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Software User Manual

Revision 3.6

Document Organization

This document has been organized such that a new user can follow sections in this document in a step-by-step manner after receiving the inverter.

Step 1

Firmware
- Firmware

  Download & store the software release package (SWRP)
- Re-flashing the inverter

Step 2

RS232 Data Acquisition

Step 3

Data Formats

(GUI + this document)

Step 4

RMS GUI
- Programming & saving EEPROM parameters
- EEPROM Parameter Configuration
- Monitoring Parameters

Step 5

Calibration Processes

Resolver
Current Offsets
V_{DC}
RTD
SIN/COS Encoder Calibration
Hall Sensor Encoder Calibration

Vehicle State Machine

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1. Firmware

As the family of Cascadia Motion inverters has expanded there are now several different firmware families to be considered. Not all inverter families run the same firmware.

Inverter Family	Processor Target	Inverters	Firmware Family
Gen 2	28234 / 30 MHz	Older PM100 built before 2013.	Versions: 19XX
Gen 3	28234 / 30 MHz	PMxxx	Versions: 19XX through 20XX
Gen 4	28335 / 30 MHz	RMxxx	Versions: 20XX (not Gen3 and Gen4 share the same 20XX firmware.
Gen 5	28377 CPU 1 / 20MHz	PMxxx-G5 / CM200	Versions: 65XX

There are firmware versions that are customer/application specific that do not conform the above firmware version numbers.

The firmware is a single file in hexadecimal format that can be downloaded and programmed into the inverter over the serial port. The title of the firmware file follows the date versioning scheme. This scheme uses the year followed by the month and then date. The format is 'RMS_yyyymmdd_nnnn_option.hex' or 'CM_yyyymmdd_nnnn_option.hex'. Gen 5 firmware follows a filename convention of 'CM_GEN5_yyyymmdd_nnnn_option.hex'.

In addition to the date code, the filename a software release number (nnnn).

The "option" refers to specific features. As noted below the main firmware is labelled as Group_1 or Group_2.

An example of a released firmware file would be RMS_20150724_1953_Group_1.hex

Where,

'20150724' is the date code, July 24, 2015

'19' is the major release number

'53' is the minor release number

Important: Starting with firmware 1900+, users will be provided with two (2) executable files. The hex file with the tag "Group_1" in the filename should be used for motor types between 0 and 59. The hex file with the tag "Group_2" in the filename should be used for motor types starting from 60 and onward.

New firmware is released on a continuous basis. The time to release firmware depends on the new feature requests, change requests, and bug reports discovered internally or by the external customers.

Each firmware release has an accompanying 'Firmware Release Notes' document that provides the following information:

(a) Important notices regarding the new firmware

(b) New features and/or change requests

(c) Bug fixes

1.1 Firmware Release Package

In addition to the document, Release Notes, the firmware release package contains the following:

(a) Firmware

(b) Tools, typically the RMS GUI and the defsyms files associated with the RMS GUI

(c) Other documentation as needed.

The firmware package is uploaded to an online repository. To access the repository navigate to the Cascadia Motion web site, www.cascadiamotion.com Go to the Documentation/Support page.

If customers need to access a previous release, many previous releases are available online at the same repository, or contact Cascadia Motion.

1.1.1 Firmware

The firmware file can be downloaded to the PM unit over the serial port (RS-232). The program C2Prog is used to download the firmware to the controller. Please see section, ‘C2Prog - Firmware Programming Guide’ for more details.

The SCI (serial communication interface) is used for three purposes. It is used for firmware download, graphical user interface (GUI) communication, and for SCI data acquisition.

At normal power up the inverter enters the SCI data acquisition mode. SCI data is transmitted in hexadecimal format. This data can be captured on a PC by using any standard communications software such as Hyper-terminal or Real-term. The data can also be captured on any type of device that has a standard serial port. The data can be used to plot specific graphs to understand vehicle performance.

If the RMS GUI is started then the controller will automatically switch from SCI data acquisition mode to communicating with the GUI. The GUI is used to reprogram EEPROM parameters and also to monitor data using Windows platform. The GUI when started will automatically search all open COM ports for the existance of an inverter. The COM port must not be in use by another program on the PC. GUI then tries to establish communication with PM unit. This may take a few seconds. Once the communication is established, GUI will show all parameters that can be monitored and reprogrammed. The GUI will also display the firmware version and date code of the firmware that is in the inverter. If the GUI is not able to find a defsyms (symbol defining active parameters for the firmware) with a date code that matches the inverter firmware date code it will flag an error. Refer to the section, ‘RMS GUI –EEPROM Parameter Programming Guide’ for details on programming EEPROM parameters into the inverter.

1.1.2 Tools

The RMS GUI and C2prog are provided for interacting with the inverter. Both of these tools can be found on the Cascadia Motion web site.

1.1.2.1 RMS GUI

The Release Package contains the GUI application and all the needed defsyms files necessary for it to run with the firmware in the Release Package.

The following instructions apply to the current public version of the RMS GUI (1.4.8) The first time that the RMS GUI is to be used it must first be installed. This is done by downloading and installing the GTK environment (gtk+-2.8.9.-setup-1.exe) from the Cascadia Motion website. After installing the GTK environment it is necessary to reboot the PC for the changes to take effect.

The GUI program allows the user to monitor various variables and to reprogram EEPROM parameters. EEPROM parameters must be programmed before the controller is operated. Refer to the section, 'RMS GUI –EEPROM Parameter Programming Guide' for more information.

It is not necessary to configure the COM port baud rate or other settings for use with the RMS GUI. The RMS GUI will automatically make the correct settings.

The RMS GUI can have problems with certain folder names. Whenever loading or saving a file using the RMS GUI please locate that file in the same folder that the RMS GUI.exe exists in.

Following files are related to the use of the GUI:

- **RMS GUI.exe:** This provides the main application to monitor data and also to reprogram EEPROM parameters. There is no setup file. Simply copy this application to an appropriate location.
- **defsyms_yyyymmdd.txt, defsyms_yyyymmdd_G3, defsyms_yyyymmdd_G2:** These are the default symbols file that includes the parameters to be monitored and reprogrammed depending on which version of hardware is being used. This is a firmware-specific file which means that each firmware has its own default symbols file. The two files can be matched through the date code in yyyymmdd format. The RMS GUI will automatically choose the correct file EXCEPT for Gen 2 inverters. For Gen 2 inverters it is necessary to manually select the defsyms file by using the File menu in the upper left corner of the Memory window of the RMS GUI.
- **gtk+-2.8.9-setup-1.exe:** This is a one-time installed library file. The computer needs to be rebooted after the installation. This file is obtained from the Cascadia Motion web site.
- **Conf folder:** The RMS GUI will automatically create a folder named "conf". The folder will contain a record of any EEPROM changes that have been made. Each time the EEPROM

is programmed a new file is created. The files are text files that can be easily viewed in a test viewer such as Notepad.

1.1.2.2 C2Prog

C2Prog is a flash programming tool for TI C2000™ MCUs. Rather than using JTAG as the communication interface between the programming tool and the MCU, C2Prog utilizes RS-232, RS-485 and CAN (Controller Area Network). The programmer is, therefore, well suited for deployment in the field where the JTAG port is typically not accessible.

C2Prog Flash Programmer uses the boot-loader feature of the MCU for rapid Flash programming over the serial line. Please download a version from the Cascadia Motion website.

The Cascadia Motion inveters are designed to be reflashed using C2prog and the SCI (RS-232 port). The inverters will enter a boot mode if the Program Enable input is grounded when low voltage power is applied to the inverter.

Reflashing the inverter should not change any EEPROM settings if the firmware is from the same family. There are non standard firmware files that will change the EEPROM. It is always a good idea to save your existing EEPROM settings before reflashing an inverter.

The Release Notes contain details on how C2prog should be configured for that particular firmware package. This data is duplicated in the table above showing the different generations of inverters (Gen 2, Gen 3, etc).

For the latest version of the application and more details, please visit http://www.codeskin.com

1.1.2.3 Realterm

Realterm is a terminal program specially designed for capturing, controlling and debugging binary and other data streams. It has more features for debugging communication ports than a Hyper-terminal. This application can be used for collecting the streaming data during bench testing.

If it is desired to capture data from the inverter using Realterm then Realterm should be configured for 57600 baud, 8 data bits, No parity.

Some of the features of this application include command line control, ability to capture to file, arbitrary baud rates, etc. For more details, please refer to http://realterm.sourceforge.net/

1.1.3 Documentation

There are a number of documents that are useful for setting up and operating the Cascadia Motion products.

- Getting Started Guide
- Hardware User Manual, description of hardware features.

- Software User Manual (this manual)
- Resolver Calibration Manual, all PM motors must have the resolver or SIN/COS encoder calibrated.
- Download Diagnostic Data, a manual covering high speed data download from the inverter.
- Inverter Discharge Process
- PM100 HV Connection Manual
- And others, see www.cascadiamotion.com Documentation / Support page for more

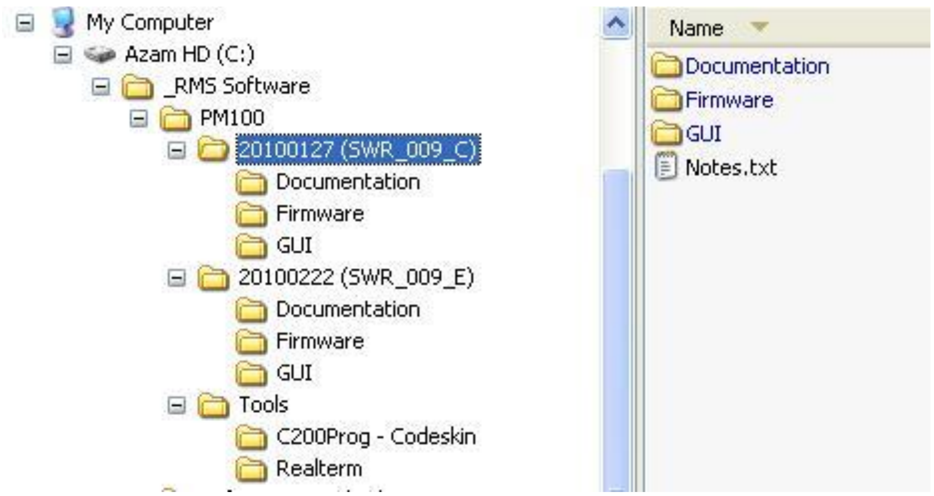
This Software Manual includes details on:

- Programming using C2Prog (in this document, section ‘C2Prog – Firmware Programming Guide’)
- Programming EEPROM Parameters using RMS GUI (in this document, section ‘RMS GUI –EEPROM Parameter Programming Guide’)
- SCI Data Acquisition
- Shudder Compensation Manual

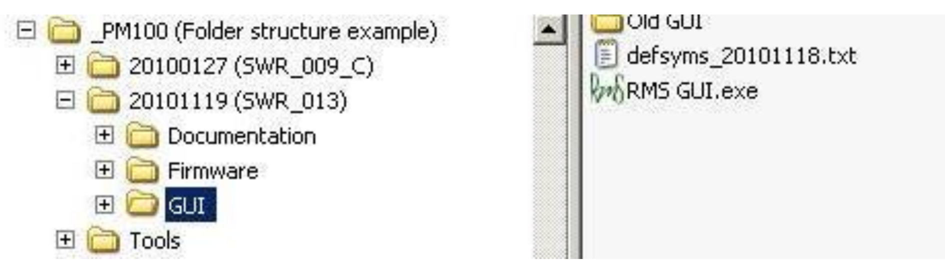
1.2 Saving Firmware Release Package

It is highly recommended that each firmware release package is downloaded and kept separate from each other. This allows a better referencing during debugging. Also, save files directly under the **C:** drive instead of 'Desktop\My Documents'.

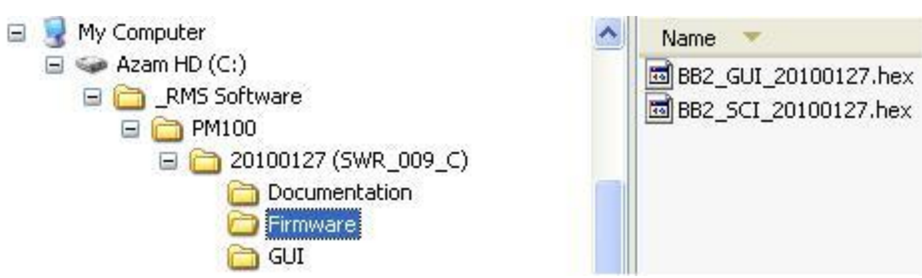
Following is a suggested folder structure to keep track of firmware versions:



High level view of folder structure



Files under subfolder 'GUI'



Files under subfolder 'Firmware'

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2. C2Prog – Firmware Programming Guide

2.1 Required Hardware

RS232 cable or RS232-USB Adapter (based on PC's port availability)

2.2 Required Software

(a) New Firmware Package, available from www.cascadiamotion.com

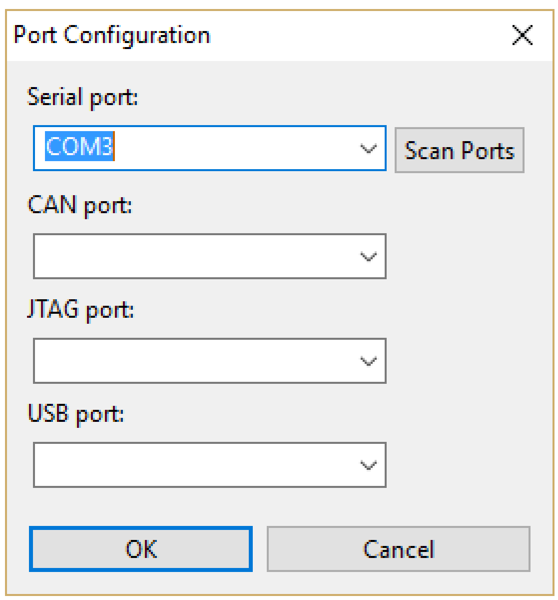
(b) The reprogramming requires the use of the C2Prog software.

- Home page: http://www.codeskin.com/
- C2Prog page: http://www.codeskin.com/c2prog-download

2.3 Programming Steps

(a) After starting the software make sure that the screen looks similar to the one below. If necessary press the expansion button next to "Programming Configuration".

(b) Make sure the proper COM selected. First click "Configure Ports" and then "Scan Ports" to see the available COM ports. Then select the proper port from the pull-down. Only serial port programming is supported at this time.



(c) Using the "Target:" pull-down menu select the correct target from the list. There are 3 current options being used on standard inverters:

- 28335 Options: 30MHz (RMxxx / inverters with -FP option)
- 28375,7,9D-CPU01 Options: 20MHz (Gen 5 / CM200)

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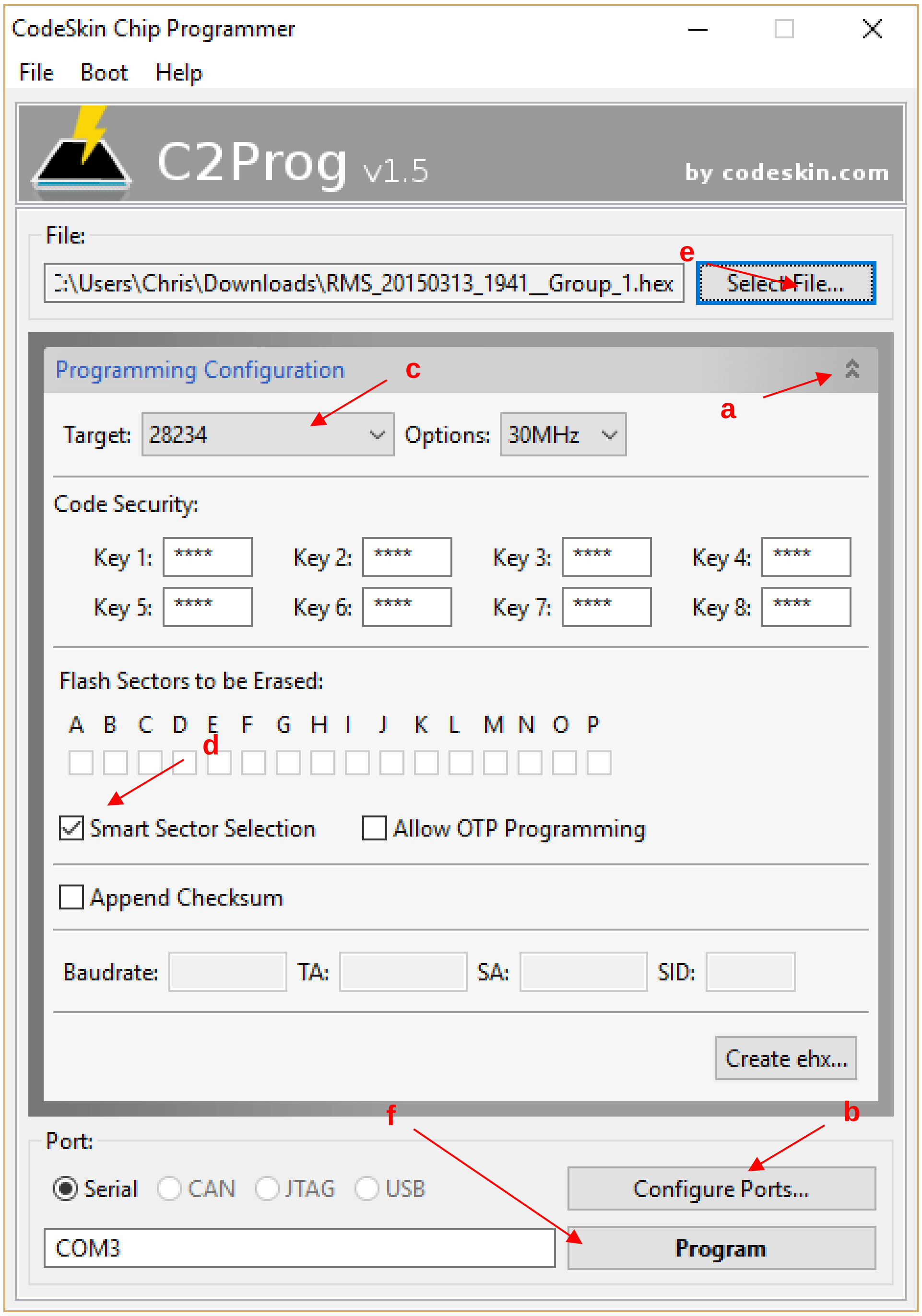
- **28234 Options: 30MHz (Gen 3, this is the most common)**



IMPORTANT: If the HW Version number starts with 234 then the Target is 28234, 30MHz.

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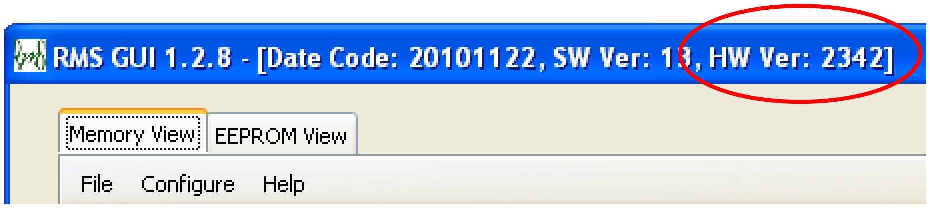


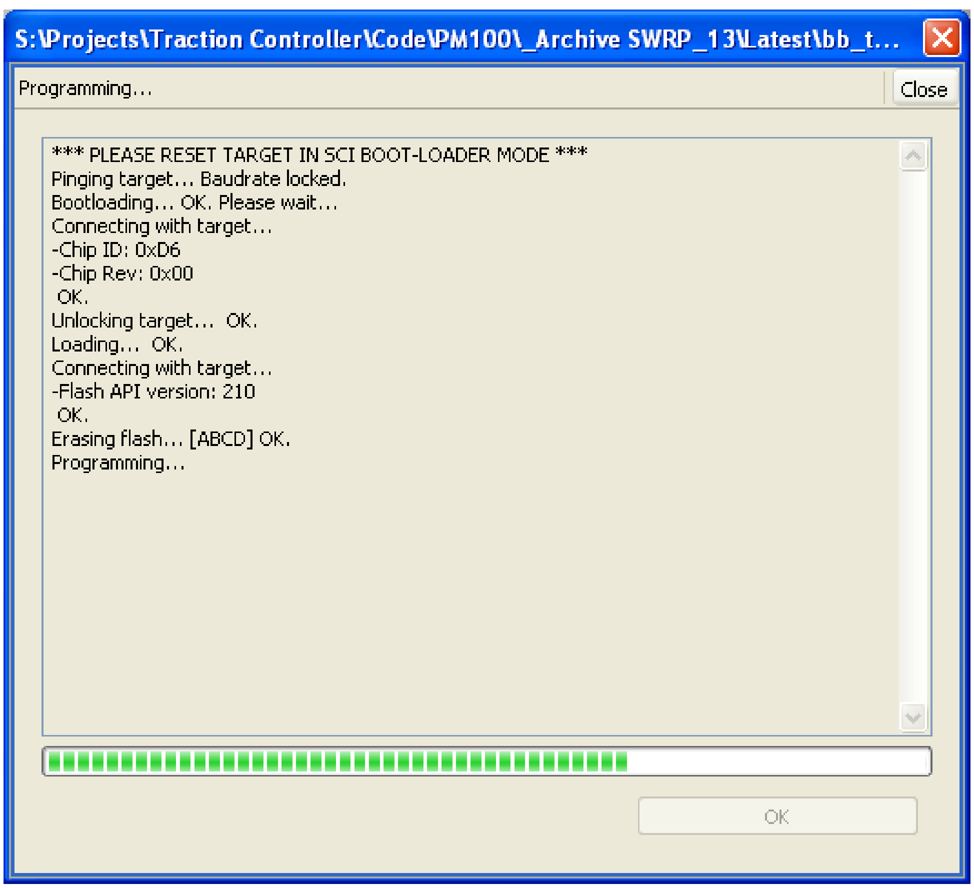
(d) Make sure that the “Smart Selector Selection” box is checked.

(e) Click the “Select File…” button on the top right hand corner and browse to the correct firmware file. The file will have a .hex extension.

(f) Turn off the low voltage power to the inverter (typically BATT+ signal). Ground the Program Enable input to the inverter. Then turn on the lower voltage power to the inverter.

(g) Now click the “Program” button near the bottom.

(h) Programming will then begin. The C2Prog software will show the status of the programming.



(i) When the programming is completed, click OK to close the Status screen. Turn off the low voltage power to the inverter. Disconnect the Program Enable input from ground. Now when the inverter is repowered the new firmware will be operational.

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3. SCI Data Acquisition Guide

3.1 Required Hardware

RS232 cable or RS232-USB Adapter (based on PC's port availability)

3.2 Required Software and Configuration

To be able to capture the SCI data is necessary to use a program that can capture data from the RS232 port of the inverter. An example of this software is Realterm. The software should be configured for the COM port that is being used by the inverter and with the RS232 settings shown in the table below:

Baud Rate	57600
Parity	None
Data Bits	8
Stop Bits	1
Hardware Flow Control	None

3.2.1 Data Records

Each parameter is 16-bits long and each nibble (4-bits) in a parameter is sent as an ASCII character. A 'record' consists of total five characters, that is, the four nibbles in a parameter and a space character. After sending all records, two additional characters, a carriage return and a linefeed, are sent.

0	0	6	8	<space>

Example Data Record

Data Record 1	Data Record 2	Data Record 3		Data Record N	<carriage return>	<linefeed>

A complete set of data records

3.2.2 Update Rate

The inverter will send out records at a periodic rate. The rate is dependent on the number of data records in each set and the availability of processor resources.

3.3 Data Acquisition Parameters

The following data records are transmitted over the serial bus:

Count	Parameter

1	The low word of the Power On Timer (increments every 3ms)
2	Filtered Accel-pot input voltage (V) times 100
3	Motor Torque feedback (Nm) times 10
4	Vehicle Torque Command (Nm) times 10
5	DC Voltage (V) times 10
6	DC Current (V) times 10
7	Motor Speed (rpm)
8	Flux Weakening Regulator Output (Apk) times 10
9	Motor Voltage Magnitude (Vpk) times 10
10	IQ Command (Apk) times 10
11	IQ Feedback (Apk) times 10
12	ID Command (Apk) times 10
13	ID Feedback (Apk) times 10
14	Modulation times 10000
15	Module A Temperature (°C) times 10
16	Motor Temperature (°C) times 10
17	Run Fault Low Word
18	Run Fault High Word
19	Torque Shudder (Nm) times 10
20	Filtered Brake pot (V) times 100

3.3.1 Utilizing the Captured Data:

Once the data is captures in a text file, it should be imported into a Microsoft Excel spreadsheet as space delimited data. After importing all data, it can be copied into *SCI Template.xls* spreadsheet which provides conversion formulae for each data record and allows the user to plot graphs to analyze the vehicle performance in more detail.

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4. Data Formats

Throughout this document, all parameters will adhere to the data formats mentioned in this section, unless specified otherwise.

The column, Variable Type follows the standard computer programming data types. These data types are defined as follows:

- Byte (char): an 8-bit value ranging from 0 – 255 for unsigned and -128 – 127 for signed characters.
- Integer (int): a 16-bit value ranging from 0 – 65535 for unsigned and -32768 – 32767 for signed integers.
- Long Integer (long): a 32-bit value ranging from $-(2^{31}+1)$ to 2^{31}.

All EEPROM data is broadcast with a multiplication factor. In order to get the actual value, divide it by the value in the column 'Multiplier' (may also be referred to as 'Prescalar').

Format	Variable Type	Range	Unit	Multiplier
Temperature	Signed Integer	± 3000.0	°C	10
Low Voltage	Signed Integer	± 300.00	Volts	100
High Voltage	Signed Integer	± 3000.0	Volts	10
Torque	Signed Integer	± 3000.0	N.m.	10
Current	Signed Integer	± 3000.0	Amps	10
Angle	Signed Integer	0 to ±359.9	Degrees	10
Angular Velocity	Signed Integer	± 30000	RPM	*N.A.*
Boolean	Unsigned Byte	0 OR 1	Binary	*N.A.*
Frequency	Signed Integer	± 3000.0	Hz	10
Power	Signed Integer	± 3000.0	kW	10
Flux	Signed Integer	0 to 30.000	Webers	1000
Proportional Gain	Unsigned Integer	0 - 655.00 OR 0 - 6.5535	*N.A.*	100 OR 10000
Integral Gain	Unsigned Integer	0 - 6.5535	*N.A.*	10000
Derivative Gain	Unsigned Integer	0 - 655.35	*N.A.*	100
Low-pass Filter Gain	Unsigned Integer	0 - 6.5535	*N.A.*	10000
Time	Unsigned Long Integer OR Unsigned Integer	*See Parameter Description*	*See Parameter Description*	*See Parameter Description*
Per-unit Value	*See Parameter Description*	*See Parameter Description*	*See Parameter Description*	*See Parameter Description*

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5. RMS GUI – EEPROM Parameters Guide

RMS GUI is a Windows application developed by Cascadia Motion. This application communicates over a RS232 port. The primary purpose of this application is to be able to monitor a specific set of parameters in real time. However, the application also provides the ability to program certain EEPROM parameters. The set of EEPROM parameters need to be modified based on each motor and other system set up by the customer. EEPROM parameters must be programmed correctly before the controller is operated.

This section provides the user with a process of updating EEPROM parameters using the GUI application.

5.1 Required Hardware

RS232 cable or RS232-USB Adapter (based on PC's port availability)

5.2 Required Software

Following software applications/files are needed to program EEPROM parameters:

- RMS GUI Application: This application is part of the Firmware Release Package and can be downloaded using the link provided in the above section, 'Firmware Release Package'.
- Default symbols file (e.g. defsyms_yyyymmdd.txt): Each released firmware requires a specific default symbols file. Please refer to section 1.1.2.1 'RMS GUI' for more details.
- Firmware file: Please refer to section 1.1.1 'Firmware' for more details.

5.3 Programming Steps

(a) Start the GUI. Firmware date code and firmware version on the title of the GUI window. The RMS GUI application also displays the COM port information in the title of the window.

(b) Click on the EEPROM View tab (labeled 'Tab 2' in figure 5.2). This will display all EEPROM parameters that can be programmed by the user.

(c) In order to change any value, click on the value under the VALUE column. Enter a new value and then click ENTER key on your keyboard.

(d) When all values are changed, click on the Program EEPROM button (labeled 'Button 3' in figure 5.2).

(e) A status message will confirm whether the programming was successful or not. Follow the on-screen instructions.

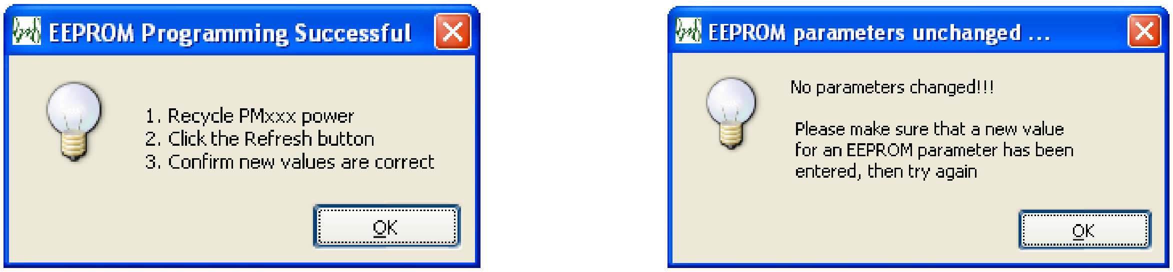


Figure 5.1

5.4 Saving EEPROM values

EEPROM values can be saved by using the Save button (labeled 'Button 4' in figure 5.2). You will be prompted for a filename to save the data to. After selecting the file you will be prompted to press "OK" to start the download.

5.5 Uploading EEPROM values

You can also load a predefined set of values by using the Load EEPROM Values button (labeled 'Button 2' in figure 5.2).

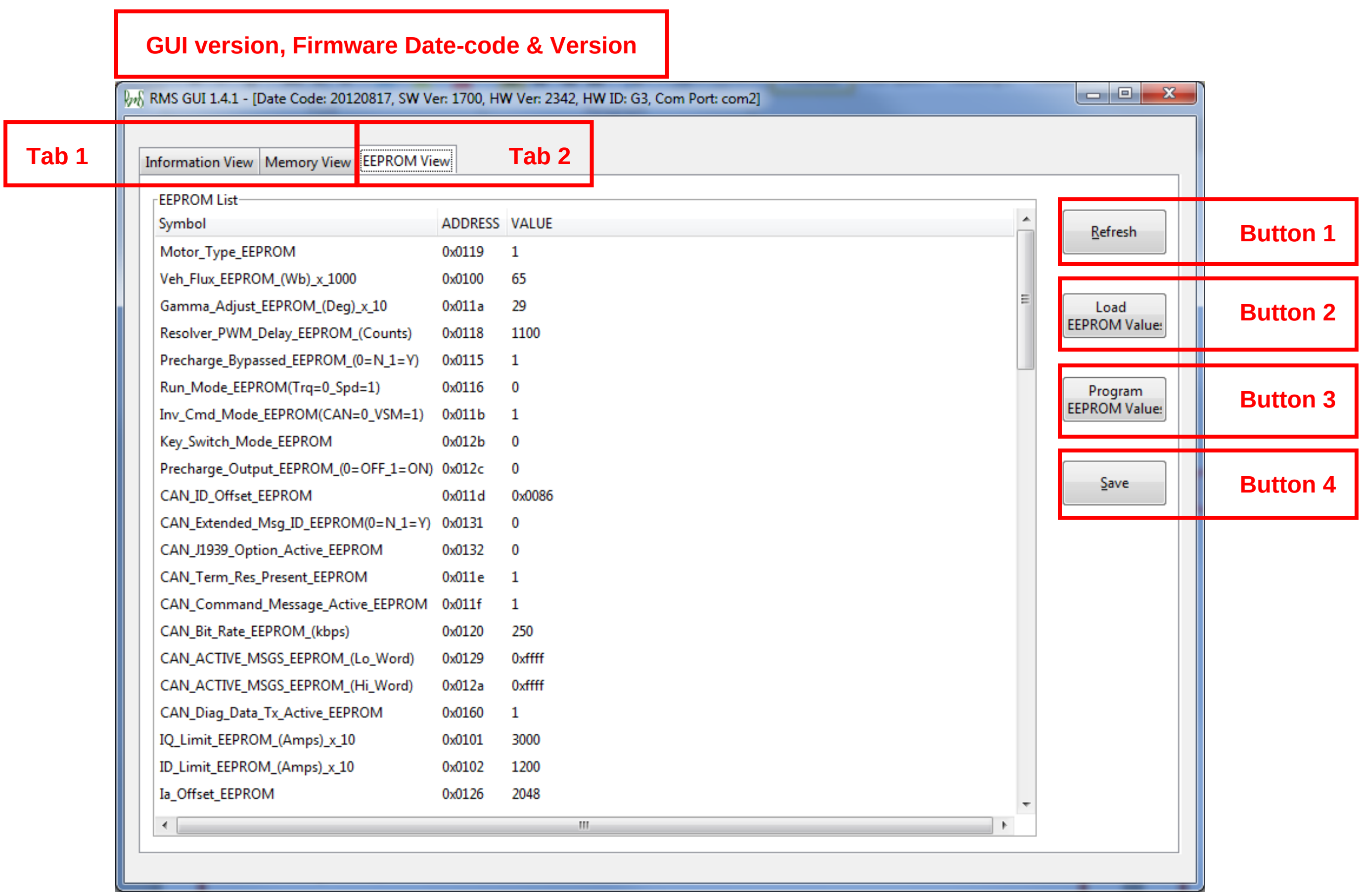


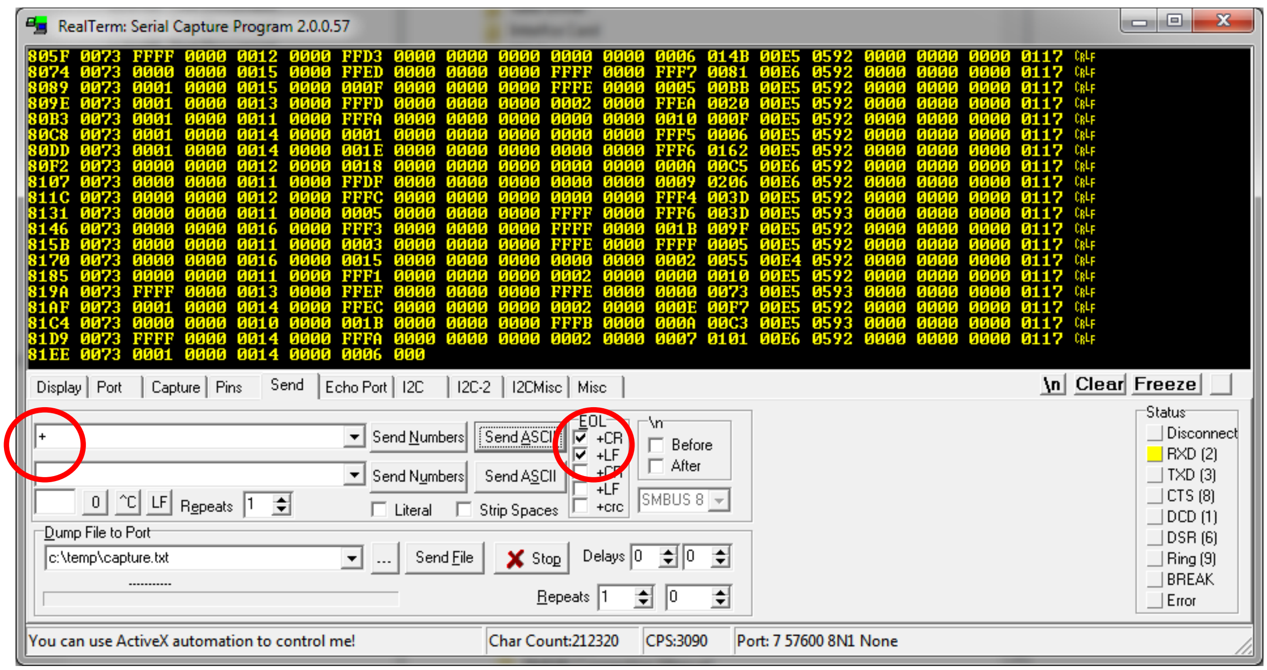
Figure 5.2

5.6 Switching back to SCI mode

Once in the GUI mode, the user has the option to switch back to the SCI data acquisition mode. However, it requires the RMS GUI application to be completely shut down. In other words, the GUI application must release the serial port.

Once the serial port is released, another terminal application such as Realterm can be started. Open the serial port and click anywhere in the window where the serial data appears. Press ‘+’ and then <Enter>. The SCI broadcast data should start to appear again.

Realterm, in particular, also has an option to send out the ASCII characters as shown below. You can enter ‘+’ in the first box and check the +CR and +LF options for carriage return and linefeed respectively. Then press the “Send ASCII” button. The SCI broadcast data should start to appear again.



6. EEPROM Parameter Setup (via GUI EEPROM View)

There are a number of internal parameters (may be considered as "calibrations") that must be set in the controller before it is ready to operate a vehicle. All of these values must be adjusted to suit the vehicle and motor you are using. These adjustments are part of personalizing the drivability and vehicle dynamics to suit the final application of the vehicle.

EEPROM Parameter setup is accomplished using the RMS GUI or by using the Parameter message of CAN. Refer to section 5, "RMS GUI – EEPROM Parameters Guide" for more information on how to update and program these parameters in non-volatile memory.

Refer to the following appendices for different categories of EEPROM parameters (each appendix is hyper-linked, press CTRL-CLICK to go to a specific table):

Appendix A: Motor Configuration Parameters

Appendix B: System Configuration Parameters

Appendix C: CAN Configuration Parameters

Appendix D: Current Parameters

Appendix E: Voltage & Flux Parameters

Appendix F: Temperature Parameters

Appendix G: Accelerator & Torque Parameters

Appendix H: Speed Parameters

Appendix I: PID Regulator Parameters

Appendix J: Shudder Compensation Parameters

Appendix K: Brake Parameters

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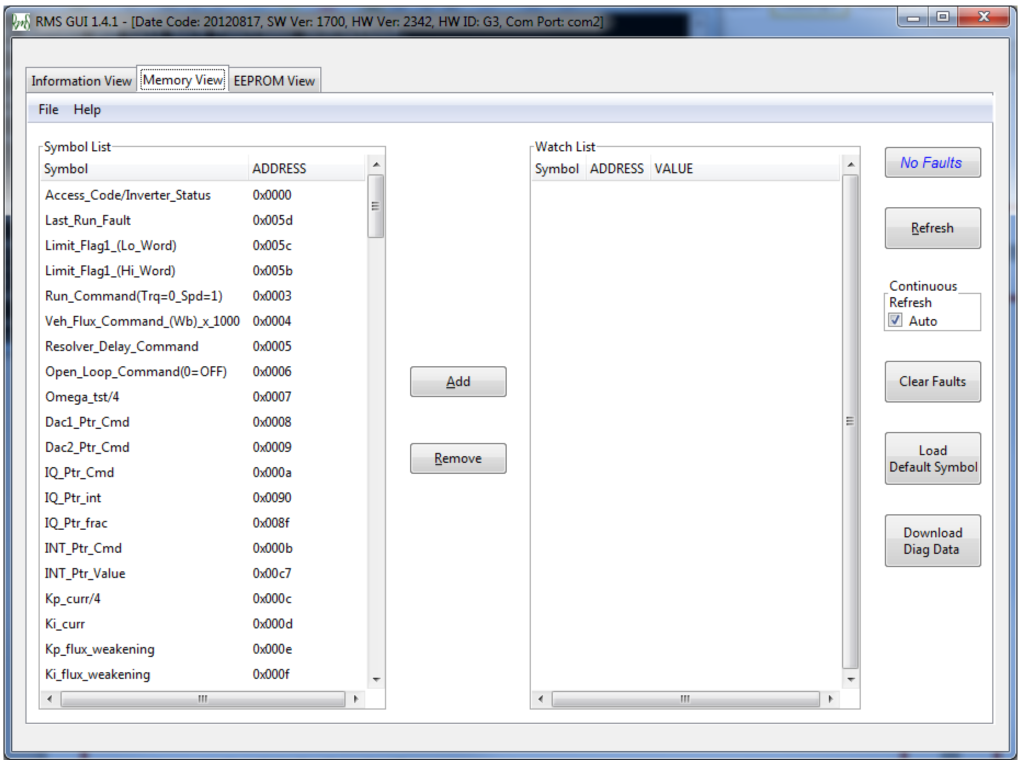
7. Monitored Parameters View (via GUI Memory View)

The GUI provides the ability to monitor several operation parameters of the controller. It is also helpful for checking connections to the controller. Items can be added or removed from the Memory Window to the Watch window to view the parameter.

Refer to the following appendix for a complete list of parameters that can be monitored through RMS GUI (each appendix is hyper-linked, press CTRL-CLICK to go to a specific table):

Appendix L: GUI Display Parameters



No Faults/Check Faults button: This button allows the user to check the fault status when the 'Auto' box is check for 'Continuous Refresh' or by clicking on this button. 'No Faults; status in blue indicates that there are no faults currently present. 'Check Faults' status indicates the presence of one or more faults. To check which faults are present, click on this button.

Clear Faults button: This button allows the user to clear all faults with the exception of a few mentioned in Appendix N (table of Run Faults).

Download Diagnostic Data button: This button allows the user to download SCI Diagnostic Data. Please refer to the user manual 'Download Diagnostic Data' for details. Please note that on some PCs it has been found that the RMS GUI will appear like it has stopped resonding during the middle of downloading of the Diag Data. Please wait several minutes for the RMS GUI to attempt to complete the download.

Load Default Symbols button: This button allows the user to load the default symbols file for the firmware in the PM unit.

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8. Calibration Processes

Before the inverter can be used successfully, it is very important to make sure that it is calibrated properly. There are several calibrations that are performed before each unit is shipped to the customer. However, some of these calibrations depend on the specific environment in which the unit is used.

User Manuals for following calibration processes are provided to customers. The calibrations can be performed as many times as needed.

Calibration Process	User Manual (PDF format)	Factory Calibrated?
Current Offset	Current Offset Calculation (only used with certain Gen 2 units, not common)	No, not necessary
DC Voltage	DC Voltage Calibration Process (factory calibrated thus not normally needed)	Yes
Hall Sensor Encoder	Encoder Hall Sensor Calibration (not normally needed)	No
SIN/COS Encoder	Encoder Calibration for SIN_COS Encoder (only necessary with certain motors that have a sin/cos encoder)	No
Resolver	Resolver Calibration Process (this process is necessary for all motors that use a resolver or SIN/COS encoder)	No
RTD	RTD Calibration Process (factory calibrated thus not normally needed)	Yes

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9. Vehicle State Machine

The drive has an internal state machine that steps through a series of actions at startup, at shutdown, and generally whenever operation “transitions” from one mode or state to another.

The particular state that the drive is in can be tracked via the RMS GUI software. The state is monitored via the VSM_State symbol. This symbol will take on the following values:

VSM_State	Name
0	Start State
1	Pre-charge sequence initial state – Turn on the pre-charge relay
2	Pre-charge sequence active state – Waiting for capacitor to finish charging.
3	Pre-charge sequence finish state – Completes the final checks before proceeding to Wait State.
4	Wait State – waiting for activation of forward or reverse.
5	Ready State – Activates the inverter state machine to begin energizing the motor.
6	Motor Running State – Normal motor running
7	Fault State – The controller has faulted
14	Shutdown in Process – In key switch mode 1, user has turned key switch to off position.
15	Recycle Power State – This indicates that the power to the controller needs to be recycled after EEPROM Programming is complete.

9.1 Start State (VSM_state = 0):

9.1.1 12V Power-up:

When the vehicle is powered up, this is the default state. If the program enable input is held low at power up it will not execute the software in the inverter and will not proceed into the Vehicle State Machine.

Default Initialization:

This is the processor setup and initialization process, including setting all I/O pins to the correct state (in/out, pull-up or –down, weak or strong, etc). At this point, the initialization process sets up a default list of parameters with pre-assigned default values.

9.1.2 Load from EEPROM:

This state will load the application parameters to configure the unit for the actual application. This also loads FACTORY CALIBRATIONS from memory, as these are just a class of EEPROM parameters.

9.1.3 Power on Self-Test (POST):

A number of tests are to be performed in this state. Each test will have an associated fault flag. Following is a list of parameters checked:

Test Area	Description
Current sensors	Check current sensors reading to be within a valid range
Accelerator input	Check accelerator input data is within a valid range
PCB Temperature Sensor	Check PC temperature is in valid range
GDB Temperature Sensor	Check gate drive board temperatures in range
Module Temperature Sensors	Check substrate temperatures for module A, module B, and module C in range
5V power	Check internal 5V and external transducer power in range
12V power	Check 12V power in range
2.5V power	Check internal 2.5V reference voltage in range
1.5V power	Check internal 1.5V reference voltage in range
HW Faults (Saturation and over current)	If exist, attempt to clear faults and then report

If a power-on self-test fault occurs it will blink the fault indicator followed by two quick blinks to differentiate POST faults from RUN faults. The number of blinks gives a general indication of the particular fault.

A particular fault code can be found by clicking on the “Check Faults” button on the “Memory View” page of RMS GUI. Parameters, “post_fault_hi and post_fault_lo have been removed from the parameter list and are not available anymore.

The list on the next page shows all POST faults:

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

Please refer to Appendix M for description of power-on self-test faults.

9.2 Pre-charge Sequence:

9.2.1 Pre-charge Initialization (VSM_State = 1)

This state declared VDC Out-of-range high fault if DC voltage is above the software over-voltage threshold. The value of software over-voltage threshold is not adjustable the user and is set based on the particular type of inverter being used..

If DC voltage is below the software over-voltage threshold, Pre-charge output is activated. State machine goes to Pre-charge Active State.

9.2.2 Pre-charge Active (VSM_State = 2)

This state controls the charging of the capacitors internal to the controllers. If the rate of charge stays within range, Main output is activated and Pre-charge output is deactivated. During the pre-charge process:

If DC voltage exceeds software over-voltage threshold, VDC Out-of-range high fault is declared.

After 3 seconds that is, the maximum pre-charge time,

- If DC voltage is less than the value of EEPROM parameter, DC Under-voltage threshold VDC Out-of-range low fault is declared.

- If DC voltage is still charging, pre-charge timeout fault is declared.

9.2.3 Pre-charge Complete (VSM_State = 3)

This state checks if the capacitor charge is stable, that is, it is not over-charged or under-charged, or there is no quick change in voltage since the pre-charge output was deactivated. If any of the conditions is true, a relevant fault is declared.

9.3 Wait State (VSM_state = 4):

This state checks for the Key Switch Mode. Based on that value, the inverter can be powered to run the motor as follows:

9.3.1 Key Switch Mode 0

This mode allows for a simple on/off ignition switch functionality. To power up the PM unit, turn the ignition to ON position. This state then checks to see that the brake switch is active and only one of /FORWARD and /REVERSE switches is active. If both switches, /FORWARD and /REVERSE, are active, the state shall declare a FWD_RVS_INVALID_STATE_FAULT. If a correct direction and the brake are active then the motor will be enabled.

9.3.2 Key Switch Mode 1

This mode allows for traditional ignition switch functionality. To power up the PM unit, turn the ignition to ON position. This state then checks to see that the brake switch has been active and start signal pulse has been received. While keeping the brakes on, only one of /FORWARD and /REVERSE switches needs to be activated. If both switches, /FORWARD and /REVERSE, are active, the state shall declare a FWD_RVS_INVALID_STATE_FAULT.

9.4 Ready State (VSM_State = 5):

The READY state shall send out the Enable Inverter Command and wait for Inverter Ready Flag to be set. The Inverter Ready Flag will be set if the inverter successfully performs a series of actions necessary to stat the motor. If inverter does not enable the motor within a specific amount of time, the state shall declare an inverter state timeout fault.

This state automatically transitions to the next state if there are not faults.

The following table lists several inverter states:

Inverter States (inv_mode)	Description
0	Precharge, power-up state
1	Stop - Inverter is not running and is in “STOP” state.
2	Open Loop State - for testing purposes
3	Closed Loop state – normal state
4	Start Time Delay – small delay before starting the inverter
5	Current Sensor Test – flux ramp and flux regulators enabled
6	Closed Loop Torque – iorque regulator is enabled
7	Torque Ramp – start torque ramp
8	Idle Run – inverter running normally
9	Idle Stop – inverter is stopped
10	Ramp Off Torque – ramps down the torque command
11	Ramp Off Flux – ramps down the flux command
12	All Ramps Off – shutoff inverter
15	Default – Stop state

9.5 Motor Running State (VSM_State = 6):

This is the normal motor running operation of the vehicle state machine. While running the drive can be switched from torque command to speed command mode, and may be exercised within the full operating envelope of the machine / drive combination.

9.6 Fault State (VSM_State = 7):

If a fault occurs either during power-On self-test, or while the drive is running, the drive will go to the fault state.

If the drive has a fault during the running state a fault code will be set and the fault indicator will begin blinking. At any given time, the fault indicator will blink only one fault.

A particular fault code can be found by clicking on the “Check Faults” button on the “Memory View” page of RMS GUI. Parameters, “run_fault_hi and run_fault_lo have been removed from the parameter list and are not available anymore.

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CAN Byte	CAN Bit	RUN Fault	CAN Byte Value	Fault Word
Byte 4	32	Motor Over-speed	1	00000001
	33	Over-current detected by software on motor phase	2	00000002
	34	DC Bus Over-voltage above the software defined limit for the inverter.	4	00000004
	35	Inverter Over-temperature (any module, GDB, or PCB sensor)	8	00000008
	36	Accelerator Input shorted to ground	16	00000010
	37	Accelerator Input open or shorted to 5V	32	00000020
	38	Direction Command Fault, an attempt to change direction command without first disabling the inverter.	64	00000040
	39	Inverter Response Time-out, inverter state machine has failed to start the motor in the allowed time.	128	00000080
Byte 5	40	Hardware Gate/Desaturation Fault, an error in the hardware has been detected in the power module gate driver circuit.	1	00000100
	41	Hardware Over-current, one of the motor phase current sensors has detected an over-current condition	2	00000200
	42	DC Bus Under-voltage	4	00000400
	43	CAN Command Message Lost	8	00000800
	44	Motor Over-temperature	16	00001000
	45	Reserved	32	00002000
	46	Reserved	64	00004000
	47	Reserved	128	00008000
Byte 6	48	Brake Input shorted to ground	1	00010000
	49	Brake Input open or shorted to 5V	2	00020000
	50	Module A Over-temperature[1]	4	00040000
	51	Module B Over-temperature[1]	8	00080000
	52	Module C Over-temperature[1]	16	00100000
	53	PCB Over-temperature	32	00200000
	54	Gate Drive Board 1 Over-temperature	64	00400000
	55	Gate Drive Board 2 Over-temperature[1]	128	00800000
Byte 7	56	Gate Drive Board 3 Over-temperature[1]	1	01000000
	57	Current Sensor Fault	2	02000000
	58	Reserved	4	04000000
	59	Reserved	8	08000000
	60	Hardware based DC Bus over-voltage	16	10000000

[1] Gen 2 inverters do not have this fault.

CAN Byte	CAN Bit	RUN Fault	CAN Byte Value	Fault Word
	61	Reserved	32	20000000
	62	Resolver Not Connected	64	40000000
	63	Inverter Discharge Active (warning)	128	80000000

Please refer to Appendix N for the table of run faults.

9.6.1 Fault Priority:

Fault indicator will blink faults in the following priority:

POST Faults (Higher priority)

RUN Faults (Lower priority)

POST faults are followed by two quick blinks to distinguish from RUN faults. For each type of fault (POST or RUN), the highest priority of a fault is based on the number of blinks. The fault with 1 blink is the highest priority and the fault with the highest number of blinks is the lowest priority fault. The fault blinking will occur such that if the highest priority fault goes away, the lower priority fault will start blinking and this pattern will continue till all faults are removed.

9.6.2 Clear Faults Command:

Once a fault is acknowledged, it can be cleared using the Clear Faults Command from the GUI. In order to clear a fault, set the Clear Faults Command to 0.

This command clears all active faults including POST Faults. The only exception is the POST Fault, EEPROM Update Required (refer to section 10.1.4 above). This fault is set after programming a new firmware in the PM controller. The purpose of this fault is to have the user accept all previous EEPROM parameters and update the new ones. If there are no EEPROM parameters to update, user should still enter the Access Code and Program EEPROM Command to accept all EEPROM parameters. Please refer to “RMS GUI – EEPROM Parameters Guide” for more details on how to program EEPROM parameters.

In CAN mode, before sending out the Clear Faults Command, make sure that the inverter is disabled. If inverter is enabled and the command is sent out, the motor may start running based on the mode and commanded Torque/Speed.

9.7 Shutdown in Process State (VSM_State = 14):

This state indicates that the inverter “Shutdown in Process”. In key switch mode 1, user has turned key switch to off position by holding the ignition input low.

9.8 Recycle Power State (VSM_State = 15):

This state indicates that the EEPROM Programming has been successfully completed. For new EEPROM values to take effect, the controller must be re-powered.

Appendix A Motor Configuration Parameters

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Motor_Type_EEPROM	0x0119	0 - 255	This parameter is used to select the motor that will be connected to the inverter. There are severa motor specifc manuals on the Cascadia Motion web site that will provide information on the correct motor type number to be used.
Resolver_PWM_Delay_EEPROM_(Counts)	0x0118	0 - 6250	This parameter adjusts a delay that is used to synchronize the resolver feedback to the PWM cycle. It is only used with motors that use resolvers. See Resolver Calibration Manual for more information on resolver calibration.
Gamma_Adjust_EEPROM_(Deg)_x_10	0x011A	0 - ±3599	This is a calibration parameter used in the alignment of the magnetic field of the motor with the resolver / SIN/COS encoder. This parameter is only used with PM type motors. See Resolver Calibration Manual for more information on resolver calibration.
Sin_Offset_EEPROM_(Voltsx100)	Please refer to the manual, “Encoder Calibration for SIN_COS Encoder”.		
Cos_Offset_EEPROM_(Voltsx100)			
Sin_Offset_EEPROM_(ADC_Counts)	0x0163	0 – 4096	This feature is dependent on the hardware version of the PM unit. 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.
Cos_Offset_EEPROM_(ADC_Counts)	0x0164	0 – 4096	

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Appendix B System Configuration Parameters

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Serial_Number_EEPROM	0x0113	0 to 65535	Used for storage of the unit serial number.
Precharge_Bypassed_EEPROM	0x0115	0 or 1	Set to 1: Setting this to a 1 will bypass the pre-charge sequence. When the drive is powered it will go directly to state "Wait State". Set to 0: Setting this to a 0 will enable the pre-charge sequence as described above. Default is 0.
Run_Mode_EEPROM	0x0116	0 or 1	Set to 1: Setting this to a 1 will force the drive into speed control mode. This mode is only recommended for demonstration purposes when the motor is not connected to a high inertia load such as a vehicle. The Accelerator input will command a speed. Contact the factory for more information. For speed mode to operate correctly the Regen Torque Limit must be greater than 0. It should be set to at least 10% of the Motor Torque Limit. Set to 0: Setting this to a 0 will place the drive into torque mode. This is the normal operating mode for the drive. Default is 0.
Inv_Cmd_Mode_EEPROM(CAN = 0_VSM=1)	0x011B	0 or 1	This parameter sets the operating mode of the inverter. Set to 0: Operate under control of the CAN bus. The CAN bus is responsible for enabling and disabling the motor. The brake, forward, and reverse switches are not used. Set to 1: Operate under control of accelerator input and switches (VSM Mode).

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Key_Switch_Mode_EEPROM	0x012B	0 or 1	This parameter provides 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. This configuration must use the IGNITION and START inputs. Key Switch Mode is only effective in VSM Mode. CAN mode remains unaffected. However, the parameter can be updated through both GUI and CAN.
Discharge_Enable_EEPROM	0x016D	0,1,2	Controls the Active Discharge process. Can be used to discharge the internal high voltage capacitors quicker than the passive discharge. See the Inverter Discharge Process Manual for more information. 0 = discharge disabled 1 = discharge is enabled without any faults 2 = discharge is enabled with faults

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Relay_Output_State_EEPROM	0x012C	0 - 0xffff	This parameter controls all relays. To keep the compatibility with previous versions (prior to firmware version 1909), this parameter should be set to 0x000C which will maintain the functionality of OK and fault outputs. Bit 0: Relay 1 – Precharge output Bit 1: Relay 2 – Main Output Bit 2: Relay 3 – OK Output Bit 3: Relay 4 – Fault Output Bit 4: Relay 5 – Pump Output Bit 5: Relay 6 – Fan Output Bit 6: Relay 7 – Reserved for future use Bit 7: Relay 8 – Reserved for future use Note: Pump Output / Fan Output functionality was implemented in software version 1984. Note: Relay 5 and 6 are not available in Gen 2 or CM200 hardware. Relay 3 thru 6 are not available in RM hardware. Bits 8-15 define potential alternative functions for each output. Currently the only alternative function is the Fault Output, if bit 11 is set the Fault output will stay on rather than blink the fault code. Please see the table below for detailed behavior of each relay.

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Precharge Output Options

	Relay #	Command Mode 0: CAN 1: VSM	Precharge Bypass 0: No 1: Yes	Output Relay Config 0: CAN Control 1: Normal Mode	CAN Command 0: Turn off 1: Turn on	Precharge States Active?	Output State Final 0: Off 1: ON	Function	Description
Precharge	1	0	0	0	0	Y	0	CAN Control	Output will toggle during prechrage. Afterwards, goes to CAN control
		0	0	0	1	Y	1	CAN Control	Output will toggle during prechrage. Afterwards, goes to CAN control
		0	0	1	0	Y	1	Normal Function	Output will toggle during prechrage. Afterwards, goes to output configuration
		0	0	1	1	Y	1	Normal Function	Output will toggle during prechrage. Afterwards, goes to output configuration
		0	1	0	0	N	0	CAN Control	Output directly goes to CAN control
		0	1	0	1	N	1	CAN Control	Output directly goes to CAN control
		0	1	1	0	N	1	Normal Function	Output directly goes to output configuration
		0	1	1	1	N	1	Normal Function	Output directly goes to output configuration
		1	0	0	x	Y	0	Normal Function	Output will toggle during prechrage. Afterwards, goes to output configuration
		1	0	0	x	Y	0	Normal Function	Output will toggle during prechrage. Afterwards, goes to output configuration
		1	0	1	x	Y	0	Normal Function	Output will toggle during prechrage. Afterwards, goes to output configuration
		1	0	1	x	Y	0	Normal Function	Output will toggle during prechrage. Afterwards, goes to output configuration
		1	1	0	x	N	0	Normal Function	Output directly goes to output configuration
		1	1	0	x	N	0	Normal Function	Output directly goes to output configuration
		1	1	1	x	N	1	Normal Function	Output directly goes to output configuration
		1	1	1	x	N	1	Normal Function	Output directly goes to output configuration

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Main Output Options

	Relay #	Command Mode 0: CAN 1: VSM	Precharge Bypass 0: No 1: Yes	Output Relay Config 0: CAN Control 1: Normal Mode	CAN Command 0: Turn off 1: Turn on	Precharge States Active?	Output State Final 0: Off 1: ON	Function	Description
Main	2	0	0	0	0	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		0	0	0	1	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		0	0	1	0	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		0	0	1	1	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		0	1	0	0	N	0	CAN Control	Output directly goes to CAN control.
		0	1	0	1	N	1	CAN Control	Output directly goes to CAN control.
		0	1	1	x	N	0	Normal Function	Output is ON. No precharge function.
		0	1	1	x	N	1	Normal Function	Output is ON. No precharge function.
		1	0	0	x	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		1	0	0	x	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		1	0	1	x	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		1	0	1	x	Y	1	Normal Function	Ouptut under precharge control. ON at the end of pecharge.
		1	1	0	x	N	0	Normal Function	Output directly goes to output configuration
		1	1	0	x	N	0	Normal Function	Output directly goes to output configuration
		1	1	1	x	N	1	Normal Function	Output directly goes to output configuration
		1	1	1	x	N	1	Normal Function	Output directly goes to output configuration

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Other outputs

	Relay #	Command Mode 0: CAN 1: VSM	Precharge Bypass 0: No 1: Yes	Output Relay Config 0: CAN Control 1: Normal Mode	CAN Command 0: Turn off 1: Turn on	Precharge States Active?	Output State Final 0: Off 1: ON	Function	Description
Fault	3	0	x	0	0 / 1	x	0 / 1	CAN Control	This output can be toggled by CAN Parameter command
		1	x	1	x	x	1	Normal Function	The output will blink a code based on any existing fault.
		1	x	1	x	x	1	Alt Function	The output will turn on when a fault exists.
OK	4	0	x	0	0 / 1	x	0 / 1	CAN Control	This output can be controlled by CAN Parameter command
		1	x	1	x	x	1	Normal Function	This output will be ON to indiciate 12-V on the inverter
Pump	5	0	x	0	0 / 1	x	0 / 1	CAN Control	This output can be controlled by CAN Parameter command
		1	x	1	x	x	1	Normal Function	"Pump" Function. Output turns on when motor is enabled.
Fan	6	0	x	0	0 / 1	x	0 / 1	CAN Control	This output can be controlled by CAN Parameter command
		1	x	1	x	x	1	Normal Function	"Fan" Function. Output turns on when power module or motor temperature exceeds limit set by EEPROM parameter.
Not Available	7	0	x	0	0 / 1	x	0 / 1	CAN Control	Reserved for future use.
		1	x	1	x	x	1	Normal Function	Reserved for future use.
Not Available	8	0	x	0	0 / 1	x	0 / 1	CAN Control	Reserved for future use.
		1	x	1	x	x	1	Normal Function	Reserved for future use.

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Appendix C CAN Configuration Parameters

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Please refer to the document, CAN Protocol for a detailed description of all CAN parameters.			

Appendix D Current Parameters

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
IQ_Limit_EEPROM_(Amps)_x_10	0x0101	See motor setup manual	This parameter sets the Q-axis current limit. The Q-axis current is an industry term for the torque producing portion of the motor current. The current level is set in terms of peak amps. For example, to set a level of 400 amps peak use a parameter setting of 4000.
ID_Limit_EEPROM_(Amps)_x_10	0x0102	See motor setup manual	This parameter sets the D-axis current limit. The D-axis current is an industry term for the flux producing portion of the motor current. For induction motors it is necessary to provide flux current to the motor. For PM motors the flux is provided by the magnets. However, at high speeds it is necessary to weaken the flux. D-axis current will be used with PM motors to reduce the magnet flux. The current level is set in terms of peak amps. For example, to set a level of 400 amps peak use a parameter setting of 4000.
Ia_Offset_EEPROM	Please refer to the document, Current Offset Calibration for a detailed description on these parameters. It is not normally necessary to make any change to these parameters.		
Ib_Offset_EEPROM			
Ic_Offset_EEPROM			

The total motor current is the vector determined by the Q-axis current and the D-axis current. So the total current is the square root of IQ^2 + ID^2. The result in is Apk, if you want the RMS value of the current then divide the total current calculated by sqrt(2).

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Appendix E Voltage & Flux Parameters

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
DC_Volt_Limit_EEPROM_(V)_x_10	0x0104	0 - 10000	This parameter is used to implement a DC Bus voltage limiting feature. The parameter should be set higher than the maximum battery voltage. It is not recommended that the system use this feature to protect the battery from over-voltage. This parameter should be set to a voltage higher than the the maximum voltage of the battery.
DC_Volt_Hyst_EEPROM_(V)_x_10	0x0105	300	Used with the above parameter.
DC_UnderVolt_Thresh_EEPROM_(V)_x_10	0x0117	0 - 10000	This is the under-voltage fault threshold voltage. If it is desired that the drive does not detect under-voltage faults the value can be set to 0.
Veh_Flux_EEPROM_(Wb)_x_1000	0x0100	0 - 30000	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. The flux value is set in units of Webers. For example to set a value of 0.1 Webers set the parameter to 100.

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Appendix F Temperature Parameters

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Inv_OverTemp_Limit_EEPROM_(C)_x_10	0x0106	-40 – 125 C	This parameter sets the Inverter temperature limit. The temperature is measured from three sensors that are mounted inside the power module. Generally the module temperature will be about 0 – 20°C higher than the water temperature. The temperature is set is 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.
Mtr_OverTemp_Limit_EEPROM_(C)_x_10	0x0121	-40 – 250 C	This parameter sets the Motor temperature limit (if the motor has a temperature sensor). The temperature is set is 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.
Full_Torque_Temp_EEPROM_(C)_x_10	-	-	Please refer to the table in Appendix G.
Zero_Torque_Temp_EEPROM_(C)_x_10			

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RMS GUI Parameter	GUI ADDRESS	Value Range	Description
RTD_Selection_EEPROM_(BITS_1_0)[2]	-	-	For Gen 3 and Gen 5/CM200 inverters this EEPROM parameter configures the type of RTD that is connected to the two different RTD inputs (valid parameters values are 0 thru 3). 0: RTD1 = PT1000 RTD2 = PT1000 1: RTD1 = PT100 RTD2 = PT1000 2: RTD1 = PT1000 RTD2 = PT100 3: RTD1 = PT100 RTD2 = PT100

[2] Gen 2 inverters do not have this feature.

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G3_RTD1_100_Ohm_Gain_EEPROM_x_10000	-	-	For some versions of code these EEPROM parameters have been removed from standard user access. If necessary the RTD inputs can be recalibrated, but they are factory calibrated. Please refer to the manual, "RTD Calibration Process".
G3_RTD1_100_Ohm_Offset_EEPROM_x_100			
G3_RTD2_100_Ohm_Gain_EEPROM_x_10000			
G3_RTD2_100_Ohm_Offset_EEPROM_x_100			
G3_RTD1_1K_Ohm_Gain_EEPROM_x_10000			
G3_RTD1_1K_Ohm_Offset_EEPROM_x_100			
G3_RTD2_1K_Ohm_Gain_EEPROM_x_10000			
G3_RTD2_1K_Ohm_Offset_EEPROM_x_100			

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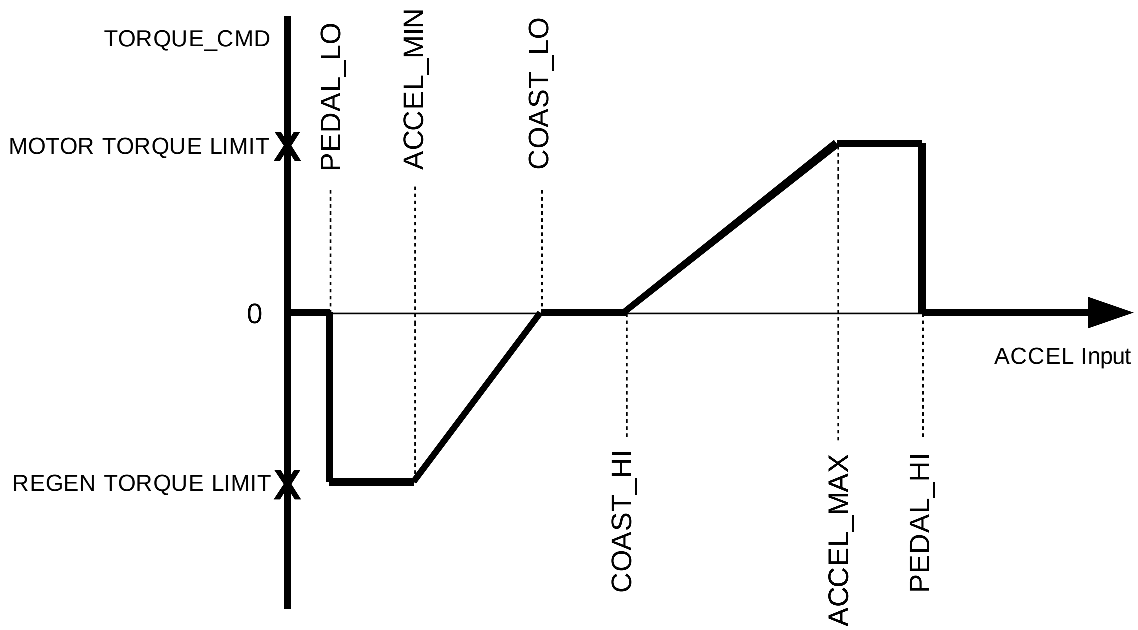
Appendix G Accelerator & Torque Parameters

The accelerator pedal input provides a torque command to the motor. The graph below details the relationship between the accelerator input voltage and the torque command:



Below is a list of the parameters that effect how the accelerator input works. The accelerator input has a range of 0 to 500. This corresponds to a physical range of 0 to 5.00 volts on the input. The parameters are designed for a pedal that provides a low input voltage when the pedal is released and a higher voltage as the pedal is pressed. If the vehicle has a pedal that operates in the opposite direction use the ACCEL PEDAL FLIPPED parameter as described below.

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For initial setup and calibration, the accel pedal voltage can either be monitored by a volt meter, or it can be monitored by the GUI software over the serial port.

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Accel_Pedal_Flipped_EEPROM_(0=N_1=Y)	0x0114	0 or 1	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). When this parameter is 1, the pedal voltage will first be processed by the equation new_pedal_voltage = 5.00 – old_pedal_voltage. Thus will make the pedal act the same as a pedal that normally increases in voltage.
Pedal_Lo_EEPROM_(V)_x_100	0x0107	1 – 500	For accelerator inputs less than this value the torque command is zero. This value should be set to a value that is lower than the lowest possible accelerator position, but higher than zero. If the accelerator input were to be shorted to ground the desired torque command is zero.
Accel_Min_EEPROM_(V)_x_100	0x0108	1 – 500	For accelerator inputs between PEDAL_LO and ACCEL_MIN the torque command is set to a constant value of REGEN TORQUE LIMIT. Depending on the desired characteristics of the vehicle this range could be very small.
Coast_Lo_EEPROM_(V)_x_100	0x0109	1 – 500	For accelerator inputs between ACCEL_MIN and COAST_LO the torque command is linearly from REGEN TORQUE LIMIT to zero. If desired this range allows the operator to control the amount of regen torque.
Coast_Hi_EEPROM_(V)_x_100	0x010A	1 – 500	For the range between COAST_LO and COAST_HI the torque command is zero. Normally this range would be fairly small.
Accel_Max_EEPROM_(V)_x_100	0x010B	1 – 500	For the range between COAST_HI and ACCEL_MAX the torque is linearly increased from zero to the MOTOR TORQUE LIMIT. This would be the normal driving range.

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Pedal_Hi_EEPROM_(V)_x_100	0x010C	1 – 500	For the range between ACCEL_MAX and PEDAL_HI the torque command is held constant at MOTOR TORQUE LIMIT. PEDAL_HI should be set above the normal range of pedal motion, but below 500.
Motor_Torque_Limit_EEPROM_(Nm)_x_10	0x0110	See Motor Manual	This parameter sets the maximum torque that can be commanded by the controller in motoring mode. It is active in both VSM mode and CAN 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. The motor torque limit should always be set at a torque that would be lower than or equal to the current limit. Torque value is set in Nm times 10. For example to set 300 Nm use a value of 3000.
Regen_Torque_Limit_EEPROM_(Nm)_x_10	0x0111	See Motor Manual	This parameter sets the maximum regen torque that can be commanded by the controller. It is active in both VSM mode and CAN mode. In VSM mode this parameter is the maximum regen torque that is commanded when the pedal is fully released. Torque value is set in Nm times 10. For example to set 300 Nm use a value of 3000.
Braking_Torque_Limit_EEPROM_(Nm)_x_10	0x0112		This parameter sets the amount of the torque applied when the brake input is active in VSM mode. It does not have any effect when in CAN control mode. Torque value is set in Nm times 10. For example to set 300 Nm use a value of 3000.
Torque_Rate_Limit_EEPROM_(Nm)_x_10	0x014B	0.1 – 250.0 Nm	This parameter adjusts how quickly the torque command is allowed to change. The parameter is set in terms of torque increment every 3 milliseconds. Torque value is set in Nm times 10. The maximum setting of this parameter (250Nm) could be higher than the motor could actually achieve.

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Full_Torque_Temp_EEPROM_(C)_x_10	0x015D	-40 – 250 ºC	Below this temperature threshold where the full torque is available. As the motor temperature is increased from Full_Torque_Temp_EEPROM_(C)_x_10 to Zero_Torque_Temp_EEPROM_(C)_x_10, the allowed torque capability is linearly decreased. 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.
Zero_Torque_Temp_EEPROM_(C)_x_10	0x015E	-40 – 250 ºC	Temperature threshold where the torque is zeo. This value should be less than Mtr_OverTemp_Limit_EEPROM_(C)_x_10.

The Motor_Torque_Limit_EEPROM_(Nm)_x_10 and Regen_Torque_Limit_EEPROM_(Nm)_x_10 parameters set the maximum value of commanded torque. They will be modified internally based on motor speed as the motor cannot put out full torque over the entire speed range.

The accelerator should be designed so that in its normal range of operation it is greater than 0 volts and less than 5 volts. The parameters Pedal_Lo_EEPROM and Pedal_Hi_EEPROM should be set so that if the input goes to 0 or 5 the torque command goes to zero.

These parameters allow the controller to be setup to command a pedal off amount of regen torque. This regen torque would mimic the engine compression feel that vehicles often have.

Example Setup:

As an example let's assume that assume that the accelerator input comes from a potentiometer. That is, the one end of the pot is connected to AGND. The other end is connected to XDCR_PWR (+5V), and the wiper is connected to AIN1. This setup is shown in the example application schematic.

First we need to determine the range of travel of this potentiometer. With the controller 12V turned on measure the voltage on the wiper of the pot (AIN1). Note how the voltage changes as the pedal is pushed and released. If the voltage increases as the pedal is pressed then the ACCEL_PEDAL_FLIPPED_EEPROM parameter needs to be set to 0. If the voltage decreases then the ACCEL_PEDAL_FLIPPED_EEPROM parameter needs to be set to 1. Whenever the parameter is set to 1 all of the other parameter

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settings must be calculated as follows (parameter = 500 – actual voltage*100). For example if you desire a parameter to be set to 1.20 volts then the actual parameter setting will be 500 – 1.20*100 = 380.

For this example we will assume that the voltage increases as the pedal is pressed. So Accel_Pedal_Flipped_EEPROM will be set to 0.

First measure the wiper voltage (AIN1) when the pedal is in the fully off position. For this example let's assume the measured value is 0.83 volts.

The Pedal_Lo_EEPROM parameter should be set to a value that is lower than this measured value. In this example let's set it to 0.40 volts (this corresponds to Pedal_Lo_EEPROM = 40). We want to set the parameter Accel_Min_EEPROM to be equal to this measured value (Accel_Min_EEPROM = 83). This will cause the torque to start increasing as soon as the pedal begins to be pressed.

Now measure the value of the wiper voltage (AIN1) when the pedal is fully pressed. For this example let's assume that measured value is 4.75 volts.

When the pedal is fully pressed we want to be commanding full torque so set the Accel_Max_EEPROM parameter to this measured value (Accel_Max_EEPROM = 475).

The Pedal_Hi_EEPROM parameter should be set to a value that is above this measured value but less than 5.00 volts. In this example let's set the value to 4.90 volts (Pedal_Hi_EEPROM = 490).

The Coast_Lo_EEPROM and Coast_Hi_EEPROM parameters define a range of pedal position where the torque command will be zero. For this example we'll define this range to be fairly narrow and with the pedal only slightly depressed. So we will set Coast_Lo_EEPROM to 1.10 volts (110) and Coast_Hi_EEPROM to 1.20 volts (120).

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Motor Over-temperature Torque Reduction

This feature allows the Torque Capability to take motor temperature into consideration. Figure G-2 shows the relationship between Torque Capability and Motor Speed. 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). Zero_Torque_Temp_EEPROM_(C)_x_10 should be less than Zero_Torque_Temp_EEPROM_(C)_x_10, which should be less than Mtr_OverTemp_Limit_EEPROM_(C)_x_10.

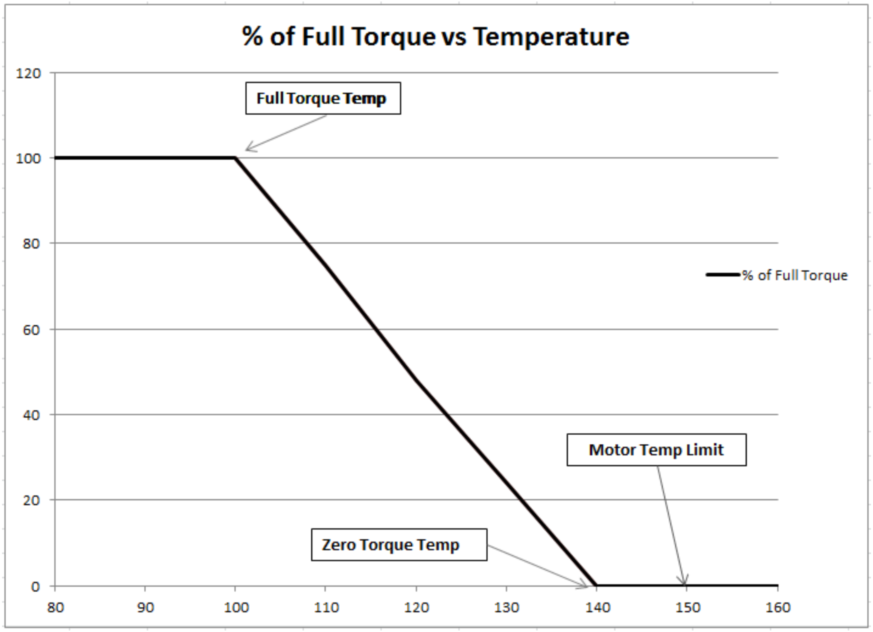

Figure G-2

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Fan and Pump Operation

Starting with version 1984 firmware a default functionality has been added for Relay 5 and Relay 6 outputs (note these are not available on Gen 2 hardware). The functionality is only available if running in VSM mode.

Relay 5 output is defined as a Pump Output. When the inverter is enabled (motor running) the Relay 5 output will be turned on. When the inverter is not enabled the Relay 5 output will turn off.

Relay 6 output is defined as the Fan Output. The controller will monitor the Power Module and Motor Temperatures. If any of the temperatures exceed the value set by the EEPROM parameter as shown below then the Relay 6 output will turn on. When the temperature drops be 5°C below the setpoint the Fan Output will be turned off.

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Fan_Activate_Temp_EEPROM_(degx10)	0x01ae	-400 to 1500	This parameter sets the temperature at which the fan output will turn on. The parameter is set in degrees Celsius time 10. For example a temperature of 40°C would be set as 400.

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Appendix H Speed Parameters

Torque Capability Curve is a function of Motor Speed, a feedback parameter from the Motor Control. Figure H-1 shows the relationship between Torque Capability and Motor Speed:

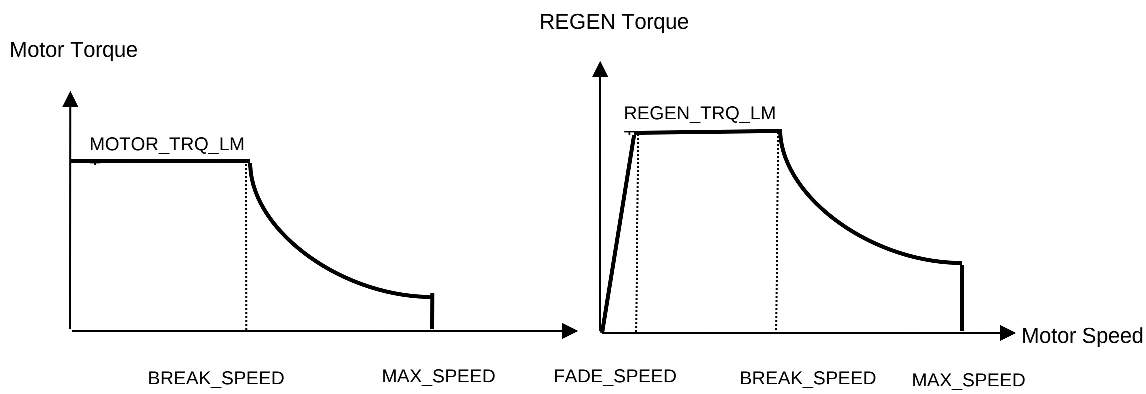

Figure H-1 – Torque Capability vs. Motor Speed

There are two types of Torque Capability curves, Motor Torque Capability and REGEN Torque Capability. The two quantities MOTOR_TRQ_LMT and REGEN_TRQ_LMT (see previous section) define the maximum values for these curves.

When motors exceed a certain speed the amount of torque that they can produce will drop. The BREAK_SPEED parameter defines a curve that represents this drop in torque. The curve is defined BREAK_SPEED divided by actual speed time the torque limit.

The purpose of this curve is to reduce the torque limit so that the accel input does not try and command torque that the motor cannot deliver. If CAN mode is used or other torque limit means the BREAK_SPEED parameter can be set equal to MAX_SPEED to eliminate this effect.

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The following table lists the calibration parameters that pertain to the above graphs. The values of these parameters come from the EEPROM and are set via the DSPGui software.

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Max_Speed_EEPROM	0x010F	1 - 30000 RPM	This parameter sets the maximum allowable speed. If the speed is above this value the torque command will be reduced to zero. (Default value: 10,000 RPM)
Regen_Fade_Speed_EEPROM	0x010D	1 - 30000 RPM	This parameter sets at which the amount of regen torque available is reduced. (Default value: 200 RPM). This parameter also controls whether regen torque can be applied when the motor is spinning in the opposite direction of the commanded direction. If the parameter is set to a value > 0 then no regen torque commands are allowed when the motor is spinning in the opposite direction of the commanded direction. If the parameter is set to 0 then regen torque commands can be given at all times.
Break_Speed_EEPROM	0x010E	1 - 30000 RPM	This parameter sets the speed at which the maximum torque command is reduced to compensate for a reduction of available torque due to field weakening. (Default value: 3000 RPM)
Speed_Rate_Limit_EEPROM_(RPM/sec)	0x014E	100 – 5100 RPM/sec	This parameter adjusts how quickly the speed command is allowed to change. The parameter is set in terms of speed increment every second. Default value is set to 100 RPM/sec. This parameter has no effect on torque mode operation.

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Max Speed Torque Reduction

This feature allows the Torque Capability to take maximum speed into consideration. Figure H-2 shows the relationship between Torque Capability and Motor Speed. When the speed goes above the Max Speed, it begins a linear reduction in the torque towards zero. The slope of the reduction is such that at (Max Speed * 1.02) the torque is zero. The torque slope would be calculated based on the available torque at max speed. This reduction of torque is applied to motoring as well as regen.

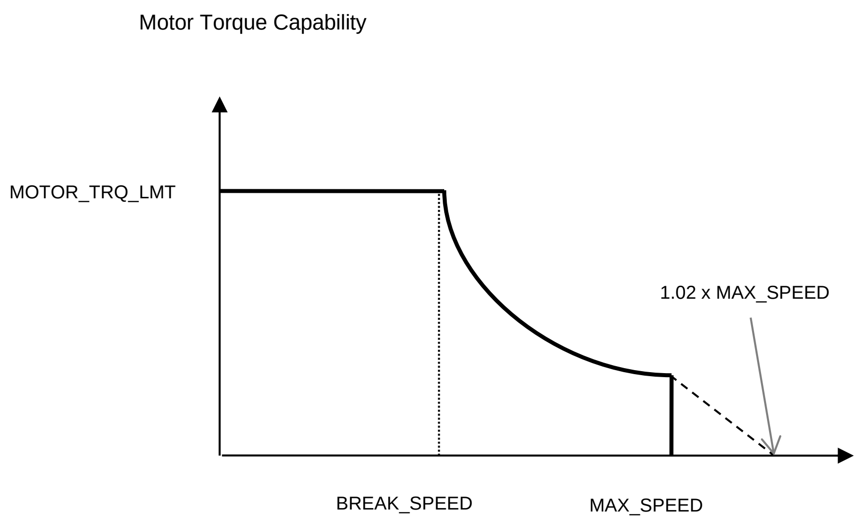

Figure H-2

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Appendix I PID Regulator Parameters

The motor controller is some instances use a torque regulator and a speed regulator. For non IPM type motors the torque regulator is used all of the time. The speed regulator is only used if the controller is in Speed Mode (see Run Mode parameter). The regulators are both based on the classic PID architecture. Each of these regulators has 4 gain values associated with them. They are:

Kp – Proportional Gain

Ki – Integral Gain

Kd – Derivative Gain

Klp – Low Pas filter gain

Generally it is not necessary to adjust these gains. In some instances if the torque regulator seems unstable it may be necessary to adjust the value.

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Kp_Torque_EEPROM_x_10000	0x12D	0 – 6.5535	Torque Regulator proportional gain. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming it using RMS GUI application.
Ki_Torque_EEPROM_x_10000	0x012E	0 – 6.5535	Torque Regulator integral gain. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming it using RMS GUI application. Setting the Ki Torque value to 0 will disable the torque regulator and make the Iq command currently be directly calculated from the torque command.
Kd_Torque_EEPROM_x_100	0x012F	0 – 655.35	Torque regulator derivative gain. This is a times 100 value. Multiply the value within the valid range by 100 before programming it using RMS GUI application.
Klp_Torque_EEPROM_x_10000	0x0130	0 – 6.5535	Torque regulator low pass filter gain. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming it using RMS GUI application.

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Kp_Speed_EEPROM_x_100	0x122	0 – 655.35	Speed regulator proportional gain. This is a times 100 value. Multiply the value within the valid range by 100 before programming it using RMS GUI application.
Ki_Speed_EEPROM_x_10000	0x0123	0 – 6.5535	Speed regulator integral gain. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming it using RMS GUI application.
Kd_Speed_EEPROM_x_100	0x0124	0 – 655.35	Speed regulator derivative gain. This is a times 100 value. Multiply the value within the valid range by 100 before programming it using RMS GUI application.
Klp_Speed_EEPROM_x_10000	0x0125	0 – 6.5535	Speed regulator low pass gain. This is a times 10000 value. Multiply the value within the valid range by 10000 before programming it using RMS GUI application.

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Appendix J Shudder Compensation Parameters

Using an electric motor in a vehicle can expose driveline resonances (shudder) that might not normally be noticed in an ICE vehicle. Typically these resonances occur at very low speeds and moderate torque levels.

The shudder compensation system implemented on the PMxxx family converters provides a mechanism for the user to try and counteract the resonance.

The basic idea is to provide a compensating torque that tries to drive any AC components of the speed to zero. That is if the speed is found to be varying (oscillating) and additional torque is added to the command that attempts to remove the oscillation.

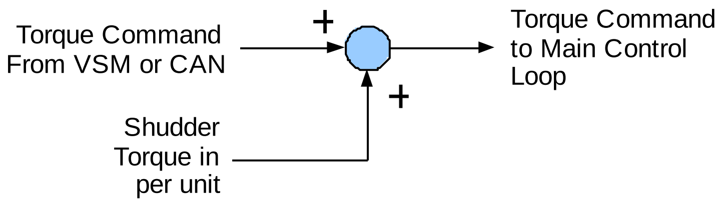

Figure 1: Shudder Torque Implementation

Figure 1 shows the mechanism for including the shudder compensation torque into the torque command. If shudder compensation is enabled the shudder torque value will be added to the normal torque command that comes from the VSM (vehicle state machine) or from a CAN command.

The mechanism for calculating the correct value of shudder torque compensation is shown in Figure 2. The compensation algorithm compares the electrical speed of the motor to a filtered version of the speed. The output of the comparison is then clamped to a value between +TCLAMP and –TCLAMP. This value is then phased out based on two speed parameters, Shudder Speed Lo and Shudder Speed Hi.

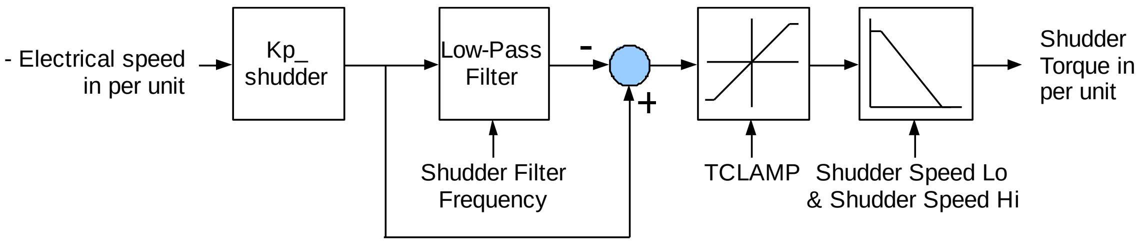

Figure 2: Shudder Compensation Algorithm

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Shudder_Compensation_Enable_EEPROM	0x0134	0, 1	This parameter is used to enable or disable the shudder compensation system. The default value is 0 for disabled. To enable the system change the value to a 1.
Kp_Shudder_EEPROM_x_100	0x0135	0.1 – 50	This parameter defines the gain of the shudder compensation controller. This parameter has a scaling factor of 100. Thus a setting of 100 gives a gain of 1.00. The default value of the gain is 20 (or a parameter setting of 2000). Testing of the vehicle system will be necessary to determine the best gain setting.
TCLAMP_Shudder_EEPROM_(Nm)_x_10	0x0136	0 – 100 Nm	This parameter defines the maximum amount of compensation torque that will be added to the commanded torque. The parameter has a scaling factor of 10. Thus a setting of 10 gives a torque of 1.0 Nm. The default value is 19.9 Nm.
Shudder_Filter_Freq_EEPROM_(Hz)_x_10	0x0137	0.1 – 20 Hz	This parameter determines the frequency of the low-pass filter used in the shudder compensation algorithm (See Figure 2). The parameter has a scaling factor of 10. Thus a setting of 10 gives a frequency of 1.0 Hz. The default value of the parameter is 3.0 Hz (setting of 30). The filter frequency should be lower than the frequency of resonance of the drive-line. Again it may be necessary to perform testing on the vehicle to determine the correct value.
Shudder_Speed_Fade_EEPROM_(RPM)	0x0140	0 – 32000 RPM	This parameters is used to define the linear phase in of the shudder torque compensation at lower speeds starting from 0 RPM. Between this value and Shudder_Speed_Lo, full value of shudder torque is used. This value must be lower than Shudder_Speed_Lo value.
Shudder_Speed_Lo_EEPROM_(RPM)	0x0138		These two parameters are used to define the phase out of the shudder torque compensation at higher speeds. Both parameters are in RPM. Below Shudder_Speed_Lo the full value of the shudder torque is used. Between Shudder_Speed_Lo and Shudder_Speed_Hi the shudder torque is linearly decreased. Above Shudder_Speed_Hi the shudder torque value is 0. At higher speeds drive-line compensation may not be necessary. These two parameters allow the system to be phased out at higher speeds. The default values are 300 rpm for Shudder_Speed_Lo and 400 rpm for Shudder_Speed_Hi. Shudder_Speed_Lo must be less than Shudder_Speed_Hi.
Shudder_Speed_Hi_EEPROM_(RPM)	0x0139		

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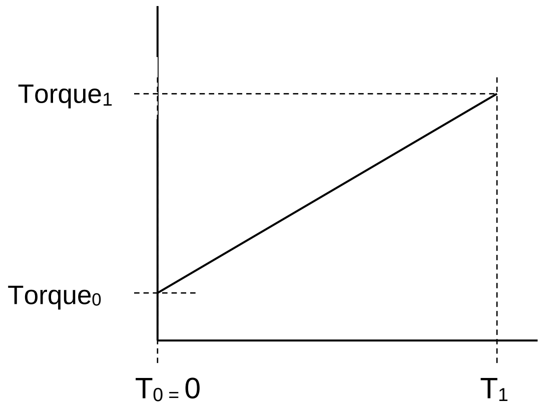
Appendix K Brake Parameters (applies to VSM mode)

The Brake input works in two modes. These modes include Switch mode and Brake Pot mode. The switch mode allows for only a single value of braking torque (regen). The Brake Pot mode allows for a variable amount of braking torque. Normally, the Brake Pot would be connected to the brake pedal of a vehicle and would change in voltage relative to the amount of brake pedal applied.

Brake Switch Mode:

In this mode, the digital input DIN3 is used. Starting with version 1984 DIN7 can also be used for the brake switch input. DIN7 allows a +12V signal for the brake input instead of a grounded signal when using DIN3. When entering braking mode, the controller ramps the torque according to the regen_ramp_rate parameter. The graph below explains the relationship between time and REGEN torque when the brake input is pressed:



Where T_0 is the start time (in seconds) which is always 0 in this case, T_1 is the ramp period indicated by the equivalent EEPROM parameter in seconds, $Torque_0$ is value of torque that is currently produced, and $Torque_1$ is the VSM Braking Torque Limit

In order to use the brake in switch mode, following parameters need to be set as follows:

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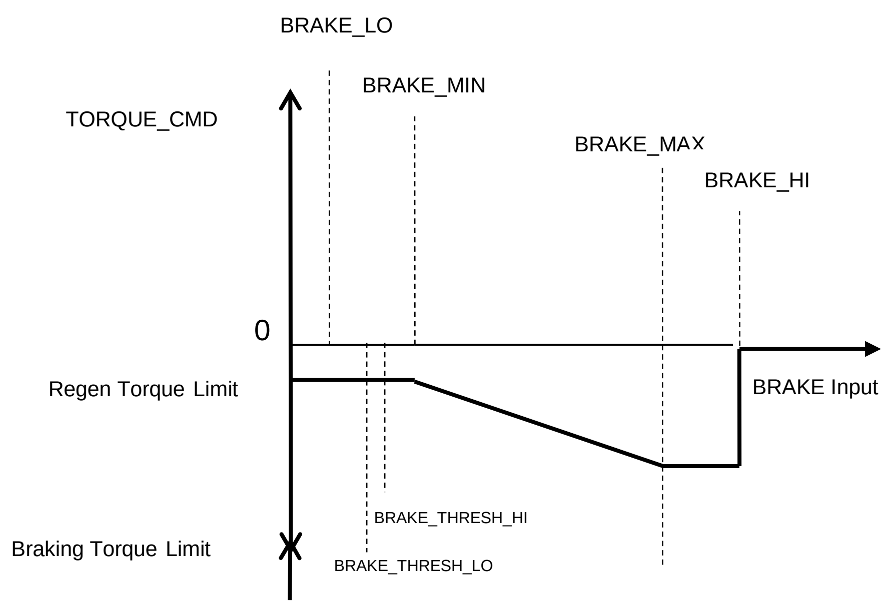
RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Brake_Mode_EEPROM_(0=SWITCH_1=POT)	0x013A	0, 1 or 2	This parameter selects the mode for the brake input. 0: Brake Switch Mode, DIN3 used for input 1: Brake Pot Mode 2: Brake Switch Mode, DIN7 used for input
Regen_Ramp_Rate_EEPROM_(Sec)_x_1000	0x0133	3 - 20000	This value of time is entered in milliseconds. This is the time in which REGEN torque value ramps down to the braking torque limit. This time can also be represented as $\|T_1 – T_0\|$.

Brake Pot Mode:

The graph below details the relationship between the brake input voltage and the REGEN torque command:



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The brake input has a range of 0 to 500. This corresponds to a physical range of 0 to 5.00 volts on the input. The parameters are designed for a pedal that provides a low input voltage when the pedal is released and a higher voltage as the pedal is pressed. If the vehicle has a pedal that operates in the opposite direction use the BRAKE PEDAL FLIPPED parameter as described below.

For initial setup and calibration, the brake pedal voltage can either be monitored by a volt meter, or it can be monitored by the GUI software over the serial port.

Below is a list of the parameters that effect how the brake input works.

RMS GUI Parameter	GUI ADDRESS	Value Range	Description
Brake_Mode_EEPROM_(0=SWITCH_1=POT)	0x013A	0 or 1	This parameter selects the mode for the brake input. 0: Brake Switch Mode 1: Brake Pot Mode
Brake_Switch_Bypassed_EEPROM	0x15F	0 – 2	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 for starting the vehicle and for regen 2: Ignore brake input only for starting the vehicle
Brake_Pedal_Flipped_EEPROM	0x013F	0 or 1	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). When this parameter is 1, the pedal voltage will first be processed by the equation new_pedal_voltage = 5.00 – old_pedal_voltage. Thus will make the pedal act the same as a pedal that normally increases in voltage.
Brake_Lo_EEPROM_(V)_x_100	0x013B	1 – 500	For brake inputs less than this value the torque command is zero. This value should be set to a value that is lower than the lowest possible brake position, but higher than zero. If the brake input were to be shorted to ground the desired torque command is zero. Below this value, Brake Input Short Fault is set.

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Brake_Min_EEPROM_(V)_x_100	0x013C	1 – 500	For brake inputs less than this value, the torque command is held at 0.
Brake_Max_EEPROM_(V)_x_100	0x013D	1 – 500	For brake inputs between BRAKE_MIN and BRAKE_MAX, the torque command is linearly decreased from 0 to Braking Torque Limit.
Brake_Hi_EEPROM_(V)_x_100	0x013E	1 – 500	For the range between BRAKE_MAX and BRAKE_HI the torque command is held constant at Braking Torque Limit. BRAKE_HI should be set above the normal range of pedal motion, but below 500. Above this value, Brake Input Open Fault is set.
Brake_Thresh_Lo_EEPROM_(V)_x_100	0x0161	1 – 500	This value is supposed to be between Brake_Lo_EEPROM_(V)_x_100 and Brake_Min_EEPROM_(V)_x_100. Below this threshold, brake is considered inactive (OFF).
Brake_Thresh_Hi_EEPROM_(V)_x_100	0x0162	1 – 500	This value is supposed to be between Brake_Lo_EEPROM_(V)_x_100 and Brake_Min_EEPROM_(V)_x_100. This value should be greater than Brake_Thresh_Lo_EEPROM_(V)_x_100 to provide some hysteresis for turning the brake switch on and off. Above this threshold, brake is considered active (ON).

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Appendix L GUI Display Parameters

The GUI provides the ability to monitor several operation parameters of the controller. It is also helpful for checking connections to the controller. Items can be added from the Item list to the Watch window to view the parameter.

RMS GUI Parameter	Description
Run_Command(Trq=0_Spd=1)	Displays the current command mode (Torque control or Speed control).
Commanded_Speed_(RPM)	Shows the Commanded speed if the controller is in Speed mode.
Feedback_Speed_(RPM)	Shows the motor speed as calculated from particular motor position feedback sensor used for the motor type (e.g. encoder/resolver).
Commanded_Torque_(Nm)_x_10	The commanded torque is displayed if the controller is in torque control mode
Feedback_Torque_(Nm)_x_10	This is the motor torque as calculated by the controller. The torque is calculated based on motor currents and the parameters of the motor. If the motor is running in reverse the Feedback Torque will have the opposite sign to the Commanded Torque.
Voltage_Feedback_Speed_(RPM)	This parameter shows the motor speed as calculated from measuring the back EMF of a PM motor. This parameter will only be valid if there is sufficient back EMF to generate a measurable voltage and the motor is not enabled. It is useful to ensure that motor phasing matches the resolver feedback (same direction/speed).
Torque_Shudder_(Nm)_x_10	Amount of torque compensation that is being applied when using the Shudder compensation feature.
V_DC_Filtered_(Volts)_x_10	DC Bus Voltage measurement.
V_MAG_Filtered_(Volts)_x_10	The magnitude of the output voltage being applied to the motor. This is represented in line to neutral peak volts.
SW_Over_Voltage_(Volts)_x_10	A hard-coded value for over-voltage threshold this is used during pre-charge process and during normal operation for over-voltage detection.
I_DC_Filtered_(Amps)_x_10	The DC Bus current. The controller can only calculate this value as it does not actually measure the DC bus current. The calculation is based on an estimate of the motor power and the DC Bus voltage.
I_MAG_Filtered_(Amps)_x_10	The motor phase current magnitude. This is the peak value of the current (not RMS).
SW_Over_Current_(Amps)_x_10	A hard-coded value for over-current threshold this is used during normal operation for over-current detection.

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Motor_Temp_(C)_x_10	Shows the motor temperature if available. The sensor used is selected automatically via the motor type. Some motors do not have a sensor selected and this will display 0 then.
Mod_A_Temp_(C)_x_10	The temperature of the sensor embedded in Phase A of the power module.
Mod_B_Temp_(C)_x_10	Phase B
Mod_C_Temp_(C)_x_10	Phase C
PCB_Temp_(C)_x_10	Temperature of the control board PCB.
GDB_Temp_(C)_x_10	Temperature of the gate driver board PCB (Gen-2 boards only).
GDB_1_Temp_(C)_x_10	Temperature of the gate driver board PCB 1 (non Gen-2 boards).
GDB_2_Temp_(C)_x_10	Temperature of the gate driver board PCB 2 (non Gen-2 boards).
GDB_3_Temp_(C)_x_10	Temperature of the gate driver board PCB 3 (non Gen-2 boards).
RTD1_Temp_(C)_x_10	Temperature of the sensor hooked to the RTD1 input.
RTD2_Temp_(C)_x_10	Temperature of the sensor hooked to the RTD2 input.
RTD3_Temp_(C)_x_10	Temperature of the sensor hooked to the RTD3 input (Gen-2 board only).
RTD4_Temp_(C)_x_10	Temperature of the sensor hooked to the RTD4 input (Gen-2 board only).
RTD5_Temp_(C)_x_10	Temperature of the sensor hooked to the RTD5 input (Gen-2 board only).
ID_Bits	3 =Gen-2 board / RM / CM200 2 =Gen-3 board / Gen 5
Inverter_Mode	The Inverter State, see description in section 11.4
VSM_State	The VSM State, see description in section 11
Inverter_Enable	Displays a 1 when the inverter is enable, 0 if disabled.
Vehicle_Direction	Shows the commanded vehicle direction, 1 = Forward, 0 = Not commanded, -1 = Reverse
Ignition_Input	Shows the state of DIN5, 1 = asserted, 0 = deasserted.
Start_Input	Shows the state of DIN6, 1 = asserted, 0 = deasserted.
Brake_Switch	Shows the state of DIN3, 1 = asserted, 0 = deasserted.
Forward_Switch	Shows the state of DIN1, 1 = asserted, 0 = deasserted.
Reverse_Switch	Shows the state of DIN2, 1 = asserted, 0 = deasserted.
Regen_Disable_Switch	Shows the state of DIN4, 1 = asserted, 0 = deasserted.

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OK_Output_Status	Shows the state of RLY3, 1 = asserted, 0 = deasserted.
Precharge_Output_Status	Shows the state of RLY1, 1 = asserted, 0 = deasserted.
Main_Output_Status	Shows the state of RLY2, 1 = asserted, 0 = deasserted.
Fault_Output_Status	Shows the state of RLY4, 1 = asserted, 0 = deasserted.
Hall_Input_1_Status	Shows the status of Hall Input 1
Hall_Input_2_Status	Shows the status of Hall Input 2
Hall_Input_3_Status	Shows the status of Hall Input 3
Encoder_Input_A_Status	Shows the status of Encoder Input A
Encoder_Input_B_Status	Shows the status of Encoder Input B
Encoder_Input_Z_Status	Shows the status of Encoder Input Z
SAT_Fault_Output_Status	Shows the status of HW Desaturation fault, 0=asserted, 1=deaaserted
OC_Fault_Output_Status	Shows the status of HW Over-current fault, 0=asserted, 1=deaaserted
VSM_Accel_Filtered	Shows the voltage applied to AIN1, 0 = 0 volts, 500 = 5.0 volts
VSM_Brake_Filtered	Shows the voltage applied to AIN3, 0 = 0 volts, 500 = 5.0 volts
Power_on_Timer_3ms_(Hi_byte)	The controller keeps a count of how many 3ms intervals have occurred since power was applied. It is represented as a 32 bit number.
Power_on_Timer_3ms_(Lo_byte)	See above.
Sin_corr_(V)_x_100	If used, the reading of the resolver SIN input. Display shows the peak value of the input. Available on Gen 2 and Gen 3 only.
Cos_corr_(V)_x_100	If used, the reading of the resolver COS input. Display shows the peak value of the input. Available on Gen 2 and Gen 3 only.
Motor_Angle_(DEG)_x_10	Shows the rotational position of the motor shaft. Can be used to verify encoder or resolver operation.
Delta_Resolver_In_Fil_(DEG)_x_10	This parameter is used for calibration of the resolver offset. It shows the offset between the back EMF angle and the resolver angle. Only valid if the motor is not enabled.
Gamma_Adjust_(Deg)_x_10	This is a command parameter. The value can be adjusted by typing the new data in the GUI. This parameter is used with the resolver calibration procedure. This parameter is an offset angle added to the resolver feedback angle. The parameter will reset to the EEPROM whenever the power is cycled to the controller.

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Go back to the section (CTRL + Click), "Monitored Parameters View (via GUI Memory View)"

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Appendix M POST Faults

POST Fault	Fault Indicator Number of Blinks	Fault Description
Hardware Gate/Desaturation Fault	5	A hardware de-saturation fault occurs for any of the following conditions: The current exceeds normal level and causes short-circuit in an IGBT An IGBT circuit is bad An over-voltage condition occurs on DC bus **Currently, this fault cannot be cleared using the 'Clear Fault Command'. In order to clear this fault, inverter power must be recycled.**
HW Over-current Fault	5	This fault occurs when any of the current sensors detect an over-current condition which could be positive or negative. All six over-current faults are ORed together to cause the HW over-current fault.
Accelerator Shorted	4	Accelerator input voltage is less than the value in EEPROM parameter, Pedal_Lo_EEPROM_(V)_x_100.
Accelerator Open	4	Accelerator input voltage is more than the value in EEPROM parameter, Pedal_Hi_EEPROM_(V)_x_100.
Current Sensor Low	3	Current sensor reading is lower than the hard-coded value (-22.5 Amps) set for this fault.
Current Sensor High	3	Current sensor reading is higher than the hard-coded value (22.5 Amps) set for this fault.
Module Temperature Low	1	*This fault is currently not active.*
Module Temperature High	1	One or more of the three module temperatures are above 125 C.
Control PCB Temperature Low	1	PCB temperature is below -24 C.
Control PCB Temperature High	1	PCB temperature has exceeded 125 C.
Gate Drive PCB Temperature Low	1	GDB temperature is below -24 C.
Gate Drive PCB Temperature High	1	GDB temperature has exceeded 125 C.
5V Sense Voltage Low	2	5V Sense reading is too low
5V Sense Voltage High	2	5V Sense reading is too high

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12V Sense Voltage Low	2	12V Sense reading is too low
12V Sense Voltage High	2	12V Sense reading is too high
2.5V Sense Voltage Low	2	2.5V Sense reading is too low
2.5V Sense Voltage High	2	2.5V Sense reading is too high
1.5V Sense Voltage Low	2	1.5V Sense reading is too low
1.5V Sense Voltage High	2	1.5V Sense reading is too high
DC Bus Voltage High	6	During pre-charge, DC voltage is above the hard-coded SW over-voltage limit. SW over-voltage limit can be checked from the monitored parameter list by adding SW_Over_Voltage_(Volts)_x_10 to the watch list.
DC Bus Voltage Low	6	DC bus voltage is below 100-V.
Pre-charge Timeout	6	DC bus voltage is not charging at the rate of 2.7 V/50 msec and 3 seconds have elapsed.
Pre-charge Voltage Failure	6	After pre-charge is complete, DC voltage has changed by more than 10-V within 15 msec.
EEPROM Checksum Invalid	7	EEPROM checksum is not valid.
EEPROM Data Out of Range	7	*This fault is currently not active.*
EEPROM Update Required	7	The number of EEPROM parameters has changed (most of the time increased), check the new parameters and set appropriate values.
Brake Shorted	8	Brake input voltage is less than the value in EEPROM parameter, Brake_Lo_EEPROM_(V)_x_100.
Brake Open	8	Brake input voltage is more than the value in EEPROM parameter, Brake_Hi_EEPROM_(V)_x_100.

Go back to the section (CTRL + Click), “Power on Self-Test (POST):”

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Appendix N Run Faults

RUN Fault	Fault Indicator Number of Blinks	Fault Description
Motor Over-speed Fault	6	Motor speed is above the value in EEPROM parameter, Motor_Overspeed_EEPROM_(RPM)
Over-current Fault	3	One or more of the three phase currents is above the hard-coded SW over-current limit. SW over-current limit can be checked from the monitored parameter list by adding SW_Over_Current_(Amps)_x_10 to the watch list.
Over-voltage Fault	2	Filtered value of DC voltage is above the hard-coded SW over-voltage limit. SW over-voltage limit can be checked from the monitored parameter list by adding SW_Over_Voltage_(Volts)_x_10 to the watch list.
Inverter Over-temperature Fault	1	One or more of the three module temperatures are above the value in EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
Accelerator Input Shorted Fault	4	Accelerator input is below the value in EEPROM parameter, Pedal_Lo_EEPROM_(V)_x_100.
Accelerator Input Open Fault	4	Accelerator input is above the value in EEPROM parameter, Pedal_Hi_EEPROM_(V)_x_100.
Direction Command Fault	7	Both directions forward and reverse are active at the same time. **This fault has been de-activated.**
Inverter Response Time-out Fault	8	Inverter has not been enabled within 2 minutes of receiving the inverter enable command either through VSM or CAN.
Hardware Gate/Desaturation Fault	5	A hardware de-saturation fault occurs for any of the following conditions: The current exceeds normal level and causes short-circuit in an IGBT An IGBT circuit is bad An over-voltage condition occurs on DC bus **Currently, this fault cannot be cleared using the 'Clear Fault Command'. In order to clear this fault, inverter power must be recycled.**
Hardware Over-current Fault	5	This fault occurs when any of the current sensors detect an over-current condition which could be positive or negative. All six over-current faults are ORed together to cause the HW over-current fault.

Under-voltage Fault	2	DC bus voltage is below the value in EEPROM parameter, DC_UnderVolt_Thresh_EEPROM_(V)_x_10.
CAN Command Message Lost Fault	9	The inverter is not able to see the heartbeat command message when in CAN mode.
Motor Over-temperature Fault	1	The motor temperature value exceeds the value in the EEPOM parameter, Mtr_OverTemp_Limit_EEPROM_(C)_x_10.
Brake Input Shorted Fault	10	Brake input is below the value in EEPROM parameter, Brake_Lo_EEPROM_(V)_x_100.
Brake Input Open Fault	10	Brake input is above the value in EEPROM parameter, Brake_Hi_EEPROM_(V)_x_100.
Module A Over-temperature Fault[3]	1	Module A temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
Module B Over-temperature Fault[3]	1	Module B temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
Module C Over-temperature Fault[3]	1	Module C temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
PCB Over-temperature Fault[3]	1	PCB temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
Gate Drive Board 1 Over-temperature Fault	1	GDB 1 temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.

[3] Not available on Gen 2 inverters.

Gate Drive Board 2 Over-temperature Fault[4]	1	GDB 2 temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
Gate Drive Board 3 Over-temperature Fault[4]	1	GDB 3 temperature has exceeded the value in the EEPROM parameter, Inv_OverTemp_Limit_EEPROM_(C)_x_10.
Current Sensor Fault	3	If current readings are not within a certain range, current sensor is assumed to be mal-functioning.
Resolver Not Connected Fault	11	The resolver is not connected.
Inverter Discharge Active	11	Inverter discharge is in process.

Go back to the section (CTRL + Click), “Fault State (VSM_State = 7):”

[4] Gen 2 boards do not have this particular fault.

Revision History

Version	Description of Versions/ Changes	Updated by	Date
2.0	This version has following manuals combined: . SW Release Package Description . PM Programming using Codeskin . RMS SCI Data Acquisition . Programming EEPROM using GUI . PM User Manual (Sections 9, 10, 11, 12, 13) Also, updated several sections based on document, “Firmware 1700 Release Notes”.	Azam Khan	9/5/12
2.1	Added “Shudder Compensation” manual to appendix.	Azam Khan	9/10/12
2.2	Peer Reviewed	Chris Brune	9/12/12
2.3	In Appendix D, provided reference of “Current Offset Calibration” manul for current offset parameters, Ia_Offset_EEPROM, Ib_Offset_EEPROM, and Ic_Offset_EEPROM.	Azam Khan	9/13/12
2.4	In section 3.3, Removed unnecessary column from the table that lists SCI broadcast parameters. From the same table, removed parameters number 17 and 18, Run Fault High Word and Limit Flag Low Word, and replaced the two with Run Fault Low Word and Run Fault High Word.	Azam Khan	10/25/12
2.5	Updated Appendix K: Brake Parameters Brake Input Bypassed EEPROM parameter can also be set to a value of 2 in addition to 0 and 1. If this parameter is set to 2, brake input will be ignored only for starting the vehicle. However, the user can continue to use it for regen.	Azam Khan	11/20/2012
2.6	SWRP 1805: Added new faults, “Resolver Not Connected” and “Inverter Discharge Active”. Sections updated: Section 9.6 Appendix N	Azam Khan	12/13/2012

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Version	Description of Versions/ Changes	Updated by	Date
2.7	SWRP 1818: Added a new feature “Max Speed Torque Reduction” Sections updated: Appendix H	Azam Khan	4/23/2013
2.8	Changed all references to the term “C2ooo” to just “C2” in accordance with the application name update. Corrected the CAN byte numbers for Run Faults to be 4, 5, 6, and 7 and adjusted bit numbers accordingly.	Azam Khan	4/15/2014
2.9	Updated the description for Relay_Output_State_EEPROM_(0=OFF_1=ON) in Appendix B System Configuration Parameters	Azam Khan	6/18/2014
3.0	In Appendix B, added detailed tables for each relay output describing it behavior based on other configuration parameters.	Azam Khan	7/17/2014
3.1	Added a new section 5.6,’Switching back to SCI mode’, that describes how to switch between GUI and SCI modes. In Appendix B, updated tables for the relay outputs. Also updated the description for Relay_Output_State_EEPROM.	Azam Khan	8/12/2014
3.2	Updated Firmware naming description. Removed broken manual links, updated manual descriptions.	Chris Brune	8/26/2015
3.3	Added Inverter Discharge EEPROM parameter to the list of parameters. Clarified list of calibrations.	Chris Brune	1/05/2016
3.4	Updated screen shots to show version 1.5 of C2prog. Updated Relay Output table to show Pump, Fan, and alternative function for Fault output. Added information on Pump and Fan output functionality and associated EEPROM parameter. Added DIN7 as being used for the Brake Switch input.	Chris Brune	9/8/2016
3.5	Updates from RMS/Rinehart Motion Systems to Cascadia Motion. Addition of information about Gen 5 / L100.	Chris Brune	11/13/2020
3.6	Name change from L100 to CM200. Corrected target for Gen3	Travis Gintz	1/14/2021