UQM hardware is transmitting a watchdog or CAN related error.

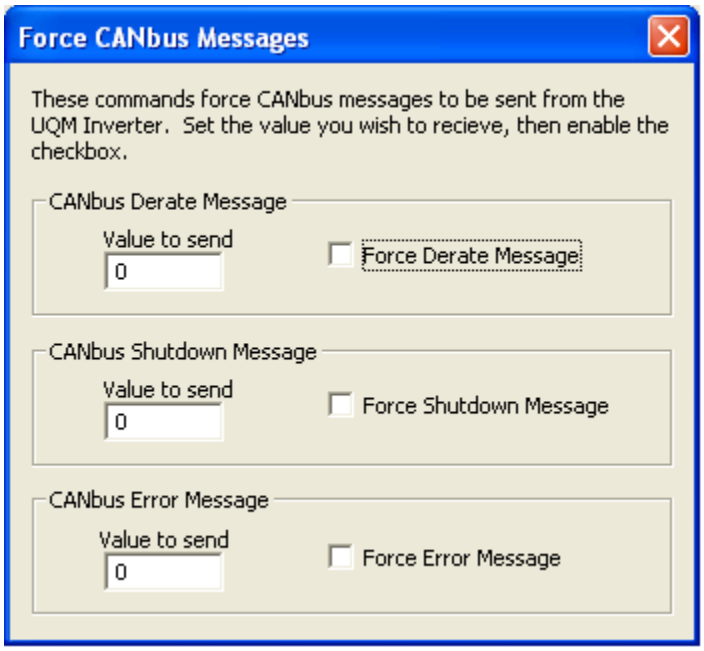
The CAN watchdog command is both received and transmitted by the UQM system (the sender and receiver addresses are swapped depending on whether the message has been received or transmitted). Bytes 1 & 8 should be used by the master controller to detect a watchdog error condition while bytes 1, 2 & 3 must be used by the master controller to prevent / clear an error condition.

Byte 8 sends the watchdog error to the host over CAN, which may be used by the host to detect a problem if the physical layer is intact. This will be sent every 0.5 seconds, if there is an error.

The message details are listed in the Appendix in Section 2.4.

2.1. Testing CAN Error Message Response

The inverter diagnostic software can be used to force the controller to transmit certain error messages over the CAN bus; this feature can be useful while testing / debugging the response of a master controller to these error messages. (See following note).



The following steps can be performed to force transmission of these error messages through the user interface (refer to Fig 1).

1. Select *Actions* → *Show CAN Tests* from the inverter diagnostic software menu
2. In the dialog that pops up enter the value to be transmitted for a particular error message and select the accompanying *Force … Message* option.
3. Uncheck the appropriate *Force … Message* option to disable forced transmission of that message.

Note 1: The values for Shutdown and Derate error messages must be 0 or 1. The value for the CANbus error message must be in the range [0, 65535]. The CANbus error message will be transmitted in the *System Error* field of the *System Status Message*.

Note 2: Setting the value of an error message to 0 but leaving the *Force … Message* option checked DOES NOT disable forced transmission of that message. This will cause the inverter to always report absence of an error condition and could potentially result in damage to the inverter and / or the entire system. This capability is intended for debug purposes only and its use is not recommended during regular operation.

3. CAN Status Message Transmission rate

If CAN transmission is enabled and transmission of drive state messages is allowed then this command sets the transmission rate of Accurate Feedback status messages. The System Status Message will also be sent at the same rate (See following note).
The following steps can be performed to program the transmission rate through the user interface (refer to Fig 1).

1. Select *Actio*ns → *System Configuration* → *Edit Current* from the inverter diagnostic software menu
2. Select the *Digital/CAN* tab in the System Configuration dialog
3. Enter the desired CAN message transmission rate (the rate MUST be a multiple of 6ms).

Note: According to the SAE J1939-21 CAN Data Link Layer specification, a proprietary CAN message using a PDU format of 239 may not be transmitted at a rate faster than 100ms. Hence, even though the user has the capability of setting the transmission rate of Accurate Feedback message as low as 6.24ms, any rate faster than 100ms would be in violation of the specification.

General Guidelines

Messages are sent constantly from host.

Once a valid CAN command is sent to the UQM unit, a valid CAN command must be sent every one-second or the system issues a watchdog error. A *CANbus Communication Error* message in the Status column (left side of main page) indicates this (see description below.) There are two methods to eliminate the CAN watchdog error:

1) Send a *Reset CAN Watchdog Error* command
2) Reset the power to the UQM system (both high voltage and 12 V)

The valid commands that must be sent every second are: *the Universal Command or the reset CAN watchdog timer*.

The user interface has an output in the Status column for CAN communication status.

If *No CANbus Communication* – Inverter is in CAN control mode but hasn't received a valid CAN message yet.

If *CANbus Communication Error* – CAN communication has ceased and inverter is disabled. To re-enable use one of the two methods mentioned above.

CAN configuration menu options

CANbus Control mode / Drive Mode	Disabled	Enabled
Speed Only	Listening to hardware inputs. CAN ignored.	Hardware inputs ignored. System in speed control, waiting for a CAN speed command message.
Torque Only		Hardware inputs ignored. System in closed loop torque control, waiting for a CAN torque command message.
Voltage Only		Hardware inputs ignored. System in voltage control, waiting for a CAN voltage command message. If speed < 200rpm, controlling to zero torque.
Torque/Speed/Voltage		Hardware inputs ignored. Switching to Voltage, Speed or Torque Control depending upon which CAN message is received

APPENDIX

UQM Proprietary Vehicle Application Layer

1 Parameter Definitions

1.1 ANALOG INPUT VOLTAGE

Use: Informational
Data Length: 1 byte
Resolution: 0.02 V/bit gain
Data Range: 0.00 to 5.00 V
Type: Status
Reference: 2.5

1.2 CONTROL BYTE

			Enable bit	Direction bit			
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Control
Data Length: 1 byte
Resolution: N/A
Data Range: All unused bits are reserved, set to 0
Type: Command
Reference: 2.3

1.2.1 Enable Bit

Use: Control
Data Length: bit 4 in Control Byte (where LSB is bit 0)
Resolution: N/A
Data Range: 1 is enabled, 0 is disabled
Type: Command
Reference: 2.3

1.2.2 Direction Bit

Use: Control
Data Length: bit 3 in Control Byte (where LSB is bit 0)
Resolution: N/A
Data Range: 1 is forward, 0 is reverse
Type: Command
Reference: 2.3

1.3 LIMITATION MOTORING

Use: Informational
Data Length: 1 byte
Resolution: 0.8%/bit gain, -100% offset
Data Range: -100% to 100%
Type: Status
Reference: 2.5

1.4 LIMITATION REGENERATION

Use: Informational
Data Length: 1 byte
Resolution: 0.8%/bit gain, -100% offset
Data Range: -100% to 100%
Type: Status
Reference: 2.5

1.5 RESET CAN WATCHDOG TIMER

Use: Control
Data Length: 1 byte
Resolution: N/A
Data Range: 0xA5
Type: Command
Reference: 2.4

1.6 RESET CAN WATCHDOG ERROR

Use: Control
Data Length: 1 byte
Resolution: N/A
Data Range: 0x5A
Type: Command
Reference: 2.4

1.7 SHUTDOWN DERATE BITS

						Shutdown bit	Derate bit
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Informational
Data Length: 1 byte
Type: Status
Bit: 7-2 Unused
1 Shutdown
Note: The microprocessor sets this bit to signal a serious error condition to the master controller that will require restarting of the system. (1 = Shutdown, 0 = No error)
0 Derate
Note: The microprocessor sets this bit to signal the master controller that an error has occurred due to which the master should reduce output demand, the system will still function but not at the rated limit. (1 = Derate, 0 = No error)
Reference: 2.6

1.8 SIGNED CURRENT

Use: Control/Informational
Data Length: 2 bytes
Byte Order: Intel
Resolution: 0.1 A/bit gain, -3212.8 offset
Data Range: -3212.8 A to +3212.8 A
Type: Measured or Command
Reference: 2.1, 2.3

1.9 SIGNED SPEED

Use: Control/Informational
Data Length: 2 bytes
Byte Order: Intel
Resolution: 0.50 rpm/bit gain, -16064 rpm offset
Data Range: -16064 rpm to +16064 rpm
Type: Measured or Command
Reference: 2.1, 2.3

1.10 SIGNED TORQUE

Use: Control/Informational
Data Length: 2 bytes
Byte Order: Intel
Resolution: 0.1 Nm/bit gain, -3212.8 offset
Data Range: -3212.8 Nm to +3212.8 Nm
Type: Measured or Command
Reference: 2.1, 2.3

1.11 SIGNED VOLTAGE

Use: Control/Informational
Data Length: 2 bytes
Byte Order: Intel
Resolution: 0.1 V/bit gain, -3212.8 offset
Data Range: -3212.8 V to +3212.8 V
Type: Measured or Command
Reference: 2.1, 2.3

1.12 SYSTEM ERROR

Inverter fault	Inverter fault occurred	Over power	ADC calibration problem	Over voltage alarm	Over speed alarm	Over voltage warning	Over speed warning
Bit 15	*Bit 14*	*Bit 13*	*Bit 12*	*Bit 11*	*Bit 10*	*Bit 9*	*Bit 8*

Inverter over temperature	Motor over temperature	Rotor over temperature	Under voltage warning	Over phase advance	Over bus current / OL	Over leg current / locked rotor / OL	Not enabled
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Informational
Data Length: 2 bytes
Byte Order: Intel
Type: Status
Bit: 15 Inverter Fault
14 Inverter Fault Occurred (Latched Inverter Fault)
13 Over Power (Only valid when system is in voltage control mode)
12 ADC calibration problem
11 Over Voltage Alarm
10 Over Speed Alarm
9 Over Voltage Warning
8 Over Speed Warning
7 Inverter Over Temperature / Open Sensor
6 Motor Over Temperature / Open Sensor
5 Rotor Over Temperature / Open Sensor
4 Under Voltage Warning
3 Over Phase Advance
2 Bus Over Current / Open Loop (See note below)
1 Leg Over Current / Locked Rotor / Open Loop (See note below)
0 Not Enabled
Reference: 2.7
Note: If both bits 1 and 2 go high simultaneously (resulting in error code 0x6) it means the system has been forced into open loop. This could be due to different reasons such as problems with the board power supply (±15V, 5V) or leg current maxima or averages not matching.

1.13 SYSTEM STATUS BITS

					System disabled in motion	CAN limits active	Force voltage control mode
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Informational
Data Length: 1 bytes
Type: Status
Bit: 7-3 Reserved
2 System disabled but motor is in motion
1 CAN Limits in effect
0 Force Voltage Control Mode
Reference: 2.7

1.14 TEMPERATURE INVERTER

Use: Informational
Data Length: 1 byte
Resolution: 1 ºC/bit gain, -40 ºC offset
Data Range: -40 ºC to +210 ºC
Type: Measured
Reference: 2.2

1.15 TEMPERATURE ROTOR

Use: Informational
Data Length: 1 byte
Resolution: 1 ºC/bit gain, -40 ºC offset
Data Range: -40 ºC to +210 ºC
Type: Measured
Reference: 2.2

1.16 TEMPERATURE STATOR

Use: Informational
Data Length: 1 byte
Resolution: 1 ºC/bit gain, -40 ºC offset
Data Range: -40 ºC to +210 ºC
Type: Measured
Reference: 2.2

1.17 WATCHDOG ERROR BIT

							Watchdog error
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Informational
Data Length: 1 byte
Type: Status
Bit: 7-1 Unused
0 Watchdog Error
Reference: 2.4
Note: After the microprocessor receives a CAN message, then it must receive another message within 1.0 seconds or it will issue this error message. (1= Error, 0 = No error)

1.18 OVER IGBT JUNCTION TEMPERATURE

							Over IGBT Junc. Temp.
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Informational
Data Length: Bit 0 of byte 5 (where LSB is bit 0)
Resolution: N/A
Data Range: 1 indicates over temperature, 0 indicates below temperature threshold
Type: Status
Reference: 2.2

1.19 IGBT JUNCTION TEMPERATURE LIMIT ACTIVE

						IGBT Junc. Temp. limit active	
Bit 7	*Bit 6*	*Bit 5*	*Bit 4*	*Bit 3*	*Bit 2*	*Bit 1*	*Bit 0*

Use: Informational
Data Length: Bit 1 of byte 5 (where LSB is bit 0)
Resolution: N/A
Data Range: 1 indicates system is limited due to over IGBT junction temperature, 0 indicates limiting is inactive
Type: Status
Reference: 2.2

1.20 IGBT JUNCTION TEMPERATURE

Use: Informational
Data Length: Byte 6
Resolution: 1 ºC/bit gain, 0 ºC offset
Data Range: 0 ºC to +250 ºC
Type: Measured
Reference: 2.2

1.21 IGBT JUNCTION TEMPERATURE LIMIT TIME

Use: Informational
Data Length: Byte 7
Resolution: 0.5 sec/bit gain, 0 sec offset
Data Range: 0 sec to +125 sec
Type: Measured
Reference: 2.2

2 Parameter Group Definitions

DA = Destination Address

2.1 ACCURATE FEEDBACK [0X04EF*RRSS*]

Signed Torque		Signed Voltage		Signed Current		Signed Speed	
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Transmission repetition rate: Increments of 0.006 seconds, 0.102 seconds default, user adjustable
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 1

Byte:			
	1,2	Signed Torque Feedback	1.10
	3,4	Signed Voltage Feedback	1.11
	5,6	Signed Current Feedback	1.8
	7,8	Signed Speed Feedback	1.9

2.2 ELECTRIC DRIVE TEMPERATURE [0X18EF*RRSS*]

	Inverter heat sink temp.	Estimated rotor temp.	Stator temp.	IGBT junction temp. status	IGBT junction temp.	IGBT junction temp. limit time	
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Transmission repetition rate: 1 s
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 6

Byte:			
	1	Reserved	
	2	Inverter Heat Sink Temperature	1.14
	3	Estimated Rotor Temperature	1.15
	4	Stator Temperature	1.16
	5	IGBT Junction Temperature Status Bits	1.18, 1.19
	6	IGBT Junction Temperature	1.20
	7	IGBT Junction Temperature Limit Time	1.21

2.3 UNIVERSAL COMMAND [0X14EF*RRSS*]

Command	Control bits	Requested torque, speed or voltage		Maximum speed, torque or current limit		Minimum speed, torque or current limit	
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 5
FOR TORQUE:

Byte:			
	1	Command 0x01	
	2	Control Bits	1.2.1, 1.2.2
	3,4	Requested Signed Torque	1.10
	5,6	Maximum Forward Speed Limit	1.9
	7,8	Maximum Reverse Speed Limit	1.9

FOR SPEED:

Byte:			
	1	Command 0x02	
	2	Control Bits	1.2.1
	3,4	Requested Signed Speed	1.9
	5,6	Maximum Torque Limit	1.10
	7,8	Minimum Torque Limit	1.10

FOR VOLTAGE:

Byte:			
	1	Command 0x03	
	2	Control Bits	1.2.1
	3,4	Requested Signed Voltage	1.11
	5,6	Maximum Current Limit	1.8
	7,8	Minimum Current Limit	1.8

2.4 CAN WATCHDOG COMMANDS [0X1CEF*RRSS*]

0xA5	Reset watchdog timer	Reset CAN watchdog error					Watchdog error bit
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Transmission repetition rate: 0.5 s
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 7

Byte:			
	1	Command 0xA5	
	2	Reset Watchdog Timer	1.5
	3	Reset CAN Watchdog Error	1.6
	4-7	Reserved	
	8	Watchdog Error Bit	1.17

2.5 LIMITED TORQUE PERCENTAGE [0X14EFRRSS]

	High bound percentage	Low bound percentage	Accel analog input	Brake analog input	Accel2 analog input		
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Transmission repetition rate: Same as Accurate Feedback
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 5

Byte:			
	1	Reserved	
	2	High bound percentage	1.3
	3	Low bound percentage	1.4
	4	Accel Analog Input	1.1
	5	Brake Analog Input	1.1
	6	Accel_2 Analog Input	1.1
	7,8	Reserved	

2.6 EMERGENCY FUEL CUTBACK COMMAND [0X0CEFRRSS]

		Shutdown / Derate bits					
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Transmission repetition rate: 0.5s periodically, and immediately if the error condition changes
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 3

Byte:			
	1	Reserved	
	2	Reserved	
	3	Shutdown Derate Bits	1.7
	4-8	Reserved	

2.7 SYSTEM STATUS MESSAGE [0X08EFRRSS]

System error bits						System status	
Byte 1	*Byte 2*	*Byte 3*	*Byte 4*	*Byte 5*	*Byte 6*	*Byte 7*	*Byte 8*

Transmission repetition rate: 0.5 s periodically, and immediately if the error condition changes
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 2

Byte:			
	1,2	System Error	1.12
	3,4,5,6	Reserved	
	7	System Status Bits	1.13
	8	Reserved	

2.8 RESERVED MESSAGE [0X10EFRRSS]

Transmission repetition rate: TBD
Data length: 8 bytes
Data page: 0
PDU format: 239
PDU specific: DA
Default priority: 4
Byte: 1-8 Reserved

3 DETAILED CAN PARAMETERS

Detailed CAN Parameters

Baud Rate	SBG	SJW	SAM	BRT	TSEG1	TSEG2
125 k	1	1	1	60	12	7
250 k	1	1	1	30	12	7
500 k	1	1	1	15	12	7
1000 k	1	1	1	10	11	3