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CAN Protocol

Revision 6.2

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1. Introduction

This document defines the CAN protocol used by the Cascadia Motion PM, RM, PM Gen 5, and CM controllers. The same CAN protocol is used for all four controller types, but certain features are not available or may be modified between the controller types.

The controllers have two CAN interfaces (CAN A and CAN B). The controller is configured to communicate only over CAN A, currently CAN B is reserved for future use.

The CAN interface has multiple purposes:

- Direct control of the motor
- Adjust EEPROM parameters
- Diagnostics and monitoring

1.1 CAN EEPROM Parameters Overview

The CAN Communication baud rate must be set to compatible with the CAN bus being used. All devices on the CAN bus must be at the same baud rate. The available baud rates include 125K, 250K, 500K, and 1M. Higher baud rates tend to be more sensitive to noise than lower baud rates. However, lower baud rates are not able to handles as many CAN messages and can become overloaded. Typical baud rates that are chosen are 250K and 500K.

For PM inverter there is a built-in user configurable CAN termination resistor (120 ohms). The RM inverter do not have a termination resistor built in to the unit. The CMxxx inverter has the ability to connect a termination resistor via making a connection in the I/O connector.

Many CAN related parameters are configurable through parameters that are available through the RMS GUI[1] application as well as CAN. GUI parameters have the same name as mentioned in this document with the exception that they end with the keyword “EEPROM”. Following parameters are used to configure CAN operation:

- **Inverter Command Mode:**
  This parameter gives the option to operate controller in either VSM mode or CAN mode. In VSM mode, the inverter is operated from the various inputs and outputs of the inverter such brake, accelerator pedal, etc. In

[1] Please refer to the document “Programming EEPROM Parameters using GUI”.

VSM mode, broadcast messages are still sent out over the CAN lines. In CAN mode, both GUI and CAN interfaces are active and can be used to monitor and modify parameters. In CAN mode the torque and speed commands come from the Command message. The various inputs of VSM mode have no effect.

0 = CAN Mode
1 = VSM Mode (Default)

- **CAN ID Offset:**
  This parameter allows the user to choose their own set of contiguous CAN message identifiers starting with the value in CAN ID Offset. For 11 bit CAN the offset covers a range of 0 – 0x7C0. The default offset is 0x0A0. The default range of CAN message IDs is 0x0A0 – 0x0CF. For the J1939 the CAN ID offset must be in the range of 0 – 0xC0. For 29 bit CAN messages the ID can be in the range of 0 – 0xFFC0.

  This feature is especially useful when there is more than one controller on the same CAN network.

  While setting base address for a controller, it must be made sure that the address range for various controllers do not contain overlapping addresses.

- **CAN Extended Message Identifier**
  This parameter allows switching between CAN standard and extended message identifiers.

  0 = Standard CAN Messages (11-bit identifiers)
  1 = Extended CAN Messages (29-bit identifiers)

- **CAN J1939 Option Active**
  This parameter allows switching to J1939 format in extended mode. This parameter works in conjunction with 'CAN Extended Message Identifier' parameter above which must be set to 1.

  0 = CAN ID will be defined as either 11 bit or 29 bit addressing per the above description.
  1 = Extended CAN Messages in SAE J1939 Format

  The CAN protocol provides a limited functionality for J1939 protocol with the following fixed parameters:

  Priority = 3 (001b)

Data Page = 0
PDU Format = 0xFF
PDU Specific = **CAN ID Offset**
Source Address = 0x01 (for both transmitted and received messages)

For example, if CAN ID Offset is set to the default 0xA0, the J1939 CAN message will be broadcast as 0xCFFA001 and so on. The heartbeat command message should be sent out as 0xCFFC001, where the source address of the sending node is still set to be 0x01.

Please refer to the section,

1.3 ***CAN*** Diagnostic Parameters Overview (Gen 5/CM only)

Several CAN diagnostics are available through the RMS GUI.

RMS GUI Watch Item	Description
CAN_Status_Bus_Off	0: Bus is active 1: CAN Bus has been turned off due to excessive errors. Note: The auto CAN Bus restart feature has been enabled. If the CAN bus controller gets turned off it will automatically restart.
CAN_Status_Error_Passive	0: Bus is active 1: CAN Bus controller has gone to the passive state.
CAN_Status_Error_Warning	0: Bus is active 1: The number of CAN errors has reached a warning limit of 96.
CAN_Status_Last_Error_Code	Indicates the last reported error on the CAN bus controller: 0: No Error 1: Stuff Error 2: Form Error 3: Ack Error 4: Bit 1 Error 5: Bit 0 Error 6: CRC Error
CAN_Tx_Error_Counter	Count of errors in sending of CAN messages. The maximum count is 255 before the counter loops back to 0.

CAN_Rx_Error_Counter	Count of errors in receiving CAN messages, maximum count is 127. For each correctly received CAN message the error counter will count down towards 0.

1.4 CAN Format to learn about how to send out a torque or a speed command using the heartbeat command message.

- **CAN Term. Resistor Present:**
  In order to use CAN communication, the CAN bus needs to be terminated with a 120 Ohm resistor. PM inverters are equipped with a user configurable termination resistor which is activated through this parameter.

  0 = Term. Resistor not active
  1 = Term. Resistor active (Default)
  If CAN Terminator Resistor is deactivated, it may be necessary to use the GUI interface only[2] since CAN communication may fail without a terminator resistor.

  The RM controller family does not have this feature and thus this parameter has no effect on the CAN network. The RM controllers do not include a CAN terminator as the default configuration.

  The CM controllers have the ability to activate a CAN terminator, but only by making an external wiring change. Refer to the Hardware manual for more information.

- **CAN Command Message Active:**
  To help with the safety of a CAN controlled system it is recommend to activate the CAN Timeout feature. The CAN Timeout feature requires a “heartbeat” CAN Command message to be sent at some regular interval. The CAN Command message controls the inverter, motor direction, and torque or speed. If the inverter does not receive a CAN command message within the CAN Timeout time (described below) then the inverter will declare a Run Fault of CAN Command Timeout. The inverter will disable the motor. It is important for the user to decide if this Timeout

[2] Please refer to the document “Programming EEPROM Parameters using GUI”.

feature is important to their application or not. If CAN communications is lost the inverter continues to hold the last received CAN Command.

0 = The CAN command message Timeout feature is disabled. The controller will hold last received CAN command.
1 = The CAN command message Timeout feature is enabled. A CAN Command message should be sent at some regular interval.

- **CAN Bit Rate:**
  250Kbps is the default bit rate. Bus speed can be changed using CAN parameter command message. However, changing this parameter requires a power reset on controller since bus speed is setup only at the initialization of CAN modules in the microcontroller. Also, this input is restricted to valid baud rates. The 4 options for valid baud rate are:

125	= 125Kbps
250	= 250 Kbps (Default)
500	= 500 Kbps
1000	= 1Mbps

- **CAN Active Messages Word:**
  This parameter is used to enable/disable CAN Broadcast Messages[3]. This parameter is represented as two parameters, CAN Active Messages (Low Word) and CAN Active Messages (High Word) in RMS GUI. Each bit represents a CAN Message broadcast status as follows:

  0 = CAN Messages broadcast disabled
  1 = CAN Message broadcast enabled (Default)

  Please refer to the table of CAN Broadcast Messages in section 2.1 for details on how to enable/disable each message.

  Note, starting with version 2042 the lowest bit of the Hi Word has an opposite effect, if the bit is 0 then it enables a high-speed message at CAN ID Offset plus 16. If the bit is 1 the message is disabled.

- **CAN Diagnostic Data Transmit Active:**
  This parameter is used to enable/disable the broadcast of the diagnostic data.
  0 = CAN Diagnostic Data broadcast disabled
  1 = CAN Diagnostic Data broadcast enabled (Default)

[3] Please refer to the section 2.1 - Broadcast Messages.

Please refer to the document, CAN Diagnostic Data, for more details on this feature.

- **CAN Inverter Enable Switch Active:**
  This parameter is used in CAN mode only.
  1 = DIN1 digital input is taken into consideration and the inverter will only be enabled if both DIN1 and inverter command are active. If either one is inactive, the inverter will be disabled.
  0 = DIN1 will have no effect on enabling or disabling the inverter (Default)

- **CAN Timeout:**
  This parameter sets the CAN Timeout time. The CAN Timeout time is the maximum time between CAN Command messages that will not generate a fault (if the CAN Command Message Active parameter is set to 1). This parameter is set as a multiple of 3 msec. For example, the default value is set to 333 which is equivalent to the actual timeout value of 999ms (333 x 3msec). This parameter delays setting the CAN Timeout fault for the amount of time it represents.

- **CAN Slave Cmd ID (implemented in version 19B9):**
  Command CAN address of the slaved controller. Must be in the range of 0x022 to 0x7FD (or set to 0 to disable). The address is set to a value that is 0x20 less than the ID offset set on the slaved controller. For example, if the slave controller has an ID offset of 0x1A0 then the CAN Slave Cmd ID is set to 0x1C0. See section on CAN Slave Mode in this manual.

- **CAN Slave Dir (implemented in version 19B9):**
  The slave controller can be commanded to the same direction command or opposite direction command based on this parameter. A value of 0 is the same direction, a value of 1 is the opposite direction.

- **CAN Fast Msg Rate / CAN Slow Msg Rate (implemented in version 2025, not available in 19XX):**
  In certain installations it is necessary to change the rate at which the CAN Broadcast messages are sent by the controller. Previously messages had a fixed transmission rate of either 10ms (the fast messages) or 100ms (the slow messages). Two new EEPROM parameters have been added that allow the message rates to be changed.

  The message rate is set by these two EEPROM parameters in terms of milli-seconds (ms). The software loop that sends the CAN messages runs with a 3 ms period. The CAN messages will be sent out at the next increment of 3ms that matches the programmed broadcast rate. For example, if the rate is set to 10ms then the actual broadcast rate will be closer to 12ms. It is important to note that many CAN messages are being triggered to be sent at the same time. The CAN controller will send them out according to the availability of the CAN bus itself and the priority of the messages. the actual time between messages will vary in actual use.

If it is desired that the original CAN message transmission rates be used then the CAN_Fast_Msg_Rate_EEPROM_(ms) parameter can be set to 10 and the CAN_Slow_Msg_Rate_EEPROM_(ms) can be set to 100.

The two parameters should not be set to a time between messages lower than 3ms.

These two parameters can be used to disable the entire set of Fast or Slow CAN messages. If either message rate EEPROM parameter is set to 0 it will disable sending of that group of messages.

1.2 CAN Diagnostic Parameters Overview (Gen 3 only)

The inverter also provides CAN diagnostic parameters that can be monitored through the GUI. These parameters are shadow parameters of the actual CAN Error and Status register used in the microprocessor.

- **CAN Status Register:**
  The Status register is displayed in real time in the GUI. This is a shadow byte that reflects the actual CAN register. This shadow register is updated every 3 msec.

CAN Status Word	Description
0x0001	**Transmit Mode (TM):** The CAN module is in transmit mode. This bit reflects what the CAN module is actually doing regardless of mailbox configuration. 1: The CAN module is transmitting a message 0: The CAN module is not transmitting a message
0x0002	**Receive Mode (RM):** The CAN module is in receive mode. This bit reflects what the CAN module is actually doing regardless of mailbox configuration. 1: The CAN module is receiving a message 0: The CAN module is not receiving a message
0x0004	**Power Down Acknowledge (PDA):** 1: The CAN module has entered the power-down mode 0: Normal operation
0x0008	**Change Configuration Enable (CCE):** This bit displays the configuration access right. This bit is set after a latency of one clock cycle. 1: The CPU has write access to the configuration registers 0: The CPU is denied write access to the configuration registers
0x0010	**Suspend Mode Acknowledge (SMA):** This bit is set after a latency of one clock cycle—up to the length of one frame—after the suspend mode was activated. The suspend mode is activated with the debugger tool when the circuit is not in run mode. 1: The module has entered suspend mode 0: The module is not in suspend mode
0x0020	**Warning Status (EW):** 1: One of the two error counters (CANREC or CANTEC) has reached the warning level of 96. 0: Values of both error counters (CANREC and CANTEC) are less than 96.
0x0040	**Error Passive (EP):** 1: CAN module is in error-passive mode. CANTEC has reached 128

	0: The CAN module is in error-active mode
0x0080	**Buss Off (BO):** The CAN module is in bus-off state. 1: There is an abnormal rate of errors on the CAN bus. This condition occurs when the transmit error counter (CANTEC) has reached the limit of 256. During Bus Off, no messages can be received or transmitted. The bus-off state can be exit by clearing the CCR bit in CANMC register or if the Auto Bus On (ABO) (CANMC.7) bit is set after 128 * 11 receive bits have been received. After leaving Bus Off, the error counters are cleared. 0: Normal operation

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- **CAN Fault Register:**
  The Faults register is also a shadow register. However, once a CAN fault occurs, shadow register will continue to display it through the GUI. The shadow faults can be cleared by setting Clear Fault Command to 0[4].

CAN Faults Word	Description
0x01	**Acknowledge Error (ACKE):** 1: The CAN module received no acknowledge 0: All messages have been correctly acknowledged
0x02	**Stuff Error (SE):** 1: A stuff bit error occurred. 0: No stuff bit error occurred.
0x04	**Cyclic Redundancy Check Error (CRCE):** 1: The CAN module received a wrong CRC. 0: The CAN module never received a wrong CRC.
0x08	**Stuck at Dominant 1 Error (SA1):** The SA1 bit is always at 1 after a hardware reset, a software reset, or a Bus-Off condition. This bit is cleared when a recessive bit is detected on the bus. 1: The CAN module never detected a recessive bit. 0: The CAN module detected a recessive bit.
0x10	**Bit Error (BE):** 1: The received bit does not match the transmitted bit outside of the arbitration field or during transmission of the arbitration field, a dominant bit was sent but a recessive bit was received. 0: No bit error detected.
0x20	**Form Error (FE):** 1: A form error occurred on the bus. This means that one or more of the fixed-form bit fields had the wrong level on the bus. 0: No form error detected; the CAN module was able to send and receive correctly.

[4] Please refer to “Software User Manual” section 11.6.2 – Clear Faults Command.

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1.3 CAN Diagnostic Parameters Overview (Gen 5/CM only)

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RMS GUI Watch Item	Description
CAN_Status_Bus_Off	0: Bus is active 1: CAN Bus has been turned off due to excessive errors. Note: The auto CAN Bus restart feature has been enabled. If the CAN bus controller gets turned off it will automatically restart.
CAN_Status_Error_Passive	0: Bus is active 1: CAN Bus controller has gone to the passive state.
CAN_Status_Error_Warning	0: Bus is active 1: The number of CAN errors has reached a warning limit of 96.
CAN_Status_Last_Error_Code	Indicates the last reported error on the CAN bus controller: 0: No Error 1: Stuff Error 2: Form Error 3: Ack Error 4: Bit 1 Error 5: Bit 0 Error 6: CRC Error
CAN_Tx_Error_Counter	Count of errors in sending of CAN messages. The maximum count is 255 before the counter loops back to 0.
CAN_Rx_Error_Counter	Count of errors in receiving CAN messages, maximum count is 127. For each correctly received CAN message the error counter will count down towards 0.

1.4 CAN Format

The CAN protocol conforms to CAN 2.0A (11 bit identifiers) as well as CAN 2.0B (29 bit identifiers)[5]. CAN Messages are transmitted with a baud rate determined by the CAN Bit Rate EEPROM parameter[6]. All messages have a data length code (DLC) of 8 bytes and follow little-endian format which implies that the least significant byte is stored at the lowest address. For example, if the command message is setup to turn the inverter on in CAN Speed mode with a speed command of 500 RPM the data bytes should look like this:

Data Byte 0	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7
44	1	244	1	0	1	0	0

- Torque Command: Sent as a value in N.m. times 10.
  For example, 30 Nm should be entered as 300 = (1 x 256) + 44
  - Data Byte 0 = 44 (Low byte)
  - Data Byte 1 = 1 (High byte)

- Speed Command: Sent as a value in RPM.
  For example, 500 RPM is entered as 500 = (1 x 256) + 244
  - Data Byte 2 = 244 (Low byte)
  - Data Byte 3 = 1 (High byte)

- Direction Command
  - Data Byte 4 = 0 (Clockwise = Reverse)
  - Data Byte 4 = 1 (Anticlockwise = Forward)

- Inverter Run Command
  - Data Byte 5 = 0 (Disable Inverter)
  - Data Byte 5 = 1 (Enable Inverter)

Each data frame is 89 bits long thus at 250kbps the bus can handle a maximum of 2808 messages per second.

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[5] Please refer to “CAN Extended Message Identifier” in section 1 - Introduction.
[6] Please refer to “CAN Bit Rate” in section 1 - Introduction.

1.5 Data Formats

Each message contains one or more items. Each item is formatted and scaled per the definitions below:

Format	Description	Range
Temperature	Signed integer, actual temperature (in °C) times 10	-3276.8 to +3276.7 °C
Low Voltage	Signed integer, actual voltage (in Volts) times 100	-327.68 to +327.67 volts
Torque	Signed integer, actual torque (in N.m) times 10	-3276.8 to +3276.7 N-m
High Voltage	Signed integer, actual voltage (in Volts) times 10	-3276.8 to +3276.7 volts
Current	Signed Integer, actual current (in Amps) times 10	-3276.8 to +3276.7 amps
Angle	Signed integer, actual angle (in degrees) times 10	0.0 to ±359.9 degrees
Angular velocity (Speed)	Signed integer, actual velocity (in RPM)	-32768 to +32767 rpm
Boolean	Unsigned byte, 1 = true/on, 0 = false/off	0 or 1
Frequency	Signed integer, actual frequency (in Hz) times 10	-3276.8 to +3276.7 Hz
Power	Signed integer, actual power (in kW) times 10	-3276.8 to +3276.7 kW
Time	Unsigned long integer or Unsigned integer. These are scaled values in counts that can be calculated by using their respective Scale Factors. For each Scale Factor, see the description column for that parameter.	NA
Flux	Signed integer, actual flux (in Webers) times 1000	-32.768 to 32.767 Webers
Proportional Gain	Unsigned integer, actual gain (unit-less) times 100 OR actual gain (unit-less) times 10000	0 – 655.35 OR 0 – 6.5535
Integral Gain	Unsigned integer, Actual gain (unit-less) times 10000	0 – 6.5535
Derivative Gain	Unsigned integer, actual gain (unit-less) times 100	0 – 655.35
Low-pass Filter Gain	Unsigned integer, Actual gain (unit-less) times 10000	0 – 6.5535
Per-unit Value	These are scaled values that can be calculated by using their respective Scale Factors. For each Scale Factor, see the description column for that parameter.	NA
ADC Count	The value for ADC counts as read directly by the registers of a microcontroller.	0 - 4095

Format	Description	Range
Pressure	Signed integer, actual pressure (in psi) times 10	-3276.8 to +3276.7 psi

1.6 CAN Database File

A CAN database file stores information for a given CAN network. For example, it includes information about CAN nodes, messages, and data bytes for each message. A CAN database file has a .dbc extension and can be used with several CAN data loggers such CANTrace, CANalyzer, CANoe, etc to log CAN data.

Cascadia Motion provides a CAN database file. The file can be downloaded from the Support section of the Cascadia Motion web site.

This file can also be edited by the user with his/her choice of a CAN database editor. For example, Kvaser's Database Editor can be used to create and edit the CAN database file. Kvaser's Database Editor can be found on the Kvaser web site, www.kvaser.com

2. CAN Messages

2.1 Broadcast Messages

Broadcast messages are sent by the controller continuously irrespective of VSM or CAN command mode. The table below shows the messages that are broadcast and the frequency at which they are sent. The addresses shown below are default addresses based on the default CAN ID Offset of 0x0A0. The CAN ID offset can be changed by using the EEPROM parameter for this variable. Using a different CAN ID offset would be specifically useful in the care where more than one controller is on the same CAN bus network. While setting CAN ID offset address for a controller, make sure that the address range for controllers does not contain overlapping addresses.

A parameter ‘CAN Active Messages Lo Word’ with parameter address 148 is defined to enable/disable individual CAN Broadcast Messages. Additionally, there is a parameter, CAN Active Messages Hi Word, that controls various CAN mailboxes related to the Command message, Slave message, BMS, OBD2, and the U2C. This message should be kept as 0xFFFF (or 0xFFFE if implementing the High Speed Message).

Each bit in CAN Active Messages Lo Word parameter represents a CAN Message broadcast status as follows:

0 = CAN Messages broadcast disabled
1 = CAN Message broadcast enabled

Slow = controlled by CAN_Slow_Msg_Rate_EEPROM_(ms), typical 10Hz
Fast = controlled by CAN_Fast_Msg_Rate_EEPROM_(ms), typical 100Hz

The controller broadcasts the following messages:

Address	Frequency	Content	CAN Active Messages (Low Word) Bit Designation
0x0A0	Slow/10 Hz	Temperatures #1	0x0001
0x0A1	Slow/10 Hz	Temperatures #2	0x0002
0x0A2	Slow/10 Hz	Temperatures #3	0x0004
0x0A3	Fast/100 Hz	Analog Inputs Voltages	0x0008
0x0A4	Fast/100 Hz	Digital Input Status	0x0010
0x0A5	Fast/100 Hz	Motor Position Information	0x0020
0x0A6	Fast/100 Hz	Current Information	0x0040
0x0A7	Fast/100 Hz	Voltage Information	0x0080
0x0A8	Fast/100 Hz	Flux Information	0x0100
0x0A9	Slow/10 Hz	Internal Voltages	0x0200

0x0AA	Fast/100 Hz	Internal States	0x0400
0x0AB	Fast/100 Hz	Fault Codes	0x0800
0x0AC	Fast/100 Hz	Torque & Timer Information	0x1000
0x0AD	Fast/100 Hz	Modulation Index & Flux Weakening Output Information	0x2000
0x0AE	Slow/10 Hz	Firmware Information	0x4000
0x0AF	100 Hz (fixed)	Diagnostic Data	0x8000
			CAN Active Messages (High Word) Bit Designation
0x0B0	333Hz (fixed)	High Speed Message, note bit of CAN Active Messages High Word must be set to 0 to activate. To activate this message the normal setting would be 0xFFFE.	0x0001

All of the above message addresses are in standard 11-bit format. The addresses in extended 29-bit and J1939 format are listed below (for the default CAN ID Offset of 0xA0):

Standard 11-bit Format	Extended 29-bit Format	J1939 Format
0x0A0	0x0A0 **X**	0x0CFFA001
0x0A1	0x0A1 **X**	0x0CFFA101
0x0A2	0x0A2 **X**	0x0CFFA201
0x0A3	0x0A3 **X**	0x0CFFA301
0x0A4	0x0A4 **X**	0x0CFFA401
0x0A5	0x0A5 **X**	0x0CFFA501
0x0A6	0x0A6 **X**	0x0CFFA601
0x0A7	0x0A7 **X**	0x0CFFA701
0x0A8	0x0A8 **X**	0x0CFFA801
0x0A9	0x0A9 **X**	0x0CFFA901
0x0AA	0x0AA **X**	0x0CFFAA01
0x0AB	0x0AB **X**	0x0CFFAB01
0x0AC	0x0AC **X**	0x0CFFAC01
0x0AD	0x0AD **X**	0x0CFFAD01
0x0AE	0x0AE **X**	0x0CFFAE01
0x0AF	0x0AF **X**	0x0CFFAF01
0x0B0	0x0B0 **X**	0x0CFFB001
0x0C0 Command Message	0x0C0 **X**	0x0CFFC001
0x0C1 Parameter Command	0x0C1 **X**	0x0CFFC101
0x0C2 Parameter Response	0x0C2 **X**	0x0CFFC201

Extended format is often denoted by the letter ‘X’. However, based on the CAN logger, this format may be represented differently. Please refer to the manual for the CAN logger that is used.

J1939 messages have the following fixed configuration:

- Priority = 3
- PDU Format = 0xFF
- PDU Specific = CAN ID Offset EEPROM
- Source Address = 1 (for both received and transmitted messages)

Enabling/Disabling Broadcast of CAN Messages

As an example, in order to disable Temperature #1, #2 and #3 messages in the above table, the parameter command message should be configured as follows:

Data Byte 7 (Low Byte)	Data Byte 6 (Low Byte)	Data Byte 5 (High Byte)	Data Byte 4 (Low Byte)	Data Byte 3	Data Byte 2	Data Byte 1	Data Byte 0
CAN Active Messages High Word		CAN Active Messages Low Word		Reserved	R/W Command	Parameter Address	
255 (0xFF)	255 (0xFF)	255 (0xFF)	248 (0xF8)	0	1	0	148

Data Byte 4 controls the following messages:

Bit 0: Temperature #1
Bit 1: Temperature #2
Bit 2: Temperature #3
Bit 3: Analog Input Voltages
Bit 4: Digital Input Status
Bit 5: Motor Position Information
Bit 6: Current Information
Bit 7: Voltage Information

In little-endian format, Byte 4 can be looked at as: Bit 7 - Bit 6 - Bit 5 - ... - Bit 1 - Bit 0

To enable all messages above, Byte 4 should be set to 0xFF (all bits set to 1).
To disable temperature messages, Byte 4 should be set to 0xF8 (Bit 0, 1, and 2 are set to 0)
To disable Motor position information, Byte 4 should be set to 0xDF (Bit 5 set to 0)

Data Byte 5 controls the following messages:
Bit 0: Flux Information
Bit 1: Internal Voltages
Bit 2: Internal States
Bit 3: Fault Codes
Bit 4: Torque & Timer Information
Bit 5: Modulation Index & Flux Weakening Output Information
Bit 6: Firmware Information
Bit 7: Diag Data

Data Byte 6 controls the following messages but user should not disable any of these messages:

Bit 0: High Speed Message (1 = off, 0 = on)
Bit 1: Not used
Bit 2: Not used
Bit 3: Not used
Bit 4: Not used
Bit 5: Not used
Bit 6: Slave Mode Command Message
Bit 7: BMS Command Message

Data Byte 7 controls the following messages but user should not disable any of these messages:

Bit 0: OBD2 General Query
Bit 1: OBD2 Specific Query
Bit 2: OBD2 Response
Bit 3: U2C TX Message
Bit 4: U2C RX Message
Bit 5: Parameter Response Message
Bit 6: Parameter Command Message
Bit 7: CAN Command Message

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Broadcast Message Definitions

0x0A0 – Temperatures #1

Byte #	Name	Format	Description
0,1	Module A Temperature	Temperature	Temperature of Power Module, Phase A
2,3	Module B Temperature	Temperature	Temperature of Power Module, Phase B
4,5	Module C Temperature	Temperature	Temperature of Power Module, Phase C
6,7	Gate Driver Board Temperature	Temperature	Temperature of Gate Driver Board

0x0A1 – Temperatures #2

Byte #	Name	Format	Description
0,1	Control Board Temperature	Temperature	Temperature of Control Board.
2,3	RTD #1 Temperature	Temperature	Temperature read from RTD input #1
4,5	RTD #2 Temperature	Temperature	Temperature read from RTD Input #2
6,7	Stall Burst Model Temperature / RTD #3 Temperature	Temperature	Gen 2: Temperature read from RTD Input #3 Gen 5 / CM: Power Module junction temperature estimate read Stall Burst Model. Only for supported inverters. See Stall Burst manual.

0x0A2 – Temperatures #3 & Torque Shudder

Byte #	Name	Format	Description
0,1	Coolant Temperature / RTD #4 Temperature	Temperature	Gen 2: Temperature read from RTD Input #4 Gen 5/ CM: Estimated Coolant temperature.
2,3	Hot Spot Temperature / RTD #5 Temperature	Temperature	Gen 2: Temperature read from RTD Input #5 Gen 5 / CM: Estimated hot spot temperature internal to inverter.
4,5	Motor Temperature	Temperature	Filtered temperature value from the motor temperature sensor.
6,7	Torque Shudder	Torque	A value of torque used in shudder compensation.

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0x0A3 – Analog Input Voltages (for firmware version before 1995)

Byte #	Name	Format	Description
0,1	Analog Input #1	Low Voltage	Voltage on Analog Input #1
2,3	Analog Input #2	Low Voltage	Voltage on Analog Input #2
4,5	Analog Input #3	Low Voltage	Voltage on Analog Input #3
6,7	Analog Input #4	Low Voltage	Voltage on Analog Input #4

0x0A3 – Analog Input Voltages (for firmware version 1995 and after)

Bit #	Name	Format	Description
0 – 9	Analog Input #1	Low Voltage	Voltage on Analog Input #1
10 – 19	Analog Input #2	Low Voltage	Voltage on Analog Input #2
20 – 29	Analog Input #3	Low Voltage	Voltage on Analog Input #3
32 – 41	Analog Input #4	Low Voltage	Voltage on Analog Input #4
42 – 51	Analog Input #5	Low Voltage	Voltage on Analog Input #5
52 – 61	Analog Input #6	Low Voltage	Voltage on Analog Input #6

0x0A3 – Analog Input Voltages (for Gen 5 / CM firmware where iM-225 motor type is used)

Bit #	Name	Format	Description
0 – 15	Oil Temperature	Temperature	Oil Temperature of iM-225 motor
16 – 31	Oil Pressure	Pressure	Oil Pressure of iM-225 motor
32 – 41	Analog Input #4	Low Voltage	Voltage on Analog Input #4
42 – 51	Analog Input #5	Low Voltage	Voltage on Analog Input #5
52 – 61	Analog Input #6	Low Voltage	Voltage on Analog Input #6

0x0A4 – Digital Input Status

Byte #	Name	Format	Description
0	Digital Input #1	Boolean	Status of Digital Input #1, Forward switch
1	Digital Input #2	Boolean	Status of Digital Input #2, Reverse switch
2	Digital Input #3	Boolean	Status of Digital Input #3, Brake switch
3	Digital Input #4	Boolean	Status of Digital Input #4, REGEN Disable Switch
4	Digital Input #5	Boolean	Status of Digital Input #5, Ignition switch
5	Digital Input #6	Boolean	Status of Digital Input #6, Start switch
6	Digital Input #7	Boolean	Status of Digital Input #7, Valet Mode
7	Digital Input #8	Boolean	Status of Digital Input #8

0x0A5 – Motor Position Information

Byte #	Name	Format	Description
0,1	Motor Angle (Electrical)	Angle	The electrical angle of the motor as read by the encoder or resolver.
2,3	Motor Speed	Angular velocity	The measured speed of the motor
4,5	Electrical Output Frequency	Frequency	The actual electrical frequency of the inverter.

Byte #	Name	Format	Description
6,7	Delta Resolver Filtered	Angle	This is used in calibration of resolver angle adjustment. The range of this parameter is ±180°. Values between 180° and 360° are shown as negative angle. For example, 270° is equal to -90°, and 190° is equal to -170°.

0x0A6 – Current Information

Byte #	Name	Format	Description
0,1	Phase A Current	Current	The measured value of Phase A current.
2,3	Phase B Current	Current	The measured value of Phase B current
4,5	Phase C Current	Current	The measured value of Phase C current
6,7	DC Bus Current	Current	The calculated DC Bus current.

0x0A7 – Voltage Information

Byte #	Name	Format	Description
0,1	DC Bus Voltage	High Voltage	The actual measured value of the DC bus voltage.
2,3	Output Voltage	High Voltage	The calculated value of the output voltage, in peak line-neutral volts.
4,5	VAB_Vd_Voltage	High Voltage	Measured value of the voltage between Phase A and Phase B (VAB) when the inverter is disabled. Vd voltage when the inverter is enabled.
6,7	VBC_Vq_Voltage	High Voltage	Measured value of the voltage between Phase B and Phase C (VBC) when the inverter is disabled. Vq voltage when the inverter is enabled.

0xA8 – Flux Information

Byte #	Name	Format	Description
0,1	Flux command	Flux	The commanded flux (only applies to induction motors)
2,3	Flux feedback	Flux	The estimated flux (only applies to induction motors)
4,5	Id feedback	Current	D-axis current feedback
6,7	Iq feedback	Current	Q-axis current feedback

0x0A9 – Internal Voltages

Byte #	Name	Format	Description
0,1	1.5V Reference voltage	Low Voltage	One of the low voltage references
2,3	2.5V Reference voltage	Low Voltage	One of the low voltage references

Byte #	Name	Format	Description
4,5	5.0V Reference voltage	Low Voltage	One of the low voltage references
6,7	12V System voltage	Low Voltage	One of the low voltage references

0x0AA – Internal States

Byte #	Name	Format	Description
0	VSM State	Internal	0 = VSM Start State 1 = Pre-charge Init State 2 = Pre-charge Active State 3 = Pre-charge Complete State 4 = VSM Wait State 5 = VSM Ready State 6 = Motor Running State 7 = Blink Fault Code State 14 = Shutdown in Process – in key switch mode 1, user has turned the key switch to off position. 15 = Recycle Power State – user must recycle power when the unit is in this state.
1	PWM Frequency	kHz	For Gen 5 / CM the PWM frequency that is currently being used is reported. The PWM frequency may change depending on operating conditions. For PMxxx inverter this value will show as 0.
2	Inverter State	Internal	0 = Power on State 1 = Stop State 2 = Open Loop State 3 = Closed Loop State 4 = Wait State 5, 6, 7 = *Internal states* 8 = Idle Run State 9 = Idle Stop State 10,11,12 = *Internal states*
3	Relay State	Internal	Bit 0: Relay 1 Status (1 = active) Bit 1: Relay 2 Status Bit 2: Relay 3 Status Bit 3: Relay 4 Status Bit 4: Relay 5 Status Bit 5: Relay 6 Status
4 – Bit0	Inverter Run Mode	Internal	0 = Torque Mode 1 = Speed Mode

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Byte #	Name	Format	Description
4 – Bit1	Self-Sensing Assist Enable	Internal	For Gen 5 / CM: 0 = Disabled 1 = Enabled Indicates if Self-Sensing Assist is currently active. Only for select motors. See Self-Sensing Assist manual.
4 – Bits5-7	Inverter Active Discharge State	Internal	Current Inverter Active Discharge State: 000 (0) = Discharge Disabled 001 (1) = Discharge Enabled, waiting 010 (2) = Performing Speed Check 011 (3) = Discharge Actively occurring 100 (4) = Discharge Completed All other states are reserved for future use.
5 – Bit0	Inverter Command Mode	Internal	0 = CAN Mode 1 = VSM Mode When in CAN Mode the inverter takes commands from the CAN messages. When in VSM Mode the inverter takes messages from the Vehicle State Machine which is operated from the various input and outputs of the inverter.
5 – Bit4 thru 5 – Bit7	Rolling Counter Value	Internal	Function only available currently on Gen 5 / CM: The value of the currently expected Rolling Counter value.
6 - Bit0	Inverter Enable State	Internal	0 = Inverter is disabled 1 = Inverter is enabled
6 – Bit1	Burst Model Mode	Internal	For Gen 5 / CM: 0 = Stall 1 = High Speed At low speeds Stall Burst Model will apply when mode is 0 (Stall) for select inverters only. See Stall Burst manual.
6 - Bit6	Start Mode Active	Internal	0 = start signal has not been activated 1 = start signal has been activated Provides latched indication of when the start signal has been received, typically used when in using VSM mode. Implemented in Gen 3 version 2044.
6 – Bit7	Inverter Enable Lockout	Internal	0 = Inverter can be enabled 1 = Inverter cannot be enabled This feature is added so that the inverter cannot be accidentally enabled. This feature requires that before sending out an Inverter Enable command, the user must send out a Inverter Disable command. Once the inverter sees a Disable command, the lockout is removed and controller can receive the Inverter Enable command.

Byte #	Name	Format	Description
7 – Bit0	Direction Command	Internal	1 = Forward 0 = Reverse, if inverter is enabled Stopped, if inverter is disabled
7 – Bit1	BMS Active	Internal	0 = BMS Message is not being received 1 = BMS Message is being received
7 – Bit2	BMS Limiting Torque	Internal	0 = Torque is not being limited by the BMS. 1 = Torque is being limited by the BMS.
7 – Bit3	Limit Max Speed	Internal	This bit is currently available only in Gen 5/CM inverters and Gen 3 version 2042+: 0 = no torque limiting is occurring. 1 = torque limiting is occurring due to the motor speed exceeding the maximum motor speed.
7 – Bit4	Limit Hot Spot	Internal	This bit/function is currently available only in Gen 5/CM inverters: 0 = Inverter hot spot temperature is below the limit. 1 = Inverter is limiting current due to regulate the maximum hot spot temperature.
7 – Bit5	Low Speed Limiting	Internal	This bit is currently available only in Gen 5/CM inverters and Gen 3 version 2042+: 0 = low speed current limiting is not occurring. 1 = low speed current limiting is applied.
7 – Bit6	Coolant Temperature Limiting	Internal	This bit is currently available only in Gen 5/CM inverters. The bit indicates that the maximum motor current is being limited due to coolant temperature.
7 – Bit7	Limit Stall Burst Model	Internal	For Gen 5 / CM: 0 = Not Limiting 1 = Limiting Indicates if Stall Burst Model is limiting the current. For select inverters only. See Stall Burst manual.

0x0AB – Fault Codes

Byte #	Name	Format	Description
0,1	POST Fault Lo	Internal	Each bit represents a fault
2,3	POST Fault Hi	Internal	Each bit represents a fault
4,5	Run Fault Lo	Internal	Each bit represents a fault
6,7	Run Fault Hi	Internal	Each bit represents a fault

POST Faults (only occur at power up)

CAN Byte	CAN Bit	POST Fault	Fault Word	Byte Value
Byte 0	0	Hardware Gate/Desaturation Fault	00000001	1
	1	HW Over-current Fault	00000002	2
	2	Accelerator Shorted	00000004	4
	3	Accelerator Open	00000008	8
	4	Current Sensor Low	00000010	16
	5	Current Sensor High	00000020	32
	6	Module Temperature Low	00000040	64
	7	Module Temperature High	00000080	128
Byte 1	8	Control PCB Temperature Low	00000100	1
	9	Control PCB Temperature High	00000200	2
	10	Gate Drive PCB Temperature Low	00000400	4
	11	Gate Drive PCB Temperature High	00000800	8
	12	5V Sense Voltage Low	00001000	16
	13	5V Sense Voltage High	00002000	32
	14	12V Sense Voltage Low	00004000	64
	15	12V Sense Voltage High	00008000	128
Byte 2	16	2.5V Sense Voltage Low	00010000	1
	17	2.5V Sense Voltage High	00020000	2
	18	1.5V Sense Voltage Low	00040000	4
	19	1.5V Sense Voltage High	00080000	8
	20	DC Bus Voltage High	00100000	16
	21	DC Bus Voltage Low	00200000	32
	22	Pre-charge Timeout	00400000	64
	23	Pre-charge Voltage Failure	00800000	128
Byte 3	24	EEPROM Checksum Invalid	01000000	1
	25	EEPROM Data Out of Range	02000000	2
	26	EEPROM Update Required	04000000	4
	27	Hardware DC Bus Over-Voltage during initialization	08000000	8
	28	Gen 3: Reserved Gen 5: Gate Driver Initialization	10000000	16
	29	Reserved	20000000	32
	30	Brake Shorted	40000000	64
	31	Brake Open	80000000	128

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RUN Faults

CAN Byte	CAN Bit	RUN Fault	Fault Word	Byte Value
Byte 4	32	Motor Over-speed Fault	00000001	1
	33	Over-current Fault	00000002	2
	34	Over-voltage Fault	00000004	4
	35	Inverter Over-temperature Fault	00000008	8
	36	Accelerator Input Shorted Fault	00000010	16
	37	Accelerator Input Open Fault	00000020	32
	38	Direction Command Fault	00000040	64
	39	Inverter Response Time-out Fault	00000080	128
Byte 5	40	Hardware Gate/Desaturation Fault	00000100	1
	41	Hardware Over-current Fault	00000200	2
	42	Under-voltage Fault	00000400	4
	43	CAN Command Message Lost Fault	00000800	8
	44	Motor Over-temperature Fault	00001000	16
	45	Reserved	00002000	32
	46	Reserved	00004000	64
	47	Reserved	00008000	128
Byte 6	48	Brake Input Shorted Fault	00010000	1
	49	Brake Input Open Fault	00020000	2
	50	Module A Over-temperature Fault	00040000	4
	51	Module B Over-temperature Fault	00080000	8
	52	Module C Over-temperature Fault	00100000	16
	53	PCB Over-temperature Fault[7]	00200000	32
	54	Gate Drive Board 1 Over-temperature Fault	00400000	64
	55	Gate Drive Board 2 Over-temperature Fault	00800000	128
Byte 7	56	Gate Drive Board 3 Over-temperature Fault	01000000	1
	57	Current Sensor Fault	02000000	2
	58	Gen 3: Reserved Gen 5: Gate Driver Over-Voltage	04000000	4
	59	Gen 3: Hardware DC Bus Over-Voltage Fault Gen 5: Reserved	08000000	8
	60	Gen 3: Reserved Gen 5: Hardware DC Bus Over-voltage Fault	10000000	16
	61	Reserved	20000000	32
	62	Resolver Not Connected	40000000	64
	63	Reserved	80000000	128

0x0AC – Torque & Timer Information

Byte #	Name	Format	Description
0,1	Commanded Torque	Torque	The commanded torque.
2,3	Torque Feedback	Torque	The estimated motor torque based on motor parameters and feedbacks.
4,5,6,7	Power on Timer	(Counts x .003) sec	This timer is updated every 3 msec. This timer will roll-over in approximately 5 months. The timer will reset to 0 at power on. Monitoring this can be useful to show when a reset of the processor has occurred.

0x0AD – Modulation Index & Flux Weakening Output Information

Byte #	Name	Format	Description
0,1	Modulation Index	Per-unit Value	This is the modulation index. The scale factor is x100. To get the actual modulation index divide the value by 100.
2,3	Flux Weakening Output	Current	This is the current output of the flux regulator.
4,5	Id command	Current	The commanded D-axis current
6,7	Iq command	Current	The commanded Q-axis current

0x0AE – Firmware Information

Byte #	Name	Format	Description
0,1	EEPROM Version / Project Code	NA	This is an EEPROM version that is assigned to each project. For factory use only!
2,3	Software Version	NA	This is the software version with major and minor release values.
4,5	Date Code (mmdd)	NA	This is the portion of date code that displays month and date information in *mmdd* format.
6,7	Date Code (yyyy)	NA	This is the portion of date code that displays year information in *yyyy* format.

0x0AF – Diagnostic Data

Byte #	Name	Format	Description
Please refer to the manual, “Download Diagnostic Data” for details.			

0x0B0 – High Speed Message (transmitted at 3ms, version 2042+)

Byte #	Name	Format	Description
0,1	Torque Command	Torque	The commanded torque.
2,3	Torque Feedback	Torque	The estimated motor torque.
4,5	Motor Speed	Angular velocity	The measured motor speed.
6,7	DC Bus Voltage	High Voltage	The actual measured DC bus voltage.

2.2 Command Message

The Command Message is used to transmit data to the controller. This message is sent from a user-supplied external controller to the motor controller. The Control Message (0x0C0) is used to operate the controller via the CAN interface.

0x0C0 – Command Message (Data Length = 8 bytes)

Byte.Bit	Name	Format	Description
0,1	Torque Command	Torque	Torque command used when in torque mode. When in Speed Mode the Torque Command values become a feedforward to the Speed Regulator (see Using Speed Mode manual).
2,3	Speed Command	Angular Velocity	Speed command used when in speed mode. Starting in version 2048 and 651D any Speed Command transmitted while in Torque mode will over-ride the Max Speed EEPROM parameter and provide a new maximum speed limit. The maximum speed limit will revert to the default EEPROM parameter value when the inverter returns to Torque mode.
4	Direction Command	Boolean	0 = “Reverse” 1 = “Forward” See section 2.3.2.2 for further definition of direction.
5.0	Inverter Enable	Boolean	0 = Inverter Off, 1 = Inverter On
5.1	Inverter Discharge[7]	Boolean	0 = Disable Discharge, 1 = Enable Discharge
5.2	Speed Mode Enable	Boolean	0 = Do not over-ride mode 1 = If controller is in torque mode then controller will change to speed mode. This is a mode over-ride bit that will change the mode from torque to speed only. It does not change the mode from speed to torque. See manual Using Speed Mode for more information.
6,7	Commanded Torque Limit	Torque	If set to 0, the default torque limits sets in the EEPROM parameters are used. If set to a positive number then the Motor and Regen Torque limits are set to the torque value sent.

[7] Please refer to the document, “Inverter Discharge Process”.

This message should be continuously broadcast at 500 milliseconds rate or faster. Of course, for most vehicle situations a message rate of 10-50 milliseconds provides better control of the vehicle. The Command Message is processed by the controller every 3ms. Sending the Command message at a rate faster than 3ms will not improve response. The message must be sent as an 8 byte message (DLC = 8).

If the Command Message is not received faster than the CAN TimeOut time and the Command Message Active Parameter is set to 1 then a CAN Command Message Lost fault will be generated.

When in CAN mode the Command messages should be sent to the controller before the inverter is powered on (or before the CAN Timeout time expires). If they are not then the Command message Lost fault will have to be cleared up on power up.

Note: Commanded Torque Limit feature was added in software version 1953. For previous versions of software these two bytes should be set to 0 and do not have any function.

2.2.1 Inverter Enable Safety Options

2.2.1.1 Inverter Enable Lockout:

This feature is added so that the inverter cannot be accidentally enabled when first powered up. This feature requires that before sending out an Inverter Enable command, the user must send out an Inverter Disable command. Once the inverter sees a Disable command, the lockout is removed and controller can receive the Inverter Enable command.

2.2.2.2 Inverter Enable Safety Switch:

A new EEPROM parameter, CAN Inverter Enable Switch Active EEPROM, is added as a safety option.

Setting this parameter to 1 will take DIN1 digital input into consideration and the inverter will only be enabled if both DIN1 and inverter command are active. If DIN1 or Inverter Enable Command is inactive, the inverter will be disabled.

If CAN Inverter Enable Switch Active EEPROM is set to 0, DIN1 will have no effect on enabling or disabling the inverter.

2.2.2.3 Sudden Reversal of the Direction Command:

This safety feature keeps the user from changing the direction command while the inverter is enabled. If the direction command is changed suddenly when the inverter is still enabled, inverter is disabled without triggering any faults. Also, the lockout condition is set again which will force the user to send an Inverter Disable command before re-enabling it.

2.2.2 CAN Message Sequence Example

Here is an example of sending out torque commands to the inverter in ‘CAN’ mode with run mode required to be ‘Torque’. These two EEPROM parameters can be set via GUI after powering up the inverter.

For the message sequence example described below, following assumptions hold true:

GUI EEPROM Parameter	Default Value	Description
Inv_Cmd_Mode_EEPROM(CAN=0_VSM=1)	0	CAN mode
Run_Mode_EEPROM(Trq=0_Spd=1)	0	Torque mode
CAN_ID_Offset_EEPROM	0xA0	Default CAN ID offset
CAN_TimeOut_(/3ms)_EEPROM	333	1 second timeout period

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Message Type	CAN ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Description
Rxd	0xAA	4	0	9	0	**0**	0	**128**	0	Torque mode Is active. Lockout is enabled.
Txd	0xC0	0	0	0	0	0	**0**	0	0	Send out inverter disable command to release lockout. **Note** that lockout will not disable if the inverter is faulted. This command should have been set up to be transmitted at a rate sufficient to prevent the CAN Timeout fault. To prevent a fault at startup start sending before the inverter is powered up.
Txd	0xC0	**100**	**0**	x [8]	x	**1**	**1**	0	0	Enable the inverter with a torque command of +10 Nm in forward direction.
Txd	0xC0	**200**	**0**	x	x	1	1	0	0	Set the torque to +20 Nm (motoring) in forward direction.
Txd	0xC0	**156**	**255**	x	x	1	1	0	0	Set the torque to -10 Nm (regenerative) in forward direction.
Txd	0xC0	X	x	x	x	1	**0**	0	0	Disable the inverter before changing the direction. If the direction is changed without disabling the inverter first. The inverter will be automatically disabled as a safety precaution.
Txd	0xC0	**100**	**0**	x	x	**0**	**1**	0	0	Set the command to +10 Nm (motoring) in reverse direction.

[8] "x" indicates a DON'T CARE value, send a zero if unsure.

2.2.3 Sign Convention for Torque and Speed

When using the controller in CAN mode, it is important to make sure that commands are entered properly to move the motor in the intended direction. Following description provides details on speed command, speed feedback, torque command, torque feedback and direction command and the possible outcome in each scenario.

2.2.3.1 CAN Speed command:

The Speed Command is a signed number. If the speed command is positive then the direction will be the direction of the direction command bit. If the Speed Command is negative then the direction will be opposite of the direction of the direction command bit.

When using speed mode it is important that the torque limits are appropriate for regulating the speed. An unloaded motor will often require some amount of regen torque to keep the speed regulated. When operating with low or negative speeds the Regen Fade Speed EEPROM parameter can prevent regen torque. The Regen Fade Speed can be disabled by setting the EEPROM parameter to 0.

2.2.3.2 CAN Torque command:

For a forward direction command:

- Positive torque command will give a positive torque feedback and is motoring for positive speed.
- Negative torque command will give a negative torque feedback and is regen for positive speed.
- Positive torque command will give a positive torque feedback and is regen for negative speed.
- *A negative torque command should not be allowed if already going negative speed.*

For reverse direction command:

- Positive torque command will give a negative torque feedback & is motoring for negative speed.
- Negative torque command will give a positive torque feedback and is regen for negative speed.
- Positive torque command will give a negative torque feedback and is regen for positive speed.
- *A negative torque command should not be allowed if already going positive speed.*

2.3 Parameter Messages

The Parameter Messages (0x0C1 and 0x0C2) are used to read and write parameters in the controller. These parameters have many different functions. Some parameters are used to set non-volatile information (EEPROM data). Some are used to change functionality. Some are used to monitor various operating parameters that are not part of the broadcast messages.

To write a parameter use message 0x0C1 with byte #2 set to 1 (write). The controller will then respond with message 0x0C2 and if successful byte #2 will be set to 1.

To read a parameter use message 0x0C1 with byte #2 to set 0 (read). The controller will then respond with message 0x0C2 containing the requested data.

Both parameter messages contain 4 bytes for the data that is read or written. Some parameters will only occupy a single byte. If the data occupies less than 4 bytes it will be loaded into byte #4 first, followed by #5, and so on.

If the parameter address is not recognized then the controller parameter response message (0x0C2) will contain 0 in both bytes 0 and 1 of the return data.

2.3.1. Parameter Message Format

0x0C1 – Read / Write Parameter Command – sent to motor controller

Byte #	Name	Format	Description
0,1	Parameter Address	Unsigned int	Each command is identified by a unique address. Refer to sections, 'Command Parameters' and 'EEPROM Parameters' for each parameters address.
2	R/W Command	Boolean	0 = read, 1 = write
3	Reserved	NA	NA
4,5	Data	See "Data Formats" section	Data should be entered as dictated in "Data Formats" section.
6,7	Reserved	NA	NA

0x0C2 – Read / Write Parameter Response – response from motor controller

Byte #	Name	Format	Description
0,1	Parameter Address	Unsigned int	Each command is identified by a unique address. Refer to sections, 'Command Parameters' and 'EEPROM Parameters' for each parameters address. Will return 0,0 if parameter address is not recognized.
2	Write Success	Boolean	0 = not written, 1 = success
3	Reserved	NA	NA
4,5	Data	See "Data Formats" section	Response data is in the format dictated in "Data Formats" section.
6,7	Reserved	NA	NA

2.3.2. Parameter Address Ranges

The parameters are categorized in several general categories. Some parameters are read-only, and some can be written and read.

Address Range	Category	Description
0 – 99	General	This address range contains general parameters for control and monitoring
100 – 499	User EEPROM	This address range is for EEPROM variables. These can only be written when the controller is not operating the motor.

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2.3.3. Command Parameters

Address	Name	Format	Description
1	Relay Command	Unsigned integer (0 – 65535)	0xAA00: Normal Run mode 0x55***nn***: External Relay Control mode Please see description below.
10	Flux command	Flux	Modify the flux command.
11	Resolver PWM Delay Command	Unsigned integer (0 – 6250)	This command is used in calibration of the timing of the A/D reading of the resolver. It is used in determining the peak of the sine wave coming from the resolver. Its default value is 1100.
12	Gamma Adjust GUI Command	Degrees	This is a calibration parameter used in the alignment of the magnetic field of the motor with the resolver. This command parameter behaves the same way as its equivalent GUI Command parameter.
20	Fault Clear	Boolean	Writing a 0 to this parameter clears any active faults. This command can be sent through CAN in CAN as well as VSM mode.
21	Set PWM Frequency	Unsigned integer (6 – 24)	On Gen 5 / CM inverters the PWM frequency can be changed from what is defined by the various EEPROM parameters. Setting the PWM frequency via this Parameter command will over-ride all EEPROM settings. The PWM frequency will revert back to the EEPROM settings when power is cycled.
22	AIN Pull-up control	Unsigned integer (0 – 7)	On CM inverters that support control of the analog pull-up resistors on AIN1-3 this Parameter will allow commanding the pull-up to be enabled. Each bit of the Parameter data control each pull-up control (bit 0 = AIN1, bit 1 = AIN2, bit 3 = AIN3).

23	Shudder Compensation Gain Control	Unsigned integer (0 – 65535)	Starting with version 2048 and 651D. If shudder compensation is being used (Shudder_Compensation_Enable_EEPROM = 1) the Parameter will allow the Kp_Shudder gain to be modified and for the Shudder Compensation to be disabled and reenabled. If the Parameter Data is set to 0 then the Shudder Compensation will be disabled. If the Parameter Data is greater than 0 then the Shudder Compensation will be enabled (if the compensation has been enabled via EEPROM) and the Kp_Shudder gain will be set to the Parameter Data value divided by 100.
31	Diag. Data Trigger	Unsigned integer (0-65535)	Starting with version 651E. A non zero value will trigger a Diag. Data dump over CAN.

Relay Command

This command is used to control relay outputs. The Gen 2 units (older PM100 units) have 4 relay outputs. Gen 3 units, newer PM100, all PM150/250, have 6 relay outputs. The RM100 controller has two relay outputs.

In order to control a relay, the inverter needs to be put into "External Relay Control" mode. This is achieved by setting byte 5 to 0x55. For byte 4, each bit corresponds to a relay. Bit 0 corresponds to relay 1 and bit 1 corresponds to relay 2. Similarly, bit 7 corresponds to relay 8 as shown in the table below. Note, the hardware does not currently support 8 relays.

Byte 5	Byte 4
0x55	R8 R7 R6 R5 R4 R3 R2 R1

For example, if the user wants to turn on relay 3, he/she needs to set the data field of the parameter command messages to 0x5504. Similarly, if relay 1 and 2 need to be turned on, a command of 0x5503 must be sent.

Setting the data byte 5 to a value other than 0x55 will kick the inverter out of the "External Relay Control" mode and in to the "Normal Run" mode. The default value for normal run mode is 0xAA.

2.3.4. EEPROM Parameters

These Parameters are sent using the command message format described in 0x0C1 to modify the EEPROM parameters used by the controller. These parameters can only be written when the motor is not enabled. Each parameter will be stored in non-volatile memory at the time of programming. When the power is recycled the parameter will become effective and used by the inverter. Parameters highlighted in yellow will take immediate effect.

All EEPROM parameters can also be modified through the GUI interface.

2.3.4.1 Motor Configuration[9]

Address	Name	Format	Description
150	Motor Parameter Set	Unsigned char (0 – 255)	This represents a set of parameter that is used for each type of motor.
151	Resolver PWM Delay	Unsigned integer (0 – 6250)	This is used in calibration of the timing of the A/D reading of the resolver. It is used in determining the peak of the sine wave coming from the resolver.
152	Gamma Adjust	Degrees	This is a calibration parameter used in the alignment of the magnetic field of the motor with the resolver. It will automatically default to the correct value when the motor type is changed.
154	Sin Offset	Low Voltage	Please refer to the manual, “Encoder Calibration for SIN_COS Encoder”.
155	Cos Offset	Low Voltage	
156	Sin ADC Offset	ADC Count	This feature is dependent on the hardware version of the controller. In some cases, the resolver sine and cosine outputs may require adjustments for improved signals. These offsets are added as ADC counts to calibrate the sin and cosine signals directly. Not commonly used.
157	Cos ADC Offset	ADC Count	

[9] For a detailed process on how to configure a specific motor, please refer to the document “Setting up the PM for *XYZ* Motor”, where XYZ refers to the specific motor for individual customer.

2.3.4.2 System Configuration

Address	Name	Format	Description
140	Pre-charge Bypassed	Boolean	0 = Pre-charge is in effect 1 = Pre-charge is bypassed
142	Inverter Run Mode	Boolean	0 = Torque Mode 1 = Speed Mode
143	Inverter Command Mode	Boolean	This parameter gives the option to operate controller in either VSM mode or CAN mode. In VSM mode, GUI is the main interface to monitor and modify parameters. The inverter takes messages from the Vehicle State Machine which is operated from the various inputs and outputs of the inverter such brake, accelerator pedal, etc. In VSM mode, broadcast messages are still sent out over the CAN lines. In CAN mode, both GUI and CAN interfaces are active and can be used to monitor and modify parameters. However, any inputs from the vehicle state machine will be ignored. 0 = CAN Mode 1 = VSM Mode (Default)
149	Key Switch Mode	Unsigned integer	Added alternate key switch modes. This allows different types of ignition for vehicles. 0 = Allows a simple on/off switch for powering up the inverter. 1 = Provides the functionality of a more traditional ignition switch with momentary START signal that powers up the inverter and keeps it powered until the ignition switch is turned off. Key Switch Mode is only effective in VSM Mode. CAN mode remains unaffected. However, the parameter can be updated through both GUI and CAN.
170	Relay Output State	Unsigned integer	Sets whether the Relay outputs have their normal function or are under CAN control. See the Software manual for more information.
173	Discharge Enable	Unsigned integer	See the Inverter Discharge Process manual for more information on the setting of this parameter.
204	Analog Output Function Select	Unsigned integer	Allows selection of parameter to be output on the analog output (available on Gen 3 units only).

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174	Serial Number	Unsigned Integer	Unit Serial Number.
251	Self-Sense Assist Enabled	Unsigned Integer	For Gen 5 / CM: 0 = OFF 1 = ON This parameter determines whether Self Sensing Assist mode is active or not. Only available for select motors. See Self-Sense Assist manual.
241	PWM Frequency	Unsigned Integer	Gen 5 / CM only: The default PWM frequency to be used, in kHz.
For Gen 5 / CM Firmware 6525 and earlier			
242	PWM High Current Limit	Current	Gen 5 / CM only: The motor current threshold that transitions the PWM frequency to the High Current PWM frequency.
243	PWM High Current Speed Limit	Speed	Gen 5 / CM only: The maximum motor speed that the inverter is allowed to be in the High Current PWM frequency.
244	High Current PWM Frequency	Unsigned Integer	Gen 5 / CM only: The PWM frequency used when the High Current PWM Frequency mode.
245	PWM High Speed Limit	Speed	Gen 5 / CM only: Above this motor speed the PWM frequency transitions to High Speed PWM Frequency.
246	High Speed PWM Frequency	Unsigned Integer	Gen 5 / CM only: The PWM frequency used when motor speed exceeds the PWM High Speed Limit.
For Gen 5 / CM Firmware 6526 and later			
246	Minimum Continuous PWM	Unsigned Integer	Gen 5 / CM only: The minimum PWM frequency to be used with Continuously Variable PWM, outside of stall. Minimum value of 6 kHz.
247	Maximum Continuous PWM	Unsigned Integer	Gen 5 / CM only: The maximum PWM frequency to be used with Continuously Variable PWM, outside of stall. Maximum value of 24 kHz.
245	Stall PWM	Unsigned Integer	Gen 5 / CM only: The PWM to be used in stall for high current, in kHz.
250	PWM Mode Configuration	Unsigned Integer	Gen 5 / CM only: The mode for switching between different PWM frequencies. 0 = Nominal PWM only, with stall region 1 = Continuously Variable PWM, with stall region. 2 = Continuously Variable PWM, no stall region.

248	Continuous PWM Dwell Time	Unsigned Integer	Gen 5 / CM only: This sets the minimum time the Continuous Variable PWM Method will stay at a given PWM frequency before transitioning. Measured in counts of 3 ms.

CAN Configuration

Address	Name	Format	Description
141	CAN ID Offset	Unsigned integer	This parameter allows the user to choose their own set of contiguous CAN message identifiers starting with the value in CAN ID Offset. This offset covers a range of 0 – 0x7C0. The default offset is 0x0A0. The default range is 0x0A0 – 0x0CF. This feature is especially useful when there are more than one controller on the same CAN network. While setting base address for a controller, it must be made sure that the address range for controllers does not contain overlapping addresses.
144	CAN Extended Message Identifier	Boolean	This parameter allows switching between CAN standard and extended message identifiers. 0 = Standard CAN Messages 1 = Extended CAN Messages
171	CAN J1939 Option Active	Boolean	This parameter allows switching between extended message identifiers with or without SAE J1939 format. 0 = J1939 formatting is not active 1 = J1939 formatting is active
145	CAN Term Resistor Present	Boolean	In order to use CAN communication, the CAN bus needs to have a termination resistor. The PM family inverters are equipped with a user configurable resistor which is activated through this parameter. 0 = Term. Resistor not active 1 = Term. Resistor active If CAN Terminator Resistor is deactivated, it may be necessary to use the GUI interface only[10] since CAN communication may fail without a terminator resistor. The RM inverters do not have this feature and thus this parameter has no effect on the CAN bus.

[10] Please refer to the document "Programming EEPROM Parameters using GUI".

146	CAN Command Message Active	Boolean	The parameter enables CAN Command Timeout feature. The CAN Timeout feature if enabled will generate a fault if the CAN Command Message is not received within the time set by CAN Timeout parameter. It is recommended that this feature be enabled. 0 = The CAN Timeout feature is disabled. 1 = The CAN Timeout feature is enabled.
147	CAN Bit Rate	Unsigned integer	The CAN Bus bit rate can be changed using this parameter. However, changing this parameter requires a power reset on controller since bus speed is setup only at the initialization of CAN modules. Also, The parameter is restricted to valid baud rates. The 4 options for valid baud rate are: 125 = 125Kbps 250 = 250 Kbps 500 = 500 Kbps 1000 = 1Mbps
148	CAN Active Messages Lo Word	Unsigned integer	This parameter is used to enable/disable CAN Broadcast Messages. Each bit represents a CAN Message broadcast status as follows: 0 = CAN Messages broadcast disabled 1 = CAN Message broadcast enabled (Default) Please refer to the table of CAN Broadcast Messages in section 2.1 for details on how to enable/disable each message.
237	CAN Active Messages Hi Word	Unsigned integer	This parameter can be used to disable individual CAN mailboxes. This parameter should not normally be used and the default value of 0xFFFF should be used.
158	CAN Diagnostic Data Transmit Active	Boolean	This parameter is used to enable/disable the broadcast of the diagnostic data. 0 = CAN Diagnostic Data broadcast disabled 1 = CAN Diagnostic Data broadcast enabled (Default) Please refer to the document, CAN Diagnostic Data, for more details on this feature.

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159	CAN Inverter Enable Switch Active	Boolean	1 = DIN1 digital input is taken into consideration and the inverter will only be enabled if both DIN1 and inverter command are active. If either one is inactive, the inverter will be disabled. 0 = DIN1 will have no effect on enabling or disabling the inverter (Default)
172	CAN Timeout	Unsigned integer	This parameter sets how long before the CAN timeout error is set. The timeout is only active if the CAN Command Message Active is set to 1. The time is set in counts of 3ms. So for example setting a value of 333 will give a timeout time of 999 msd.
177	CAN OBD2 Enable	Boolean	0 = OBD2 Support is disabled 1 – 7 = OBD2 Support is enabled with the address offset defined by the value.
178	CAN BMS Limit Enable	Boolean	0 = BMS CAN Message Torque Limiting is disabled. 1 = BMS CAN Message Torque Limiting is enabled.
233	CAN Slave Cmd ID	Unsigned Integer	0 = disable slave mode 0x22 thru 0x7FD enables Slave mode CAN message output.
234	CAN Slave Dir	Unsigned Integer	0 = Direction command of Slave controller is the same as the Master. 1 = Direction command of Slave controller is the opposite of the Master.
235	CAN Fast Msg Rate	Unsigned Integer	Sets the broadcast rate in ms of messages that are in the Fast group. If set to 0 will disable all Fast group messages. Implemented in version 2025.
236	CAN Slow Msg Rate	Unsigned Integer	Sets the broadcast rate in ms of messages that are in the Slow group. If set to 0 will disable all Fast group messages. Implemented in version 2025.
238	CAN Debounce Counter Max	Unsigned Integer	Gen 5 / CM only: The value of the Debounce Counter at which the controller will declare a fault. If this EEPROM parameter is set to 0 it will disable the rolling counter function.
239	CAN Debounce Up Count	Unsigned Integer	Gen 5 / CM only: The number of counts that the Debounce Counter will increment when a Rolling Counter error has been flagged.
240	CAN Debounce Down Count	Unsigned Integer	Gen 5 / CM only: The number of counts that the Debounce Counter will decrement when a correct Rolling Count message has been received.

2.3.4.3 Current

Address	Name	Format	Description
100	Iq Limit	Current	This parameter sets the Q-axis current limit.
101	Id Limit	Current	This parameter sets the D-axis current limit.
107	Ia Offset EEPROM	ADC Count	The offset values are in ADC counts. Each offset should be set to 2048 which is the 0-Amps mid-point. These do not normally need to be calibrated. They are auto-calibrated on most inverters.
108	Ib Offset EEPROM		
109	Ic Offset EEPROM		

2.3.4.4 Voltage & Flux

Address	Name	Format	Description
102	DC Voltage Limit	High Voltage	This parameter sets the over-voltage limit to protect the unit. This limit should be set based on total voltage provided by the power supply/battery pack. This parameter does not generate any faults.
103	DC Voltage Hysteresis	High Voltage	This is the hysteresis value used to bring the inverter out of the over-voltage condition. Most of the time, the default value is sufficient and this value seldom needs to be changed.
104	DC Under-voltage Limit	High Voltage	This parameter sets the under-voltage limit. This limit should be set based on total voltage provided by the power supply/battery pack. A fault is generated when the voltage drops below this limit. To disable the under-voltage fault, set this limit to 0.
106	Vehicle Flux Command	Flux	This parameter sets the back EMF (flux) constant for the motor. It will automatically default to the correct value when the motor type is changed. Most of the time, the default value is sufficient and this value seldom needs to be changed.

2.3.4.5 Temperature

Address	Name	Format	Description
112	Inverter Over-Temperature	Temperature	This parameter sets the Inverter temperature limit. The temperature is set in degrees Celsius times 10 (85°C is set as 850). If the temperature exceeds this value then the inverter will turn off and declare a fault.
113	Motor Over-Temperature	Temperature	This parameter sets the Motor temperature limit (if the motor has a temperature sensor). The temperature is set in degrees Celsius times 10 (150°C is set as 1500). If the temperature exceeds this value then the inverter will turn off and declare a fault.
114	Zero Torque Temperature	Temperature	Temperature threshold where the torque is zeo. This value should be less than Mtr_OverTemp_Limit_EEPROM_(C)_x_10.
115	Full Torque Temperature	Temperature	This is the temperature threshold where the full torque is operational. This parameter affects the calculation of torque capability. Based on the calculation of the slope and offset of the line from Full_Torque_Temp_EEPROM_(C)_x_10 to Zero_Torque_Temp_EEPROM_(C)_x_10, the new torque capability is reduced by a factor of (slope * Motor Temperature + offset). This parameters should be less than Zero_Torque_Temp_EEPROM_(C)_x_10 which should be less than Mtr_OverTemp_Limit_EEPROM_(C)_x_10.
203	RTD Selection	Boolean	This parameter allows the user to select either 100 Ohms or 1000 Ohms for RTD1 and RTD2 (Gen 3 units only). Bit 0 = 0 -> RTD1 is 1000 Ohms = 1 -> RTD1 is 100 Ohms Bit 1 = 0 -> RTD2 is 1000 Ohms = 1 -> RTD2 is 100 Ohms

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2.3.4.6 Accelerator Pedal[11]

Address	Name	Format	Description
120	ACCEL Pedal Low	Low Voltage	This parameter sets a limit below which the torque command is 0. This should be set to a value that is lower than the lowest possible acceleration position but higher than 0. If the accelerator input goes below this value, torque command is set to 0, the inverter will turn off and declare the ACCEL SHORTED fault.
121	ACCEL Pedal Min	Low Voltage	This parameter sets a limit such that between that limit and ACCEL Pedal Low, torque command is set to a constant value set through REGEN Torque Limit.
122	ACCEL Coast Low	Low Voltage	This parameter sets a limit such that between that limit and ACCEL Pedal Min, torque command is linear from REGEN Torque Limit to 0.
123	ACCEL Coast High		This parameter sets a limit such that between that limit and ACCEL Coast Low, torque command is 0.
124	ACCEL Pedal Max	Low Voltage	This parameter sets a limit such that between that limit and ACCEL Coast High, torque command is linear from 0 to Motor Torque Limit. Normally, this will be the driving range.
125	ACCEL Pedal High	Low Voltage	This parameter sets a limit such that between that limit and ACCEL Pedal Max, torque command is set to a constant value of Motor Torque Limit. This should be set to a value that is higher than the highest possible acceleration position but less than 500. If the accelerator input goes above this value, torque command is set to 0, the inverter will turn off and declare the ACCEL OPEN fault.
132	Accel Pedal Flipped	Boolean	This parameter determines if the pedal increases in value as it is pressed or behaves the other way around. If the pedal increases in voltage as it is pressed use a value of 0 (not flipped). If the pedal decreases in voltage as it is pressed use a value of 1 (flipped).

[11] Please refer to the document “Software User Manual” for more details.

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2.3.4.7 Torque[12]

Address	Name	Format	Description
129	Motor Torque Limit	Torque	This parameter sets the upper limit of the torque that can be commanded by the controller in motoring mode. However, if the current limit of the drive is reached before the torque command has been achieved the controller will limit on the current first. If this happens the operator will feel an additional amount of unused pedal range at the top end.
130	REGEN Torque Limit	Torque	This parameter sets the upper limit of torque that is commanded when the accelerator pedal is released. Normally this value would be set to a small percentage of the available motor braking torque, to simulate engine braking. This value only sets the torque limit when the pedal is released with no brake applied. The torque applied when the brake is active is set by a separate parameter (Braking Torque Limit).
131	Braking Torque Limit	Torque	This parameter sets the amount of the torque applied when the brake is active.
164	Kp Torque	Proportional Gain	This parameter sets the proportional gain for the torque regulator. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming. Input is restricted to a valid range as indicated in the format table.
165	Ki Torque	Integral Gain	Integral gain for the torque regulator. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming. Input is restricted to valid range as indicated in the format table.
166	Kd Torque	Derivative Gain	Derivative gain for the torque regulator. This is a times 100 value. Multiply the value within the valid range by 100 before programming. Input is restricted to valid range as indicated in the format table.
167	Klp Torque	Low-Pass Filter Gain	Low-pass filter gain for the torque regulator. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming. Input is restricted to valid range as indicated in the format table.

[12] Please refer to the document “Software User Manual” for more details.

168	Torque Rate Limit	Torque	This parameter sets the filtering for the torque command. During filtering, the change in torque command is limited to this value. The smaller this value is the slower the ramp for the torque command will be and vice versa. This parameter is limited between 0.1 and 250 Nm.

2.3.4.8 Speed[13]

Address	Name	Format	Description
111	Motor Over-speed	Angular Velocity	This parameter sets the over-speed value for the motor. If motor speed exceeds this value, inverter will turn off and declare the MOTOR OVERSPEED fault.
128	Max Speed	Angular Velocity	The parameter sets the maximum allowable speed. If the speed is above this value the torque command will be reduced to zero.
126	REGEN Fade Speed	Angular Velocity	The parameters sets at which the amount of REGEN torque available is reduced.
127	Break Speed	Angular Velocity	The parameter sets the speed at which the maximum torque command is reduced to compensate for a reduction of available torque due to field weakening.
160	Kp Speed	Proportional Gain	Proportional gain for the speed regulator. Input is restricted to valid range as indicated in the format table.
161	Ki Speed	Integral Gain	Integral gain for the speed regulator. Input is restricted to valid range as indicated in the format table.
162	Kd Speed	Derivative Gain	Derivative gain for the speed regulator. Input is restricted to valid range as indicated in the format table.
163	Klp Speed	Low-Pass Filter Gain	Low-pass filter gain for the speed regulator. Input is restricted to valid range as indicated in the format table.
169	Speed Rate Limit	Speed	This parameter sets the filtering for the speed command. During filtering, the change in speed command is limited to this value. The smaller this value is the slower the ramp for the speed command will be and vice versa. This parameter is limited between 100 and 5100 RPM.

[13] Please refer to the document “Software User Manual” for more details.

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2.3.4.9 Shudder Compensation[14]

Address	Name	Format	Description
187	Shudder Compensation Enable	Boolean	0: Shudder compensation feature is disabled. 1: Shudder compensation feature is enabled.
188	Kp Shudder	Counts x 100	This parameter provides shudder compensation gain. It is entered as a x 100 value.
189	TCLAMP Shudder	Torque	This parameter provides maximum compensation torque.
190	Shudder Filter Frequency	Frequency	This parameter provides the frequency value for the shudder filter.
191	Shudder Speed Fade	Angular velocity	The parameter provides a value such that from 0 speed to this value, the shudder compensation begins to fade from 0 to shudder torque, and vice versa.
192	Shudder Speed Low	Angular velocity	The parameter provides the value at which the shudder compensation begins to fade to 0.
193	Shudder Speed High	Angular velocity	The parameter provides the value at which the shudder compensation is 0.

[14] Please refer to the document "Shudder Compensation Manual" for more details.

2.3.4.10 Brake Pedal

Address	Name	Format	Description
180	Brake Mode	Boolean	This parameter is used to switch mode as follows: 0: Brake switch mode allows using brake as a binary switch input. Also, this mode activates the 'Automatic REGEN Torque Ramp Down' feature using the EEPROM Parameter REGEN Ramp Period. 1: Brake Pot mode allows using brake as a variable input between 0 – 5 volts. This mode activates the 'Automatic REGEN Torque Ramp Down' feature using EEPROM parameters from address 181 – 184 below.
181	Brake Low	Low Voltage	This parameter is used in Brake mode 1. This parameter sets the lower limit of the brake pot below which brake short fault is set.
182	Brake Min	Low Voltage	This parameter is used in Brake mode 1. This parameter sets the minimum limit for calculating the braking torque.
183	Brake Max	Low Voltage	This parameter is used in Brake mode 1. This parameter sets the maximum limit for calculating the braking torque.
184	Brake High	Low Voltage	This parameter is used in Brake mode 1. This parameter sets the high limit above which brake open fault is set.
185	REGEN Ramp Period	(Counts x 0.001) sec	This parameter is used in Brake mode 0. This value of time is entered in milliseconds. This is the time in which REGEN torque value ramps down to the braking torque limit.
186	Brake Pedal Flipped	Boolean	0: Brake pedal reads 0 V when completely released and 5 V when completely pressed. 1: Brake pedal reads opposite to the above.
199	Brake Input Bypassed	Boolean	This parameter decides if the brake input should be ignored or not in VSM mode: 0: Do not ignore brake input (process as usual) 1: Ignore brake input (brake is considered OFF)

2.3.4.11 Reserved *(for future use)*

Address	Name	Format	Suggested Category
153, 194-198, 200-201	Reserved	Reserved	For factory use only

2.4 OBD2 Messages (available in 19B3 and after)

Cascadia Motion has added some OBD2 functionality to the CAN system.

The goal of this functionality is to allow the use of an OBD2 diagnostic tool. For example a CAN to Bluetooth adapter can be used with an Android application (e.g. Torque app).

Cascadia Motion has successfully used the OBDLink LX Bluetooth adapter with the Torque app (https://torque-bhp.com/).

The inverter is utilizing the vehicle specific portion of the OBD2 protocol. To access inverter information requires the use of Custom PID codes. All of the items shown in the Memory View of the RMS GUI can be accessed via the Custom PID codes.

To enable OBD2 set the following EEPROM parameter, CAN_OBD2_Enable_EEPROM > 0 and less than 8. The value used provides an offset. The default would be to set it to 1. The support for the Torque app (list of Custom PID codes for the app) provided by Cascadia Motion assumes that the value is set to 1. If multiple inverters exist on the CAN bus (or other devices) the parameter can bet set to different values for each inverter to avoid a conflict between two inverters.

The inverter CAN setup must be setup to be compatible both with other devices on the CAN network (if any) as well as the CAN OBD2 device. Most OBD2 devices will support either 250k or 500k baud.

Each RMS GUI Memory View item is assigned a Custom PID. The PID used is the Memory View address plus 0x1000. So for example Feedback Speed is at memory view address 0x0097. The Custom PID to access the Feedback Speed is at 0x1097.

The OBD2 implementation uses the Mode 22 for the Custom PID.

The OBD2 protocol and the implementation of it have certain CAN ID addresses. The inverter will respond at the following CAN addresses:

Query at 0x7DF (general OBD2 receive address)
Query at device specific (what is normally used) at 0x7DF + value of CAN_OBD2_Enable_EEPROM
Respond at 0x7E7 + value of CAN_OBD2_Enable_EEPROM

The controller does not respond to DTC type enquiries. It only responds to the enhanced data queries (mode 22h).

Cascadia Motion has created a spreadsheet of the available parameters for use with the Torque app, please contact support for more information.

2.5 Orion BMS Support (available in 19B3 and after)

Cascadia Motion has added support for the Orion BMS (or other BMS that transmits a compatible BMS message). The BMS CAN message will be used to limit the maximum torque commands to a level that approximates the amount of DC (battery) current that will be flowing.

The BMS CAN Message must be configured as follows:

CAN Message ID: 0x202 (514 decimal) – Can not be changed
CAN Message Format:

Byte 0 and Byte 1 contain the maximum discharge current in Amps
Byte 2 and Byte 3 contain the maximum charge current in Amps

Data format is Little Endian (Intel)

Currents can be transmitted as positive or negative numbers the code will correctly interpret them as charging and discharging currents. In other words it ignores the sign.

For example, 0x02 0x01 0x04 0x02 0x00 0x00 0x00 0x00 will yield a discharge current limit of 258 A and charge current limit of 516 A.

It is up to the user to make sure that both the inverter and the BMS are at the same CAN baud rate.

The Orion BMS Support can be enabled by using the EEPROM Parameter, CAN_BMS_Limit_Enable_EEPROM. By setting this parameter to 1 the firmware will begin accepting messages from the BMS.

To check to see if the inverter is receiving the BMS CAN message check the parameter BMS_Limit_Msg_Status in the GUI. If the result is 1 then the message is being received. If the controller stops receiving the CAN message from the BMS then the result will be 0 after 1 second has elapsed.

The BMS_Limit_Msg_Status flag is also available in the Internal States Broadcast CAN message. Additionally in the Internal States message is a flag indicating when the maximum torque level is being limited by the BMS.

The BMS torque limiting function does not use the inverter measured or estimated DC current. It uses a simple equation to estimate the amount of torque:

Maximum torque = DC bus voltage * DC Current Limit / speed

In this equation the speed is mechanical speed in rad/s and torque is in Nm. The simple equation does not consider motor and inverter efficiency and thus will have accuracy issues that vary with operating conditions. To prevent the maximum torque from being excessively large the speed used in the above equation has a lower limit (525rpm for 10 pole motor)

If the inverter is receiving a charge/discharge current limit that would result in a reduced amount of available torque then it will begin to limit the maximum torque available from the accelerator or brake pedal (VSM mode).
If the vehicle is operated at lower speeds and the battery current limits are normal then the operator would not notice any effect. The maximum battery current draw would always be low even at maximum torque command because the motor speed is low.

If the motor speed is high and if the full accelerator application would exceed the battery current limit then the maximum point of the accelerator would be reduced. So even if the operator did not apply full throttle the operator would note that for a given amount of throttle the amount of torque produced is reduced.

In CAN mode it will also limit the torque command coming from the CAN command message. The BMS CAN Message will also limit the torque in speed mode.

2.6 CAN Slave Operation (available in 19BB and after)

In some cases multiple controllers and motors are used in an electric vehicle powertrain. In the case where two motors are used and both motors are connected in such a way that they should operate at the same commanded torque then it is possible to operate one of the controllers in a slave mode.

To **enable** Slave Operation the CAN_Slave_Cmd_ID_EEPROM parameter must be set to CAN Command Address of the Slave Controller. This address is the Slave Control CAN ID Offset plus 0x20 (32 decimal). The Slave CAN message will be sent at a fixed rate of approximately 10ms regardless of the broadcast rates set by the Fast and Slow CAN rate EEPROM parameters.

To **disable** the Slave CAN message from being sent set the CAN_Slave_Cmd_ID_EEPROM value to be 0.

In this mode one controller, the Master, that decides what the torque command is. The second controller is the Slave and will have the same torque command as the Master.

The Slave controller can only be set to Torque mode and should be an identical type of motor with the same motor setup (current, speed, torque limits). The Slave controller must be in CAN mode.

If the Master controller is in Torque mode then the Slave controller will be sent the same commanded torque. The Slave controller is sent the torque command that the master is processing. However, the torque command does not contain any shudder compensation. If the Master controller is in speed mode then the Slave controller is sent the torque command that is being used in the internal speed regulator.

The Slave controller will still respond to speed and temperature limits for the motor that it is controlling. If the Orion BMS feature is enabled then the torque limit of the master will take into account that the slave controller is consuming the same amount of DC current.

In some installations that multiple motors the physical placement of the motors dictates that the motors although turning in the same physical direction are turning in opposite electrical directions. Thus from the point of view of the controller it is necessary to have a Slave command that is commanding the opposite direction. This can be handled using the CAN_Slave_Dir_EEPROM parameter. With a setting of 0 the Slave controller will receive the same commanded direction that the Master is operating in. With a setting of 1 the Slave controller will receive a direction command that is opposite of the Master controller.

The Master and Slave controller must be set to the same CAN baud rate and the same Extended message setting.

It is recommended that the CAN_Command_Message_Active feature be used to prevent an unsafe condition if the Slave controller were to stop receiving CAN messages.

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To make sure that the Slave controller command message is being sent make sure that the CAN_ACTIVE_MSGS_EEPROM has bit 22 set (this would be in the high word).

2.7 Rolling Counter (available in Gen 5 and CM)

There could be failure modes where a CAN message can be retransmitted or lost for a time. It is possible that a simple timeout on reception is not enough to detect this error. To mitigate this issue a Rolling Counter is to be added to the CAN Command Message.

The Rolling Counter is a U4 number that will be incremented from 0 to 15 and repeat. The Rolling Counter value will be transmitted by the system controller to the inverter.

At power on the inverter will not know what the correct rolling counter value is. The first received CAN Command message will set the Rolling Counter current value to the received value plus one.

When a Command Message is received the Rolling Counter current value will be set to the received value plus one regardless of whether the received Rolling Counter value is correct or not.

The inverter will check the Rolling Counter for validity. If an error has occurred, then it will flag that an incorrect rolling counter value has been received.

Each time an error has been received then it will increment a Debounce Counter. The Debounce Counter is incremented by the Up Count Value. Each time that a correct Rolling Counter value is received the Debounce Counter will be decremented by a Down Count value. The Debounce Counter minimum value is limited to 0.

If the Debounce Counter reaches a Debounce Counter Max value then a fault will be triggered and the inverter will be disabled. The Debounce Counter will be held at the Debounce Counter Max value even if more faults occur.

The Fault triggered by this Debounce Counter will be the already existing CAN Command Message Lost fault, bit 11 of Run Faults.

When faults are cleared (through the GUI or CAN) the Rolling Counter and the Debounce Counter will be reset to their power on values.

The table below shows the EEPROM parameters associated with this feature.

EEPROM Parameter	GUI Addr	CAN Addr	Description
CAN_Debounce_Counter_Max_EEPROM (default value is 20)	0x1B8	0x0EE	The value of the Debounce Counter at which the controller will declare a fault. If this EEPROM parameter is set to 0 it will disable the rolling counter function.
CAN_Debounce_Up_Count_EEPROM (default value is 5)	0x1B9	0x0EF	The number of counts that the Debounce Counter will increment when a Rolling Counter error has been flagged.
CAN_Debounce_Down_Count_EEPROM (default value is 3)	0x19A	0x0F0	The number of counts that the Debounce Counter will decrement when a correct Rolling Count message has been received.

CAN Command Message Modification

The existing CAN Command message will be modified with the addition of a Rolling Counter value as shown in bold below.

Byte 0 and Byte 1	Byte 2 and Byte 3	Byte 4	Byte 5 Bit 0	Byte 5 Bit 1	Byte 5 Bit 2	**Byte 5 Bit 4-7**	Byte 6 and Byte 7
Torque Command	Speed Command	Direction	Inverter Enable	Inverter Discharge	Speed Mode Override	**Rolling Counter**	Torque Limit

CAN Status Message Modification

The Status message is modified to provide information about the currently expected Rolling Counter value. The CAN message details are provided in the section of this document that describes the Internal States message.

GUI Monitoring

It is possible to monitor the current state of the Rolling Counter using the RMS GUI.

GUI Monitor Parameter	GUI Addr	Description
CAN_Rolling_Count_Flag	0x9D	Will flag when a Rolling Counter error has occurred. Will clear when a correct message has been received.
CAN_Debounce_Count	0x9E	Current value of the Debounce Counter

Examples

Below are several examples of what would happen with various received Rolling Counter values. The example assumes that the default EEPROM values are used.

Rolling Counter Value Received						
Msg 1	Msg 2	Msg 3	Msg 4	Msg 5	Msg 6	**Results**
0	1	2	3	4	5	Rolling Counter is good, Debounce Counter = 0, no fault
0	2	3	4	5	6	One missed message, Debounce counter reached 5, but then decremented back to 0, no fault
0	2	4	5	6	7	Two missed (+10), 3 correct (-9) Debounce Counter = 1, no fault
0	1	3	5	7	9	Four missed (+20), fault is declared

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Revision History

Version	Description of Versions / Changes	Responsible Party	Date
0.1	Initial version	Chris Brune	9/30/2009
0.2	• Moved Inverter Command Mode (CAN Mode Type) and Inverter Run Mode from 0x0C0 – Command Message to 0x0AA – Internal States • Added more EEPROM parameters.	Azam Khan	11/17/2009
0.3	• For Parameter Messages, changed the range of General and User EEPROM parameters from 1 – 99 and 100 – 500 to 0 – 99 and 100 – 499 respectively. • Added a broadcast rate of 5 msec for the command message (0x0C0). • Added messages 105, 106, and 145 • Changed messages 110 and 141 to be reserved for future use.	Azam Khan	11/30/2009
0.4	• Changed message 104 to "Reserved" for future use. • Changed Message 141 to "CAN ID Offset" and added its description in Broadcast Messages section and also in System Configuration table. • Added message 146 as "Restricted" for factory use only.	Azam Khan	12/02/2009
0.5	• Added a new address 147 for CAN Bit Rate in table "System Configuration" for Parameter Messages. • Updated the description column for Motor Parameter Set to add more motor types.	Azam Khan	01/25/2010
0.6	• Added an example on the use of little-endian format for CAN data bytes	Azam Khan	01/27/2010
0.7	• Added a new address 113 for Motor Over-temperature in table Fault Limits for Parameter Messages. • Added Motor Temperature to the broadcast message 0x0A2. • Added speed regulator gains	Azam Khan	02/18/2010
0.8	• Added Speed Regulator Gains (section 2.3.4.6) • Updated section 1.2 with the formats of Speed Regulator Gains. • Corrected the description for Fault Clear in section 2.3.3.	Azam Khan	02/22/2010
0.9	• Added a new address 148 for CAN Active Messages Word in System Configuration table in Parameter Messages section. • Updated section 2.1 Broadcast Messages with details on how to enable/disable broadcast messages. • Added Power-on Timer to the broadcast msg 0x0AC.	Azam Khan	03/24/2010

1.0	• Updated description for Digital Input Status in Broadcast Messages (Message ID 0x0A4) • Added a new address 149 for Key Switch Mode in System Configuration table in Parameter Messages section.	Azam Khan	04/14/2010
1.1	• Added a new address 170 for Pre-charge Output in System Configuration table in Parameter Messages section.	Azam Khan	04/26/2010
1.2	• Added more description on how to disable CAN broadcast messages in section “2.1 Broadcast Messages”.	Azam Khan	04/27/2010
1.3	• Added Delta Resolver Filtered to the broadcast message 0x0A5. • Added a new broadcast message 0x0AD to send Modulation Index and Flux Weakening Output information. • Added Inverter Enable State and Direction Command to byte 6 and 7 respectively, to the broadcast message 0x0AA.	Azam Khan	06/29/2010
1.4	• Added Id- and Iq-commands to the broadcast message 0x0AD. • Updated the format for modulation index in message 0x0AD.	Azam Khan	08/10/2010
1.5	• Changed the description and range for parameters with the format, Angle.	Azam Khan	11/24/2010
1.6	• Rearranged EEPROM parameter sections into categories based on the type of parameters. • Described CAN configuration in more detail and also added it to the introduction section.	Azam Khan	12/1/2010
1.7	• Added two more parameters in section CAN Configuration: - CAN Extended Message Identfiers - CAN J1939 Option Active • Added two new EEPROM parameter sections: - Shudder compensation - Brake Pedal • Updated the format table for Kp, Ki, Kd, and Klp gains.	Azam Khan	1/19/2011
1.8	• In section 2.3.1, changed the number of data bytes from 4 bytes (4, 5, 6, 7) to 2 bytes (4, 5). • Added a new section on “CAN Diagnostics Parameter Overview” in section 1.	Azam Khan	3/15/2011
1.9	• Corrected the example on page 10 for the direction command which is supposed to be on Byte 4 and Inverter command on Byte 5.	Azam Khan	4/4/2011

2.0	• Updated section 1.3, CAN Format, to elaborate CAN command using example values. • Updated section 2.1, Broadcast Messages, Message 0xAC to show the correct resolution for the Power on Timer. • Added description for several EEPROM parameters. • Clarified that the CAN Command Message must be broadcast every 500 msec or faster.	Azam Khan	6/1/2011
2.1	• Added a new section 1.5 for the CAN Database file.	Azam Khan	6/20/2011
2.2	• Added Resolver PWM Delay Command and Gamma Adjust GUI Command to provide the Resolver Calibration Process through CAN. • Updated section 2.3.4 EEPROM Parameters on how EEPROM parameters are programmed. • Added Inverter Enable Lockout bit to message ID 0x0AA in section 2.1, Broadcast Messages.	Azam Khan	9/11/2011
2.3	• Added a new torque parameter, 'Torque Rate Limit' that controls the ramp rate for torque command.	Azam Khan	12/07/2011
2.4	• Added two new messages 0xAE (Firmware information) and 0xAF (diagnostic data). • Added a new parameter CAN Diag Data Tx Active that controls the broadcast of diagnostic data. • Updated section 2.1 to show all faults with different assignment views.	Azam Khan	9/6/2012
2.5	• Added the "discharge" command to the heartbeat command message.	Azam Khan	11/5/2012
2.6	• Updated section 1.1: Added a new EEPROM parameter CAN Inverter Enable Switch EEPROM. • Added a new section 2.2.1, Inverter Enable Safety Options • Updated section 2.3.4.3, CAN Configuration for the new EEPROM parameters, CAN Inverter Enable Switch EEPROM.	Azam Khan	12/5/2012
2.7	• SWRP 1805 • Updated broadcast message 0x0AB for the two new faults, "Resolver Not Connected" and "Inverter Discharge Active".	Azam Khan	12/13/2012
2.8	• Added description regarding the limited J1939 CAN Messaging option in section 1.1.	Azam Khan	02/05/2013
2.9	• Updated section 2.2.1 Inverter Enable Safety Options with the safety feature "Sudden Reversal of the Direction Command".	Azam Khan	6/21/2013
3.0	• Added CAN message IDs in extended and J1939 format.	Azam Khan	7/8/2013
3.1	• Updated section, Command Parameter, for issuing relay commands (Address 1). This change in the method of controlling relays is effective for firmware release 1909 and later.	Azam Khan	10/22/2013

3.2	• Added a new section 2.2.2 to provide example to the user regarding an example of CAN message sequence. • Added section 2.2.3 which explains the sign convention for torque and speed commands. • Highlighted EEPROM parameters that will take effect immediately as opposed to the parameters that take effect after power cycle.	Azam Khan	11/07/2013
3.3	Updated the section, 1.4 Data Formats to cover each data type to its full range.	Azam Khan	04/02/2014
3.4	Corrected the CAN byte numbers for Run Faults to be 4, 5, 6, and 7 and adjusted bit numbers accordingly.	Azam Khan	04/15/2014
3.5	Corrected the value of -10 Nm to be (255x256) + 156 instead of (255x256) + 246 (which is equal to -1 Nm).	Azam Khan	07/28/2014
3.6	Removed the references to the GUI addresses. GUI addresses are correct in the defsyms files and may change based on the availability of memory. Mentioning these addresses in the documentation is redundant.	Azam Khan	8/12/2014
3.7	Added CAN Timeout count EEPROM parameter (implemented in firmware 1935). Clarification added to the command message formatting. Added some clarification to the parameter message.	Chris Brune	12/12/2014
3.8	Updated the Internal States Message (0xAA) to show the Inverter Active Discharge state parameter (byte 4, bits 5 thru 7).	Chris Brune	3/9/2015
3.9	Corrected issue with the number of relay outputs. Added information about Commanded Torque Limit. Corrected information about sign of Speed command. Moved Motor Temperature foldback parameters to the Temperature section.	Chris Brune	8/26/2015
4.0	Added reporting of DIN7 and DIN8 and Relays 5 and 6, active in software version 1954	Chris Brune	8/28/2015
4.1	Changed 0xAA message to be transmitted every 10ms instead of 100ms (implemented in software version 1958).	Chris Brune	11/5/2015
4.2	Updated 0xA7 to indicate that message shows VAB and VBC when the inverter is disabled and Vd and Vq when the inverter is enabled.	Chris Brune	12/6/2016
4.3	Changed the analog input message (0xA3) to contain all 6 analog inputs, starting with firmware 1995.	Chris Brune	1/3/2017
4.4	Clarified that OBD2 support is upcoming. Added several EEPROM parameter messages with support starting in 1998 version.	Chris Brune	1/22/2017
4.5	Additional Updates to the OBD2 section. Added section about the Orion BMS.	Chris Brune	7/3/2017
4.6	Added Speed Mode Enable bit description. Modified document to reflect more generically RM and PM controllers. General clarifications.	Chris Brune	1/9/2018

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4.7	Updated BMS support. Updated Internal States message to show BMS support status bits. Update OBD2 to show active support in main code. Add new EEPROM parameters for OBD2 and BMS.	Chris Brune	5/3/2018
4.8	Added Slave Mode documentation.	Chris Brune	8/10/2018
4.9	Added information about Slave Mode direction.	Chris Brune	9/12/2018
5.0	Updated formatting for Cascadia Motion. Clarification of CAN timeout feature. Updated fault code for Hardware over voltage fault. General cleanup of wording.	Chris Brune	12/6/2019
5.1	Added documentation about fast/slow CAN message rates. Added clarification about rate of Slave Command. Clarified CAN Active Messages parameters. Added separate Parameter address for the Hi word.	Chris Brune	3/18/2020
5.2	Corrected broadcast rate description for several messages.	Chris Brune	7/22/2020
5.3	Add information about Gen 5 / L100 specific messaging. Add information about rolling counter available on Gen 5 / L100. Add information about new Gen 5 / L100 EEPROM parameters.	Chris Brune	11/18/2020
5.4	Add information on new fast CAN broadcast message. Update limiter flags also available on Gen 3 software.	Chris Brune	11/24/2020
5.5	Changed references to L100 to CM. The L100 has been renamed the CM200. The CM200 is part of the CM family. Corrected issues with the J1939 messaging explanation. Added information of Gen 5 / CM CAN diagnostic features.	Chris Brune	3/23/2021
5.6	Added Start Mode Active to Status Message.	Chris Brune	5/5/2021
5.7	Clarified and added Gen 3/Gen 5 Fault bit definitions. Clarified minimum fast/slow CAN message update rate.	Chris Brune	8/18/2021
5.8	Added information about Torque Command being a feedforward when in speed mode. Added new feature information about Speed Command providing a speed limitation in Torque mode. Added section Parameter command for Shudder Compensation.	Chris Brune	12/9/2021
5.9	Added section Parameter command for Diag. Data trigger.	Andrew Louie	2/21/2022
6.0	Added Stall Burst Model information. Added Self-Sense information. Added information on updates to variable PWM.	Andrew Louie & Christian Tigges	1/17/2023
6.1	Updated information about BMS CAN Message	Chris Brune	2/24/2023
6.2	Fix error in J1939 Addresses. Clarify J1939 Source Address. Clarify use of Regen Fade Speed with speed mode.	Chris Brune	8/25/2023