BORGWARNER

CM Hardware Users Manual

Document: 0A-0162-03

Installation guide for all CM series inverters
(CM200DX, CM200DZ, CM350DZ, and CM350SiC)

Contents

1 Safety First

ATTENTION	When you see this symbol, PAY ATTENTION. This indicates that something important is about to be said, that concerns your safety and the proper operation of the equipment.
DANGER	When you see this symbol, you are being alerted to an IMMEDIATE DANGER that could cause severe injury or even death. You MUST review these sections carefully and do everything possible to comply with installation and operation requirements, or you risk injury or death to yourself or anyone else who uses the equipment or the vehicle. Failure to comply with safety requirements will void all warranties and could expose you as the installer to liability in the event of an injury. Use the equipment in the manner in which it was intended.
CAUTION	When you see this symbol, you are being advised that the issue under discussion has a serious safety or equipment reliability implication. Use caution and be conservative. Use equipment in the manner described in this Hardware User's Manual.

Safety is entirely the responsibility of the installer of this equipment. BorgWarner Portland (formerly Cascadia Motion) has done everything it can to ensure that the traction inverter itself conforms to international standards for safety. This does NOT mean that your installation will be safe, or that it will not interfere with other systems on board your vehicle. It is your responsibility as the installer to review this entire Hardware User's Manual, to understand the implications of each and every section, and to know what might be unique about your system application that then presents a unique hazard or potential safety issue – and to solve it.

2 Functional Overview

The CM inverter family is intended as a traction inverter for EV and HEV drive systems, and includes both the motor control function and a rudimentary vehicle controller strategy in the same box. The system uses a torque commanded vector control scheme that has been used on AC Induction and PM Synchronous motors in many applications.

The motor control subsystem software is intended to mate one layer below the vehicle controller firmware. This vehicle controller subsystem handles the driver interface (accel and decel / brake pedal inputs, FWD/REV controls, etc) and the vehicle interface (power sequencing, built in test, fault handling and safety issues). It is essentially a state machine in front of the motor inverter software with a defined interface between the two software processes.

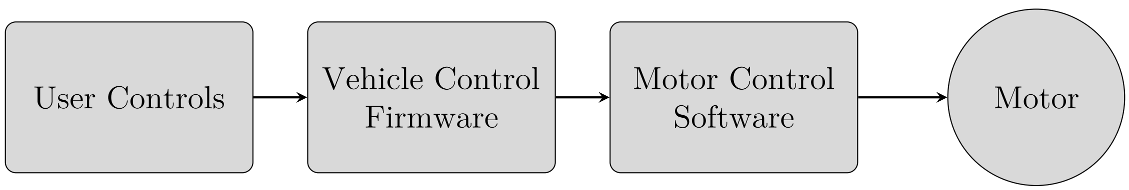


Figure 1: General Architecture of Vehicle Control.

The principle set of parameters used by the inverter to control its operation are are EEPROMs (electrically erasable programmable read-only memory) loaded in the inverters internal memory. By default, integrated modules are set up in Torque Control Mode, with default motor parameters loaded. Inverters purchased standalone (without an attached or accompanying motor) will need configured parameters to match the load motor and operating characteristics before running for the first time. These parameters personalize the drive to the motor and the vehicle.

3 Installing the Inverter

All CM inverters have 4 mounting locations, one at each corner. Mounting orientation is not critical. The inverter should be mounted in a location that is not exposed to direct spray from water. Each mounting hole is sized to handle up to a M10 socket head cap screw. For dimensional drawings refer to the product page on the Cascadia Motion website.

3.1 Liquid Cooling Connections

The inverter must be cooled by passing liquid through it. The inverter includes two ports to be used for liquid cooling. The CM200DX and CM200DZ have a symmetrical design and are less sensitive to fluid direction. The CM350DZ and CM350SiC should have fluid exiting the port nearest the 48 pin low voltage connector. See table below for coolant specifications:

Coolant Type	50/50 mix; ethylene glycol (antifreeze) / water; with Aluminum corrosion inhibitor additive*
	50/50 mix; propylene (antifreeze) / water; with Aluminum corrosion inhibitor additive*
Coolant Temperature	-30°C to +45°C full power, 45°C to +80°C de-rated output -40 to +100°C max survivable range
Flow Rate	12 LPM minimum, CM200DX/DZ
	24 LPM minimum, CM350DZ/SiC
Pressure Drop	CM200DX/DZ, 0.3 bar (4.3 psi) @ 12 LPM @ 25°C
	CM350DZ, 0.16 bar (2.3 psi) @ 24 LPM @ 25°C
	CM350SiC, 0.52 bar (7.6 psi) @ 24 LPM @ 25°C
Port Size	CM200, SAE ORB -06, comes with 5/8" hose barb and -8 AN fitting
	CM350, SAE ORB -10, comes with 5/8" hose barb and -10 AN fitting

* Note: Many modern commercial antifreezes have this included in the formula.

For proper operation of the inverter the coolant must flow at a rate equal to or above the minimum specified flow rate at all times that the inverter is enabled. The flow rate should not be reduced when the inverter is "not being run hard". The design of the heat exchanger does not allow for reduced or no coolant flow. It is possible to adjust the fan speed on the coolant radiator as needed depending on the operating conditions of the inverter.

Since the maximum coolant temperature is less than the boiling point of water the cooling system does not need to be operated under pressure. Other devices (e.g. motor, charger, DC/DC converter) that are added in series with the inverter increase the total pressure drop of the system. Even simple fittings and hose length will contribute to the total system pressure drop. The total system pressure may add up to a level that is beyond the capability of the chosen pump. The best practice is to measure the actual coolant flow after the system has been assembled.

As noted above proper coolant flow is essential to the operation of the inverter. If the flow rate is not sufficient the power module internal to the inverter can be damaged even though the indicated power module temperatures are below an over-temperature threshold. The power module temperature sensors are located in such a way that they are much closer to the temperature of the coolant than they are to the temperature of the transistors and diodes used inside the power module.

Loss of coolant for even a few seconds can result in failure of the power module.

BorgWarner Portland (formerly Cascadia Motion) recommends that the user install a device to ensure that the coolant pump is operating properly at all times when the inverter is enabled. The inverter should be immediately stopped if the coolant is not flowing.

There are many ways that coolant flow could be measured. A flow sensor could be added to the cooling loop. Often these types of sensors produce a pulse output. To read the pulse output would require the use of a device to interpret this signal (BorgWarner Portland does not supply this).

Another option is to monitor the pressure in the cooling system. Typically the inverter would be placed near the end of the cooling loop, just before the radiator. Thus a typical cooling loop application may look like: pump outlet, inverter, radiator/reservoir, pump inlet. Typically the reservoir is at ambient atmospheric pressure. Then the inverter should be at a pressure that is higher than ambient. If a pressure switch is placed at the input coolant port of the inverter it should be able to detect that coolant is flowing.

Various types of coolant pressure switches exist. If a type is used that closes the switch when the pressure is above a certain level is used then this could be inserted in series with the `KL15_EN` line or just connected directly to one of the inputs for monitoring via CAN.

3.2 CM200 and CM350 Signal Connectors

The CM200DX/DZ and CM350DZ/SiC use the same Low Voltage I/O connector and have the same connections. A Molex CMC 48 way connector is used for all low voltage signals. Note, the iM-225/iM-375/iM-425 motor assemblies use variants of the CM200DX/DZ and CM350DZ/SiC that have identical low voltage inverter connections.

Connector Information:

- Mating Housing: Molex 64320-3311
- Strain Relief: Molex 64320-1301
- Contact, CP 0.6, 0.5mm2/20AWG, Wire OD 1.4-1.7mm: Molex 64322-1239

- Contact, CP 0.6, 0.75mm2/18AWG, Wire OD 1.4-1.7mm: Molex 64322-1219
- Contact, CP 1.5, 0.5-1mm2/18AWG, Wire OD 1.4-2.15mm: Molex 64323-1319
- Blind plug, CP 0.6: Molex 643251010
- Blind plug, CP 1.5: Molex 643251023

Please refer to the Molex web site for details on the connector. BorgWarner Portland (formerly Cascadia Motion) highly recommends the use of the factory crimper for the contacts. Note that this connector has two different contacts sizes, A1 thru K4 are the CP 0.6 size, L1 thru M4 are the CP 1.5 size.

I/O Connector - 48 Pin:

Pin Number	Pin Name	Description	Notes
A1	`/SIN`	Resolver Sine winding -	
B1	`SIN`	Resolver Sine winding +	
C1	`/COS`	Resolver Cosine winding -	
D1	`COS`	Resolver Cosine winding +	
E1	`EXC`	Resolver excitation output	
F1	`/EXC`	Resolver excitation return	
G1	`GND`	Resolver Shield Ground	DO NOT connect to 12V system ground or motor case.
H1	`ENC_A`	Encoder Channel A input	Refer to Appendix D for analog encoder and hall sensor options.
J1	`ENC_B`	Encoder Channel B input	Refer to Appendix D for analog encoder and hall sensor options.
K1	`ENC_Z`	Encoder Channel Z input (Index)	Refer to Appendix D for analog encoder and hall sensor options.
L1	`RLY1`	High Side Driver	If pre-charge function is used this output serves as the pre-charge contactor coil driving output
M1	`KL30_BATT`	12V/24V Constant Voltage	Intended for constant 12V power, when in the off state input current is less than 1mA
A2	`CANA_H`	CAN Channel A High	CAN high Port A
B2	`CANA_L`	CAN Channel A Low	CAN low Port A

C2	CANA_T	CAN A Terminator Loop	Short to CANA_L to include a 120 ohm terminator from CANA_H to CANA_L.
D2	CAN_GND	CAN ground	CAN is isolated from GND/KL31. CAN shield should be connected here. DO NOT connect to 12V system ground.
E2	CANB_T	CAN B Terminator Loop	Short to CANB_L to include a 120 ohm terminator from CANB_H to CANB_L.
F2	CANB_H	CAN Channel B High	
G2	CANB_L	CAN Channel B Low	
H2	/PROG	Program Enable	If connected to RS232_GND at power up inverter will go into bootloader mode for use with C2prog software. DO NOT connect to 12V system ground.
J2	EN_PWR	5V power for encoder	
K2	DGND	Digital Ground	Ground return for encoder signals.
L2	RLY2 (Main)	High Side Driver	If the pre-charge function is used this output serves as the main contactor output.
M2	KL15	Switched 12V/24V	Turns on internal power supplies to power up the inverter and start communications.
A3	RTD1P	RTD1 Positive	Allows connection of PT100 or PT1000 RTD for temperature monitoring.
B3	RTD1N	RTD1 Negative	See RTD1P

C3	RTD2P	RTD2 Positive	Allows connection of PT100 or PT1000 RTD for temperature monitoring.
D3	RTD2N	RTD2 Negative	See RTD2P
E3	DIN1	Digital Input 1 - STG	Forward Enable Switch (if used)
F3	DIN2	Digital Input 2 - STG	Reverse Enable Switch (if used)
G3	DIN3	Digital Input 3 - STG	Brake Switch (if used)
H3	DIN4	Digital Input 4 - STG	Digital Input 4 - STG
J3	HVIL_IN	High Voltage Interlock Input	When all high voltage plugs are installed HVIL_IN will be connected to HVIL_OUT.
K3	XDCR_PWR	5V power for transducers	Used with sensors connected to analog inputs.
L3	RLY3	Lo-Side Relay Driver	OK Indicator Drive / 12V Power Relay Coil Drive
M3	KL15_EN	Safety Switched 12V/24V	If voltage is removed then inverter will declare a hardware gate fault, a completely hardware based disable of the PWM from the inverter.
A4	AGND	Analog Ground	For use with analog inputs. DO NOT connect to 12V system ground.
B4	AIN1	Analog Input 1	
C4	AIN2	Analog Input 2	
D4	AIN3	Analog Input 3	
E4	AIN4	Analog Input 4	
F4	RS232_GND	RS232 Ground	Normally connected to pin 5 of DB9 connector. DO NOT connect to 12V system ground.

G4	`RS232_RXD`	RS232 Inverter Receive	Normally connected to pin 3 of DB9 connector.
H4	`RS232_TXD`	RS232 Inverter Transmit	Normally connected to pin 2 of DB9.
J4	`HVIL_OUT`	High Voltage Interlock Output	See `HVIL_IN`
K4	`AGND`	Analog Ground	For use with analog inputs. DO NOT connect to 12V system ground.
L4	`RLY4`	Lo-Side Relay Driver	Fault Indicator Coil Drive
M4	`KL31_GND`	12V/24V System Ground	12V/24V system return.

3.3 External Power Connections

3.3.1 DC+ / DC-:

High Voltage (traction) DC/Battery power is provided to the inverter via two wire ports located either at the rear of the inverter (CM200DX/DZ) or the front (CM350DZ/SiC). The DC power must be run through an external pre-charge circuit to safely charge the capacitors inside the inverter before the main contactor engages (refer to application schematic in figure 4). The main contactor provides a safety disconnect of the DC power in case of a fault condition. Make sure that the wire to the drive is sized properly to handle the current.

DANGER Before changing the wiring make sure that the internal DC bus capacitors are discharged. The voltage should be measured at the terminals before disconnecting. If there is any doubt about the safety wait at least 10 minutes after power has been removed before touching the terminals.

The CM200DX/DZ uses Rosenberger HPK family connectors for making connection to the DC bus input of the inverter. The HPK family is available in various wires sizes between 16mm^2 and 50mm^2.

The CM350DZ/SiC uses Amphenol Powerlock 2 family connectors, which offers wire sizing up to 120mm^2.

BorgWarner Portland (formerly Cascadia Motion) offers 70mm^2 CM350 cables and 50mm^2 CM200 cables most commonly for purchase. Contact PDS PDX sales for information on custom wire sizing.

3.3.2 Phase A/Phase B/Phase C:

Phase A, Phase B, and Phase C are wired to the motor. It is important the 3 wires be wired to the motor such that they give the proper direction of rotation. The motor wires are the most likely to generate EMI and they also carry a higher average current than the DC power wires. When installed in the vehicle these wires should be kept as short as possible, and shielded wire is required. This can be done by adding a copper braid over the wires, or using wire that includes a shield.

The CM200DX/DZ uses Rosenberger HPK connectors for the AC connections. The CM350DZ/SiC uses Amphenol Powerlock 2 family connectors. Again, the cables must use shielded wire. The shield is connected to the chassis of the inverter and the chassis of the motor.

3.3.3 Pre-Charge Circuit:

An external pre-charge circuit must be used with the inverter. The circuit limits peak inrush current into the inverter when the main contactor is engaged. The pre-charge circuit adds a resistor, relay, and fuse in parallel with the main contactor. When the inverter is powered on the inverter will first engage the pre-charge relay to charge the capacitors internal to the inverter. If the capacitors charge properly then the main contactor can be engaged.

The pre-charge resistor should be sized to rapidly charge the capacitor, but not dissipate too much power in a fault condition. The pre-charge resistor should be sized so that if the inverter had a short on its input the pre-charge resistor would not fail. If using the built in pre-charge functionality, the pre-charge relay will only remain closed for about 3 seconds. The pre-charge sequence must complete before this time or the inverter will declare a fault condition and open the pre-charge relay. The pre-charge circuit should be fused with a small fuse appropriate to the wire used. Since the pre-charge current is generally very low, approximately 0.5 amps in the example below, small wire can be used (recommend 18 AWG). A 5 amp fuse would be appropriate for this wire. Note, the inverter can be used bypassing the pre-charge functionality built into the inverter software, in this case the user is responsible to complete the necessary pre-charge and monitor voltage accordingly.

Sizing Example:

A typical application of the CM200DX could have a maximum DC bus voltage of 320 volts. If a 600 ohm resistor were chosen this would result in a power dissipation of 171 watts. This is typically within the short term rating of a 50 watt wire-wound resistor. However make sure to consult the resistor manufacture data to ensure a sufficient surge tolerance. The internal capacitance of the inverter is approximately 650uF. It takes approximately 3 time constants before the inverter will close the main contactor, thus in this example it will take 1.17 seconds for the pre-charge to complete.

BorgWarner Portland (formerly Cascadia Motion) can provide the following parts if needed. Reference the following:

DX Inverters

- Pre-charge Relay (30A, 12V COIL): p/n 77-0026
- Pre-charge Resistor (600 ohm 50W): p/n 53-0006
- Pre-charge Fuse (5A 500V): p/n G1-0013-01

DZ Inverters

- Pre-charge Relay (50A/1000V, 12V COIL): p/n 77-0034
- Pre-charge Resistor (1K ohm 100W): p/n 53-0008
- Pre-charge Fuse (5A 1000V): p/n G1-0015-01

Model	Internal Capacitance	Maximum Pre-charge Resistor	BorgWarner Portland Part Number
CM200DX	650uF	600 ohms	53-0006
CM200DZ	255uF	2000 ohms	53-0008
CM350DZ	510uF	1000 ohms	53-0008
CM350SiC	700uF	1000 ohms	53-0008

3.3.4 Main Contactor:

The main contactor is the switching element between the DC high-voltage power source (typically a battery) and the inverter. The main contactor must be sized to handle the operating currents of the inverter. In addition the main contactor must be able to open under a fault condition. Generally only one contactor is needed, the application schematic shows the main contactor in series with the positive path from the battery to the inverter. BorgWarner Portland (formerly Cascadia Motion) has successfully used the following: Gigavac GX14BA, p/n 77-0035. The contactor must be rated to handle DC voltage, AC only rated contactors and relays must not be used. DC rated contactors are usually polarity sensitive. That is, the normal operating current should flow in a particular direction. Refer to the contactor data sheet for more information.

3.3.5 Main Fuse:

The DC Power input to the inverter must be fused. The fuse must be rated for the voltage of the battery as well as rated to open under the short circuit current that the battery can produce. Generally, this fuse (or equivalent fusible link) may be a part of the battery pack, but if the pack protection is not present or adequate, this fuse is required to prevent a potential battery pack fire. The fuse should be rated to handle the maximum DC input current of the inverter. A semiconductor type fuse is recommended.

3.3.6 Passive Discharge of High Voltage DC Bus:

As noted above, the inverter contains a large amount of DC bus capacitance. This capacitance will store energy long after the high voltage has been removed from the unit. If other provisions have not been made for discharging these capacitors then the unit wiring should not be touched for at least 10 minutes after the high voltage has been removed from it. The voltage will slowly decay due to internal resistors inside the unit. The resistor values are shown in the table below:

Model	Passive discharge Resistance	DC Link Capacitance	Three time Constants	Y-Capacitance
CM200DX	70K ohms	650uF	137 s	136nF
CM200DZ	70K ohms	255uF	54 s	136nF
CM350DZ	60K ohms	510uF	92 s	188nF
CM350SiC	167K ohms	700uF	120 s	282nF

For reference the value of three time constants is shown. This time would dissipate the voltage to less than 5% of the original value. Three time constants would allow the voltage to decay to a value that is normally safe to touch. However, the capacitors will still have some energy stored in them.

The passive resistance value shown in the table in connected to the high voltage DC bus at all times. The inverter will draw a corresponding amount of current from the high voltage at all times. For example if a CM200DX is being used at 320V it would draw 320/70K = 4.6mA even when the inverter is disabled. If it is desired to have the DC bus voltage discharge faster the user must either provide an external method of discharge, or consider the use of the Active Discharge feature of the inverter. Consultant the CM Software Users Manual for more information on Active Discharge.

The above table also shows the Y-Capacitance value for the inverter. The Y-Capacitance is the total amount of capacitance connected between the DC bus and the chassis of the inverter. Half of the shown amount is connected to each side of the DC bus (DC Bus Positive / DC Bus negative).

3.3.7 12/24V Power:

The inverter requires a source of 12V or 24V power to operate. The inverter will turn on and communicate without high voltage present. This allows setup of parameters without high voltage.

The CM200DX/DZ and CM350DZ/SiC all require a permanent low voltage connection and a switched low voltage connection. Refer to Figure 2 for more details.

The CM200DX/DZ and CM350DZ/SiC allow for operation from both 12V and 24V systems.

CM200DX @ 12 kHz	12V, non-operating	0.6 A
	12V, operating	1.0 A
	24V, non-operating	0.3 A
	24V, operating	0.5 A
	KL30 input current with KL15 off	< 1 mA
CM200DZ @ 12 kHz	12V, non-operating	0.6 A
	12V, operating	1.2 A
	24V, non-operating	0.3 A
	24V, operating	0.6 A
	KL30 input current with KL15 off	< 1 mA
CM350DZ @ 12 kHz	12V, non-operating	1.2 A
	12V, operating	1.8 A
	24V, non-operating	0.6 A
	24V, operating	0.9 A
	KL30 input current with KL15 off	< 1 mA
CM350SiC @ 12 kHz	12V, non-operating	0.6 A
	12V, operating	1.1 A
	24V, non-operating	0.3 A
	24V, operating	0.6 A
	KL30 input current with KL15 off	< 1 mA

These currents do not include any high-side or low-side drivers:

- Any hi-side driver output currents, including the main and pre-charge contactor relay drive currents, will come through the BATT+ pins and will add to the above currents.
- Any low-side driver output currents, including indicator lamp current, will come through the GND pins, and should be considered in sizing this connection.

3.3.8 Grounding:

The inverter housing has a dedicated threaded hole for connecting the case to ground. The inverter housing must be connected to the motor case. It must also be connected to the vehicle chassis and this assumes that the vehicle chassis is at the same potential as the 12V GND. The inverter housing should not be allowed to be more than a few volts above the 12V GND. If the inverter housing is isolated from the rest of the system hazardous voltages could develop on the housing.

4 Typical Application Wiring

4.1 Inverter LV Power Wiring:

The CM drives require a permanent battery tie on `KL30_BATT` for proper operation. This channel draws <1mA and ensures proper device start-up and shutdown sequencing. For vehicle applications it will be desired to control each of the other 12V tied signals (`KL15` and `KL15_EN`) independently as they each have a unique functionality. The ideal wiring is presented in the Figure below.

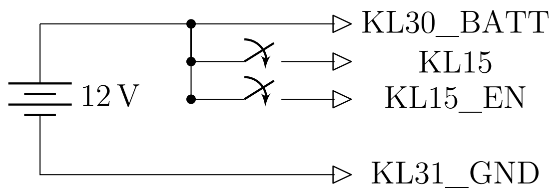


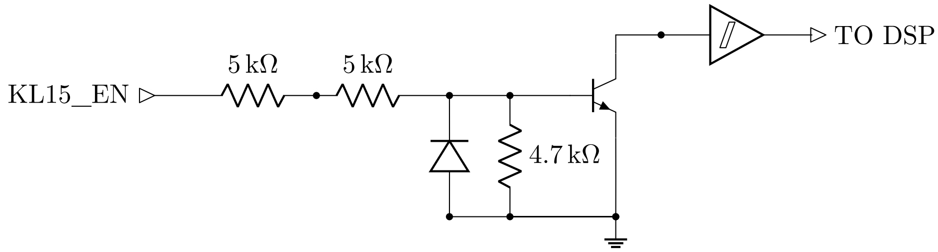
Figure 2: Vehicle Application for 12V Wiring

Each of the different KL inputs play a different role in startup and error communication. The functionality is described below in more detail.

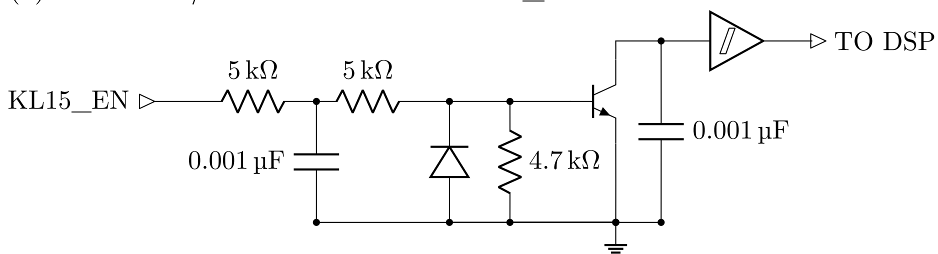
Pin Number	Pin Name	Usage
M1	KL30_BATT	Permanently tied to the battery + and draws <1mA of current. Used to keep low voltage live for proper inverter enable and disable sequence.
M2	KL15	The switched 12/24V used to turn on internal communications and wake the inverter for communication.
M3	KL15_EN	The safety pin to allow a completely hardware based disable of the PWM.The inverter will throw a constant fault and the inverter output will be disabled if this pin is open circuited. It needs to be tied to 12/24V to enable the drive.
M4	KL31_GND	The 12/24V ground return that should be connected permanently.

Note: `KL30_BATT`, `KL15`, and `KL15_EN` all have pull-downs applied internally in the inverter.

The CM200DX/DZ and CM350DZ vs the CM350SiC have slightly different internal applications of `KL15_EN` presented below which impacts noise tolerance.



(a) CM200DX/DZ and CM350DZ KL15_EN Circuit



(b) CM350SiC KL15_EN Circuit

Figure 3: KL15_EN Schematics for CM Inverters

Note: The CM350SiC has added capacitors for better noise rejection compared to the CM200DX/DZ and CM350DZ.

4.2 Pre-charge Circuit Wiring:

The pre-charge circuit can be handled by the CM inverter or externally. The inverter relay connections are not required unless the drive is configured to manage pre-charge.

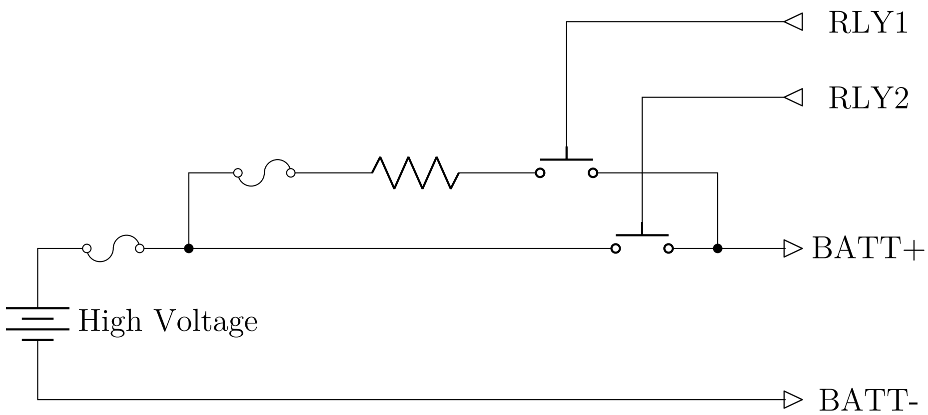


Figure 4: Pre-charge Circuit Wiring

Generally the contactor with the resistor in series is a high voltage rated relay (such as Sensata Gigavac P105 series) and the contactor connecting directly to the high current fuse is a high current, high voltage contactor such as the Sensata Gigavac GX16 series contactor. It is also generally a good idea to have pre-charge coming after the main fuse, in case main fuse blows pre-charge will be disabled.

4.3 Typical Motor Wiring:

See Appendix B for a more detailed connection schematic.

4.4 CAN Interface:

The inverters have one active CAN interface (CAN A). The inverter contains hardware to support a second CAN interface (CAN B), but currently only CAN A is active. CAN B is reserved for future use. Refer to the CAN Protocol documentation in the CM Software Users Manual for the various ways that the CAN bus can be configured.

The CAN interface has multiple purposes:

- Provides direct control of the motor.
- Provides diagnostic and monitoring capabilities.
- Provides user-adjustable configuration.

The user can change the following hardware related configuration parameters:

- Inverter Command Mode: Setting this parameter to 1 allows the CAN mode to become active.
- CAN Bus Speed: Allowed speeds are 125 Kbps, 250 Kbps, 500 Kbps, or 1 Mbps. Enter 125, 250, 500, or 1000 to program the configuration parameter.
- CAN Terminator Resistor: The resistor can be applied or opened.

For more information on CAN interface and messages, please refer to the CAN Protocol documentation in the CM Software Users Manual.

4.5 RS-232 Interface:

There is one RS-232 serial interface. This port can be used to set up and tune the inverter, and to download inverter software updates from a PC. With the RMS GUI this provides a simple Windows PC based software package for monitoring and changing parameters.

By default the inverter will broadcast data as defined in the defsym files provided with the inverter software. The data is broadcast at a rate of 3 Hz and can be used to monitor performance and energy consumption data in real time.

For more information on RS232 data logging refer to the CM Software Users Manual.

It is recommended to use an FTDI adapter for best results:

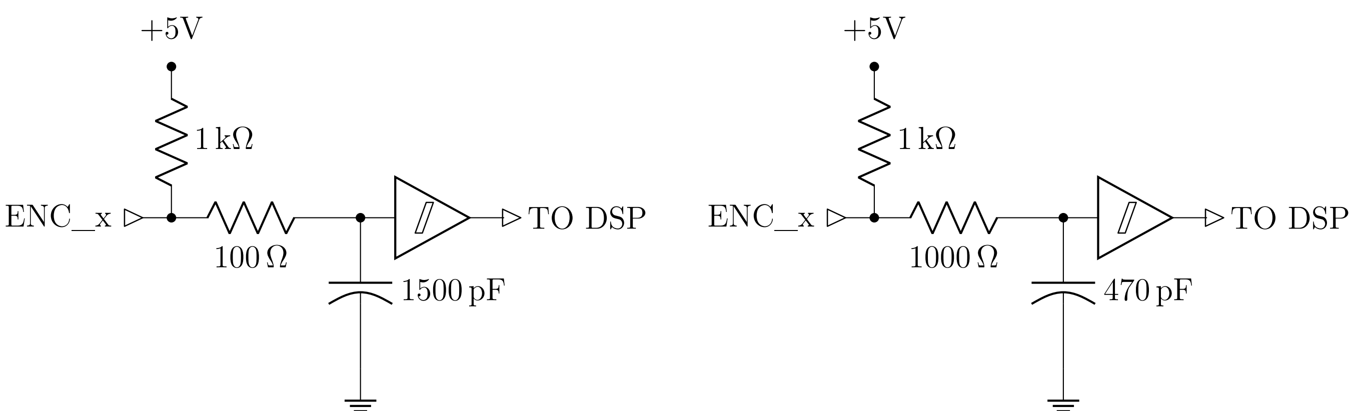
US232R from FTDI:
`https://ftdichip.com/product-category/products/cables/`

It is highly recommended to use a galvanically isolated RS232 adapter like this one from Startech:
`https://www.startech.com/en-us/cards-adapters/icusb2321fis`

4.6 Encoder Interface:

The CM inverters offer encoder support for motors equipped with a positional encoder. Specifically the CM350SiC, CM350DZ, and CM200DX/DZ offer support for both digital and analog encoders. At this phase all standard CM motor offerings use a resolver, and thus this is only for custom motors outside of the CM catalog.

For a digital encoder, the inverter provides a 5V interface to power the external encoder then receives, level translates, and filters the signals from A, B and INDEX channels.* For induction motor applications the INDEX channel is not used, but it may be wired. The encoder is connected internally to the TI DSP QEP Module (Quadrature Encoder Peripheral), which has special hardware for wide dynamic range speed and angle calculation from the encoder data. The drive has internal pull-up resistors on these inputs, and works with encoders that have either bi-polar or open-collector outputs.



(a) CM200DX/DZ and CM350DZ Digital Encoder

(b) CM350SiC Digital Encoder

Figure 5: Digital Encoder Schematics

*Note: An INDEX channel is not provided for the CM350SiC.

There are options for analog encoder inputs and hall inputs for all CM inverters. Refer to Appendix D for more info.

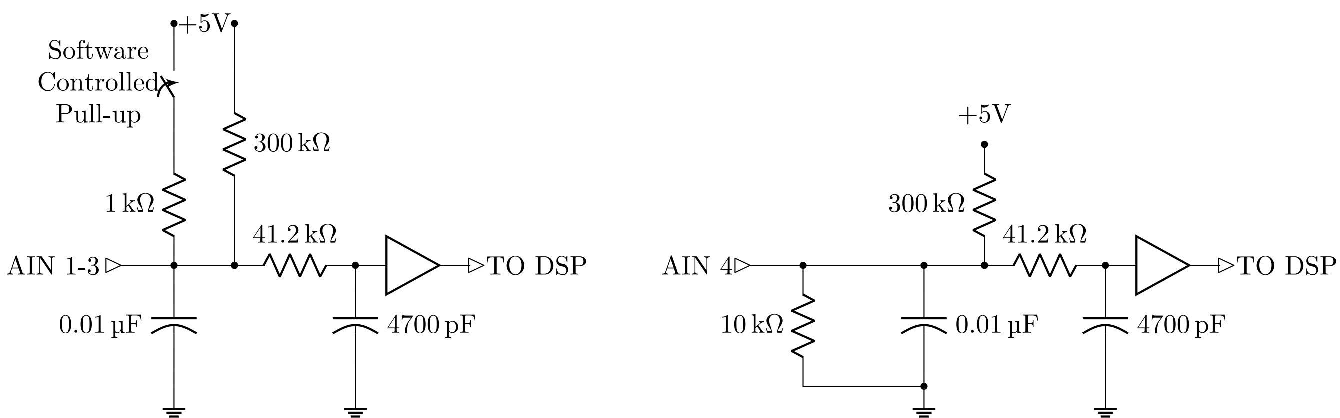
4.7 Resolver Interface:

A resolver is a position sensor that is often used with Permanent Magnet type motors. There are various types of resolvers. The resolver requires an excitation voltage and provides a SIN and COS feedback.

The CM inverters use a dedicated Resolver to Digital Converter (RDC) with predefined 10kHz excitation frequency that is not synchronized with the PWM frequency. For CM inverters the target SIN/COS voltage is dependent on how the RDC is configured. For all catalog BorgWarner Portland (formerly Cascadia Motion) configurations (i.e. iM-225DX-D, iM425SiC-D, etc) this is pre-configured by default and will not need user adjustment. For custom motors, contact BorgWarner Portland for more information.

4.8 Analog Inputs:

The CM Inverters have 4 analog inputs. The inputs are intended for general analog signal sensing (0 – 5V). There are also 2 RTD inputs, selectable as PT 100 or PT1000 by software. The CM inverters provide programmable **pull-up** resistors (1K) on `AIN1`, `AIN2`, and `AIN3`. These pull-ups can be turned on and off via software. This is shown in the Figure below.



(a) Analog Input Schematic with Programmable Pull-up. (b) Analog Input Schematic with Fixed Pull-down.

Figure 6: Analog Input Schematics

The inverter software assigns the analog inputs based on the motor type. See Appendix A, for more details.

A 5V power supply (`XDCR_PWR`) is provided for powering sensors or potentiometers. The total supply current available from this supply is limited to 100mA.

The analog signals should be referenced to one of the analog ground (`AGND`) pins available on A4 or K4. This will reduce noise. Analog ground should NOT be connected to GND or the vehicle chassis.

Description	Parameter	Value
Analog Inputs		
Input Range	V_{range}	0 - 5.00 V
Offset Voltage	V_{ofs}	+50mV
Gain Accuracy	G	+5%
ADC Resolution		12b
RTD Inputs - PT 1000 type		1000 Ω / 0°C
Offset - 25°C		± 3°C
Temperature error - additional error over temperature		± 3°C
RTD Inputs - PT 100 type		100 Ω / 0°C
Offset - 25°C		± 3°C
Temperature error - additional error over temperature		± 3°C

The inverter provides two differential inputs for RTDs. RTD1 should be connected to `RTD1N` and `RTD1P`, RTD2 should be connected to `RTD2N` and `RTD2P`. Do not tie the RTD lines to GND or AGND.

4.9 Digital Inputs

There are 4 Switch to Ground (STG) digital inputs for general interface to the vehicle and for feedback from external contactors and switchgear as required in the application. These STG inputs are designed to be used in an application that switches the input to ground.

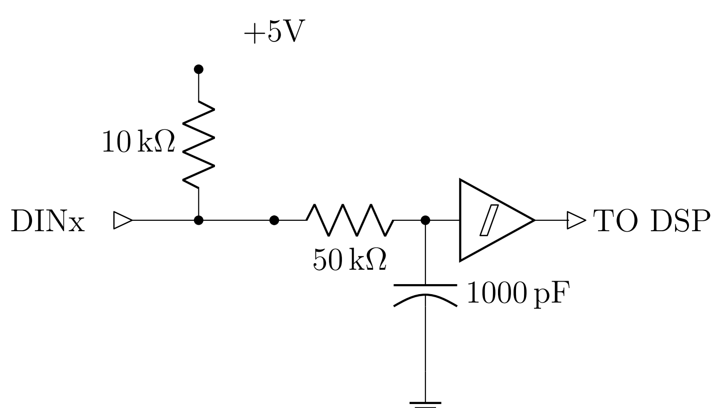


Figure 7: Switch to Ground Schematic

The vehicle control system assigns the digital inputs as follows. Note: These are only active in VSM Mode.

Input	Type	Signal Name	Function
DIN1	STG	FWD_ENA	This input should be connected to a switch that grounds this input when the user is commanding forward direction.
DIN2	STG	REV_ENA	This input should be connected to a switch that grounds this input when the user is commanding reverse direction.
DIN3	STG	BRAKE	This input should be connected to a switch that grounds the input when the brake is pressed.
DIN4	STG	REGEN Disable	This input should be connected to a switch that grounds the input to enable this feature (that is, disable REGEN).

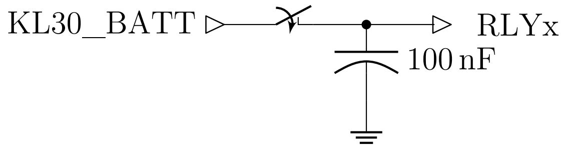
The electrical parameters of the digital inputs are shown in the table below.

Description	Parameter	Value
Voltage level for ON	$V_{STG\text{-}ON}$	<0.9 V
Voltage level for OFF	$V_{STG\text{-}OFF}$	>4.2 V
Pull-up resistor to 5V	$R_{STG\text{-}PU}$	2.4 kΩ
Maximum Voltage on Input	$R_{STG\text{-}MAX}$	18 V

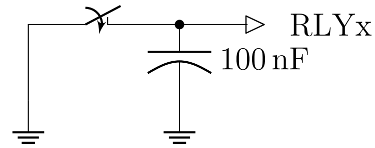
Note: Digital inputs are equipped with some hysteresis to ensure a steady signal.

4.10 Digital Outputs:

There are 4 digital outputs available. These outputs are classified as High-Side Drivers (HSD), and Low-Side Drivers (LSD). The schematics are provided below:



(a) High Side Driver



(b) Low Side Driver

Figure 8: Digital Outputs

The vehicle control system assigns the outputs as follows:

Output Name	Type	Function Name	Function
RLY1	HSD	PRE-CHARGE DRIVE	This output provides power to the pre-charge relay.
RLY2	HSD	MAIN DRIVE	This output provides power to the main contactor.
RLY3	LSD	OK INDICATOR	This output provides a grounded signal to the OK indicator. The indicator turns on when power is applied to the drive and the drive has completed the pre-charge sequence. If used, this output is also used to power the external 12V power relay.
RLY4	LSD	FAULT INDICATOR	This output provides a grounded signal to a fault indicator. The indicator will blink a fault code if the drive has detected a fault.

The electrical parameters of the digital outputs are shown in the table below.

Description	Parameter	Value
Hi-Side Drivers (RLY1-2)		
Output Current - Continuous	$I_{CONT\text{-}HSD}$	1 A
Output Current - Surge	$I_{PK\text{-}HSD}$	5 A
Lo-Side Drivers (RLY3-4)		
Output Current - Continuous	$I_{CONT\text{-}LSD}$	-1 A
Output Current - Surge	$I_{PK\text{-}LSD}$	-5 A

Remember the voltage output of these drivers are limited to `KL30_BATT` voltage and 0.

5 Quick Start Guide

This section will detail the bare minimum to begin communication with a CM inverter as a starting point. The implementation in this setup will likely be insufficient for robust applications and all other previous sections need be considered for proper end goal implementation of the drive.

5.1 Setup Steps with Low Voltage

5.1.1 Download all Relevant Software Tools

The first step is to make a relevant directory on a PC that will be used to control and interact with the CM inverter. It is recommended to make a folder on the C: drive for BW_Software. The latest firmware package can be downloaded from the Cascadia Motion website. All firmware packages should be saved under the BW_Software location and saved in their separate folders to aid in debugging. For example standard GEN5 firmware would be saved in a file path as such: C:\BW_Software\GEN5_CC_CM_DateCode_65XX. Where the 'XX' will be replaced by a specific number that is updated as new Gen5 firmware versions are released.

Additionally you will need the following software applications in order to program the inverter (if necessary) and use the RMS GUI for serial communication:

- **gtk+-2.8.9-setup-1.exe:** This is a one-time installed library file. The computer must be rebooted after the installation.
- **C2Prog:** This is a flash programming tool specifically designed for TI C2000™ MCUs using RS-232.

Both of these items can be found on the Cascadia Motion website, and further details can be found in the CM Software Users Manual.

5.1.2 Simple Communication and Programming Wiring

The first step to interacting and working with the CM drive will be to provide LV power and connect the serial RS-232 and/or CAN to open communication with the drive.

The simplest form of LV wiring will be to connect inverter pins `KL30_BATT`, `KL15`, `KL15_EN` together and apply +12/24V and connect `KL31_GND` to -12/24V. This will power the inverter in the simplest terms for initial communication. Further details on LV power can be found in this manual in subsection 4.1.

Communication with the Serial RS-232 will require connection of the following pins to a DB9 for communication with a standard RS-232 device:

Inverter Pin Number	Pin Name	DB9 Pin
F4	`RS232_GND`	5
H2	`/PROG`	5
G4	`RS232_RXD`	3
H4	`RS232_TXD`	2

To enter programming mode to flash new firmware to the drive, the drive must be placed in programming mode. This is done by connecting pin H2 to `RS232_GND` on power up. Applying or removing short to ground after power up will have no effect and the drive will stay in whatever mode it was in at power up. Detailed steps to program the inverter will be discussed later in 5.1.6. Programming of the inverter is not required to begin communication with the unit.

A full wiring diagram of this can be found in Appendix B.

5.1.3 Using the RMS GUI

RMS GUI is a Windows application developed by BorgWarner Portland (formerly 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 what motor is connected and other customer system parameters. EEPROM parameters must be programmed correctly before the controller is operated. This is discussed in further detail in the CM Software Users Manual.

For the purposes of getting started apply the following steps to access the GUI and communicate with the drive.

1. Apply 12/24V power to the drive via the wiring discussed in section 5.1.2.
2. Open the GUI from the directory of the relevant firmware created in section 5.1.1.

Its not unlikely there may be some form of error the first time communicating with drive. The following troubleshooting items address the most common issues generally seen.

- Ensure the wiring is correct for power and the serial RS-232. Confirm the drive is not in programming mode, and that there is current draw into the drive. **This is the most common cause of communication issues. It can be difficult to identify wiring harness issues, so it is important to follow best practices when assembling the harness.**
- If the GUI opens but presents the fault stating 'Error Locating/Loading the default symbols file' it is likely the firmware on the drive is different than the firmware in your current directory.
  - Option 1: The top of the GUI should state a 'Date Code' for the firmware loaded on the drive. Go the Cascadia Motion website and find the same corresponding archived firmware release and place that firmware package in the same parent directory as suggested in5.1.1 then open the GUI from that release package.
  - Option 2: Move forward to section 5.1.6 and program the inverter with the latest firmware from the Cascadia Motion website. It is recommended only to do this after communication has been made with the drive or at the recommendation of BorgWarner Portland.

There may be some faults active in the drive at this stage given lack of motor or HV wiring. However being able to view these faults via the button in the top right of the Memory View, means serial communication is open! With the GUI open and talking it is now possible to view common system parameters which are sent via serial. For example, the inverter module temperature can be viewed by selecting Mod_A_Temp_(C)(x10) in the Symbols List of the Memory View and selecting the Add button in the middle. The parameter and corresponding value will then populate in the Watch List. If the value appears unusually static or as a set of ????, select the box in Continuous Refresh to configure the RMS GUI to constantly reload this value as its reported from the inverter.

5.1.4 Saving EEPROMs

As discussed in the CM Software Users Manual, the RMS GUI has multiple capabilities around loading and saving EEPROM values which define how the drive operates. It is highly recommended to save the factory EEPROMs loaded on the unit before modifying any EEPROMs for custom applications. This can be done in the EEPROM View tab. In this tab, selecting Save to File, and giving an appropriate name such as 'Default_EEPROMs_CurrentDate' will save the factory EEPROMs that can be restored later if necessary. This step is not necessary to operate the drive but will significantly improve any debug activity later.

5.1.5 CAN Communication and Commands

The principal means of communication with CM Drives is via CAN. In typical applications this is controlled via a VCU. At the initial phase of prototyping this may not be available yet. Thus a separate CAN tool will likely be useful. BorgWarner Portland (formerly Cascadia Motion) recommends the use of a Kvaser Leaf Light v2 as a simple means of USB-to-CAN interface to talk to the drive straight from a PC. This is not the only tool which accomplishes this task, but is one that is the most readily available with free software from Kvaser.

Communication via CAN will also require wiring the CAN communication pins correctly. Namely:

Pin Number	Pin Name	DB9 Pin
A2	`CANA_H`	7
B2	`CANA_L`	2
D2	`CAN_GND`	3
C2	`CANA_T`	2

Note that every CAN bus needs a 120 ohm terminator on each end, i.e. two total. Connection of C2 to A2 applies one internally via the drive.

The first step is to connect to the CAN Bus, if using the Kvaser Leaf Light v2 this is done via the free Kvaser CanKing software. You will need to confirm/do the following:

1. Confirm the CAN device is registering to the computer and in the CanKing Software the CAN Channel is set to the device (not the Virtual Driver).
2. Confirm the Bus speed matches that of the drive. BorgWarner Portland drives have an EEPROM selectable CAN bit rate. The BorgWarner Portland default is generally 250 kbits/s. This can be confirmed on the RMS GUI via the EEPROM CAN_Bit_Rate_EEPROM_(kbps). For starters, if this is not already set to a value of 250, do so now.
3. Apply 12/24V to the inverter LV.
4. If using the CANKing software select Go On Bus to connect. The bus statistics should increase to some nominal travel between 10 and 30%, and the On Bus light at the bottom should turn green. If only only Error Frames are being read, confirm the Bus Speed and the presence of two terminating

resistors and attempt to connect again. If issue still persist refer to the CAN communication section of the CM Software Users Manual.

At this phase, when connected to the bus, its now possible to send a command to the drive. The command message of all BorgWarner Portland drives is message 192. To send a CAN command complete the following steps:

1. Apply 12/24V, if not already doing so.
2. Connect the bus following the steps above.
3. In the CANKing software select Messages then Universal to open the command message window.
   - Set CAN Identifier to 192, this is the command CAN message in BorgWarner Portland drives
   - Set the DLC to 8, this sets CANKing to send an 8 Byte CAN message
4. In the Output window of CANKing right click and select Fixed Positions, this will allow you to see the repeating messages and any added messages without the scrolling.
5. Select Send, you should then see the message 192 populate in the Output Window.
   - Note that you must always send a Byte 5 of 0 after power cycle to wake CAN before the BorgWarner Portland drive will accept any additional CAN command.

At this phase its been confirmed that communication via CAN has been established with the drive. At this phase it is assumed that there is not a complete wire harness present and thus Faults exist on the drive for the related disconnection of the motor temperature, bus voltage, and resolver/encoder. In later section of this Quick Start Guide a real command will be sent to enable the drive and spin the motor.

5.1.6 Test Programming the Inverter

An important step early on is to confirm the program mode wiring is also correct. This can be accomplished by simply reprogramming the drive with the same firmware that it already has loaded. The process of programming via C2Prog is discussed in further detail in the CM Software Users Manual, but a quick guide is presented here to expedite the startup process.

The firmware files are the .hex files present in the firmware release package. Generally there are two .hex files for Group_1 and Group_2. These two firmware files contain the exact same functional code. The difference is what motors each group supports, i.e. which control tables and motor configuration parameters like resolver or motor temperature settings are present in the stored memory of each file. Before reprogramming the drive its important ot confirm which group is currently loaded. This can be done by viewing the Group_Number in the Memory View tab.

To program the inverter, follow these steps, and refer the CM Software Users Manual for failure of any step. **Note:** It is very important to have stable LV power though the entire programming operation.

1. Remove 12/24V power from the inverter.
2. Connect H2 to `RS232_GND`.
3. Apply 12/24V power to the inverter.
4. Open C2Prog.

5. For the Firmware Image, navigate to your firmware directory and select the .hex file for the appropriate group number.
6. For CM inverters, change the Target to: 28379,378,377,375D-CPU1, and SCI.
7. Select the Port for which the RS-232 line is connected to the PC. If unknown, it is possible to guess and check by attempting to program multiple times each with a different Port selected.
8. Select Program.

If the progress bar at the bottom of the new pop up screen progresses it means the selections are correct and programming has begun. If it does not it possible the drive is not in programming mode or C2Prog the wrong configuration settings/Port. For a more detailed process refer to the CM Software Users Manual.

After programming is complete, its also important to confirm the drive is still communicating via Serial. To do follow the steps above partially reverse order.

1. Remove 12/24V power from the inverter.
2. Disconnect H2 to `RS232_GND`.
3. Apply 12/24V power to the inverter.
4. Open the RMS GUI.
5. Select a module temperature from the Symbol List and confirm its still reporting.

This concludes all start-up steps that can be accomplished with just low voltage. The next section will cover steps for spinning the system with voltage applied. Past this point caution must be taken for safety around high voltage and a spinning motor.

5.2 Setup Steps with High Voltage

With Low Voltage communication working, the next step is application of high voltage via the DC connectors and cooling. It is important to be confident in the drive communication, discussed in the previous section, and target application of the drive before applying high voltage. This section will primarily focus on spinning of an integrated BorgWarner Portland (formerly Cascadia Motion) unit in speed mode unloaded. This is likely not the final target configuration for the drive, but offers a safer starting platform to spin the unit to confirm wiring.

5.2.1 Full Application Wiring/Connection

Full details for HV, LV, and cooling connections can be found in the earlier sections of this manual. The summarized steps with relevant sections are:

1. Connect cooling. The inverter CANNOT be enabled for any significant load with active cooling. Connecting and flowing the coolant before any HV connections are present is generally a good idea incase of unexpected leaks. Section 3.1 details the cooling connections for the drive and motor.
2. Connect HV cables. In the case of an integrated unit this will just be the DC cables. Regardless, its best to connect these without HV live if possible. Section 3.3.1 and 3.3.2 details those connectors.

3. Connect the wire harness. At this phase a more complete wire harness will be required given the application of voltage. Application wiring is detailed in Section 4. An example full wiring schematic is also presented in Appendix B.

With the above three items connected, but before application of HV, move to the next section to confirm the relevant EEPROM settings for a free spin test.

5.2.2 Free Spinning in Speed Mode

All integrated units directly from BorgWarner Portland (formerly Cascadia Motion) ship in torque mode with a calibrated resolver. If attempting to run a standalone inverter without a paired BorgWarner Portland motor you will need to perform a resolver calibration, which also involves spinning the motor but with a different goal, refer to the CM Software Users Manual to perform this calibration.

Starting with an integrated unit confirm/perform the following steps prepare to send a spin command:

1. In the RMS GUI EEPROM View select Save to File to save the default stock EEPROMs (if not already performed in Section 5.1.4)
2. Confirm the following EEPROMs:
   - Gamma_Adjust_EEPROM_(Deg)_x_10 is non zero
   - Angle_Advance_Factor_EEPROM_x_100 is non zero
   - DC_UnderVolt_Thresh_EEPROM_(V)_x_10 is above the HV that will be connected
3. Change the following EEPROMs:
   - Run_Mode_EEPROM(Trq=0_Spd=1) = 1, this puts the drive in speed mode where the command will be a speed and an internal torque regulator will run to attain that speed.
   - Motor_Overspeed_EEPROM_(RPM) = 1000, for this initial spin test we will only spin slowly and this EEPROM will cause the drive to fault if it gets out of control and begins to run away.
   - Max_Speed_EEPROM_(RPM) = 500, this will limit the max receivable speed command ot be 500 [rpm] so errors in commands are avoided.
   - Motor_Torque_Limit_EEPROM_(Nm)_x_10 = 500, this will limit the torque application to a max of 50 [Nm], free spinning should take much less than this but ensures no excessive torque is commanded if an error is present.
   - Regen_Torque_Limit_EEPROM_(Nm)_x_10 = 500, this will limit the torque application to a max of -50 [Nm], free spinning should take much less than this but ensures no excessive torque is commanded if an error is present.
4. Select Program EEPROM Values and power cycle the LV to the inverter.

The drive should now be configured to spin for the first time in a controlled speed mode! Past this phase HV will be applied and the shaft may spin, thus confirm the following safety items before proceeding.

1. High voltage safety is being practiced and all high voltage terminals outside the inverter are isolated. It is the users responsibility to ensure HV safety and training standards are met.
2. The motor shaft is unobstructed. The speed regulator will apply the torque necessary to meet the speed command. Meaning if something is coupled to the shaft it will apply increased torque.

3. The motor is secured/bolted down. If any fault occurs that stops the rotor abruptly, the angular momentum can cause the motor to jump.
4. The application of HV to the system will require some form of pre-charge. Without accounting for an externally applied pre-charge, connecting the inverter directly to HV will cause excessive currents as the capacitors charge resulting in arcing or contactor welding. Refer to section 4.2 for further details on wiring a pre-charge circuit.

To spin the motor follow these steps:

1. Apply HV to the drive DC terminals **accounting for pre-charge**.
   - You can confirm the drive is seeing HV via the GUI parameter: V_DC_Filtered_(Volts)(x10)
2. Send all zeros to wake the CAN, Message 192: 0 0 0 0 0 0 0 0
   - You should see the zeros command on the Output Window of CANKing
3. Enable the drive to confirm its fault free but with no speed command (Byte 5 = 1), Message 192: 0 0 0 0 0 1 0 0
   - You can confirm the drive is enabled if no faults are present and the EEPROM Inverter_Enable = 1
   - If the drive does not enable, check for faults, confirm CAN communication is live, and/or send the all zeros command again.
4. Send a speed command of 500 [rpm], Bytes 2 and 3 control the speed command in a low and high bit configuration of 255, Message 192: 0 0 244 1 0 1 0 0
   - The shaft should now be spinning!
   - The lower and upper bit structures works as such. The upper Byte (3) is multiples of 255 and the lower Byte (2) is directly speed. i.e. 500 rpm = 1*256 + 244
5. Send a speed command of 0 [rpm], Message 192: 0 0 0 0 0 1 0 0
   - It is always recommended to keep the drive enabled until the motor speed reaches zero. This ensures the drive can actively control any high BEMF that may be present at higher speeds.
6. Disable the drive, Message 192: 0 0 0 0 0 0 0 0

You have now confirmed the drive can spin, and you have the rudimentary framework for communicating and controlling the system. The speed limits can now be increased to test higher free spin speed or you can reload the default EEPROMs (either manually or via the Load EEPROMs button) to bring the drive back to its factory default in Torque mode. Past his point, happy application testing!

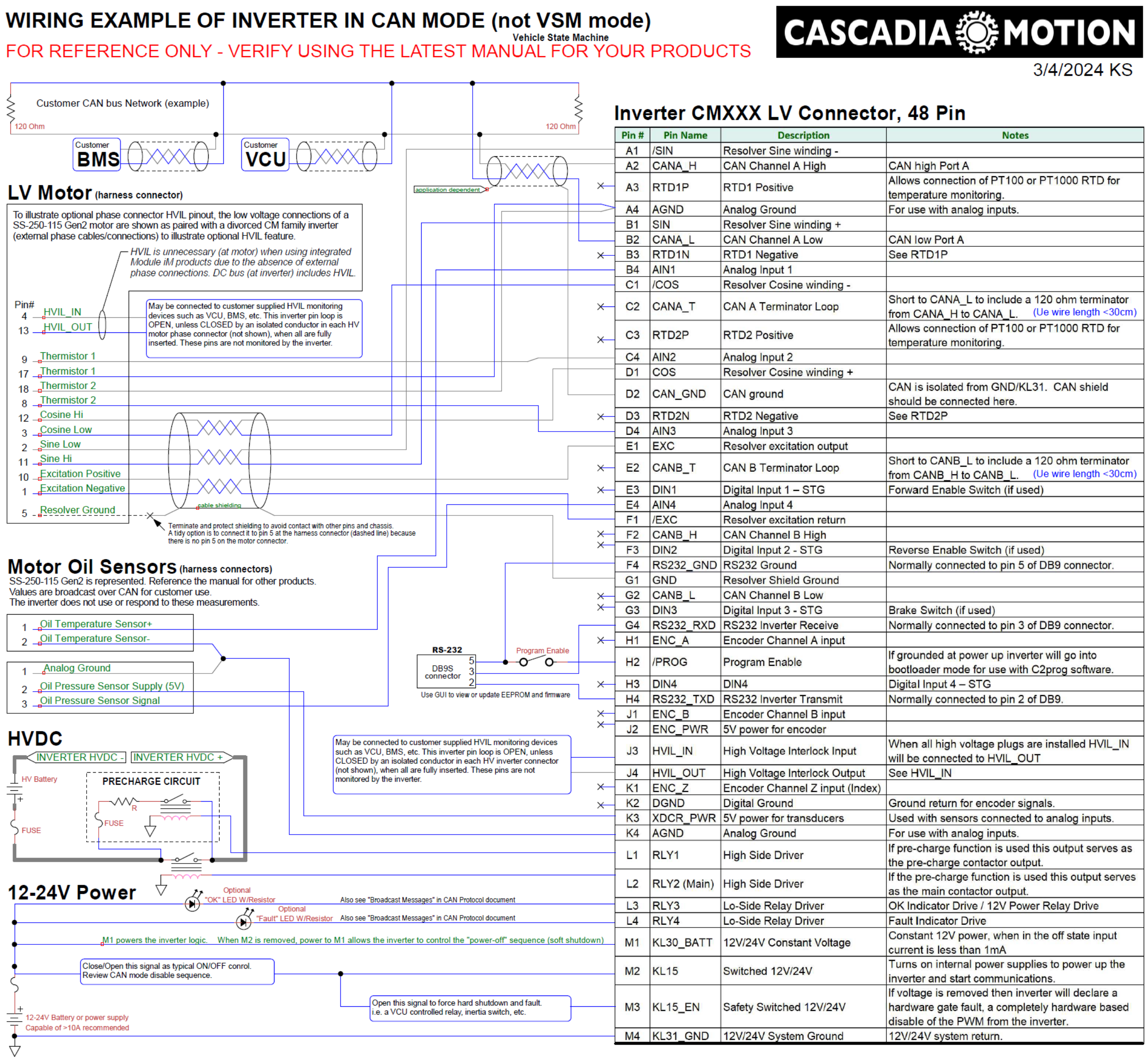
A Analog Input Motor Mapping

The standard CM offering of paired or remote motors will require the following analog input wiring.

CM Catalog Product	AIN Channel	Motor Connection
iM-225DX-D iM-225DZ-S iM-375DZ-D iM-425DZ-D iM-375SiC-D iM-425SiC-D	AIN1	Motor Oil Temperature Sensor (External Connector)
	AIN2	Motor Temperature Sensor (Resolver Connector)
	AIN3	Motor Temperature Sensor (Resolver Connector)
	AIN4	Motor Oil Pressure Sensor (External Connector)
iM-225DX-DW iM-225DZ-SW iDM-190DX-D iDM-375SiC-D	AIN1	-
	AIN2	Motor Temperature Sensor (Resolver Connector)
	AIN3	Motor Temperature Sensor (Resolver Connector)
	AIN4	-

Remote Mount pairing will also follow this same wiring. To match a remote mounted inverter and motor refer to its CM integrated equivalent. i.e. An SS-250-115-DOM with a CM200DX is the same electrically as an iM-225DX-D.

B Example Wiring Diagram



Inverter CMXXX LV Connector, 48 Pin

Pin #	Pin Name	Description	Notes
A1	/SIN	Resolver Sine winding -	
A2	CANA_H	CAN Channel A High	CAN high Port A
A3	RTD1P	RTD1 Positive	Allows connection of PT100 or PT1000 RTD for temperature monitoring.
A4	AGND	Analog Ground	For use with analog inputs.
B1	SIN	Resolver Sine winding +	
B2	CANA_L	CAN Channel A Low	CAN low Port A
B3	RTD1N	RTD1 Negative	See RTD1P
B4	AIN1	Analog Input 1	
C1	/COS	Resolver Cosine winding -	
C2	CANA_T	CAN A Terminator Loop	Short to CANA_L to include a 120 ohm terminator from CANA_H to CANA_L. (Ue wire length <30cm)
C3	RTD2P	RTD2 Positive	Allows connection of PT100 or PT1000 RTD for temperature monitoring.
C4	AIN2	Analog Input 2	
D1	COS	Resolver Cosine winding +	
D2	CAN_GND	CAN ground	CAN is isolated from GND/KL31. CAN shield should be connected here.
D3	RTD2N	RTD2 Negative	See RTD2P
D4	AIN3	Analog Input 3	
E1	EXC	Resolver excitation output	
E2	CANB_T	CAN B Terminator Loop	Short to CANB_L to include a 120 ohm terminator from CANB_H to CANB_L. (Ue wire length <30cm)
E3	DIN1	Digital Input 1 – STG	Forward Enable Switch (if used)
E4	AIN4	Analog Input 4	
F1	/EXC	Resolver excitation return	
F2	CANB_H	CAN Channel B High	
F3	DIN2	Digital Input 2 - STG	Reverse Enable Switch (if used)
F4	RS232_GND	RS232 Ground	Normally connected to pin 5 of DB9 connector.
G1	GND	Resolver Shield Ground	
G2	CANB_L	CAN Channel B Low	
G3	DIN3	Digital Input 3 - STG	Brake Switch (if used)
G4	RS232_RXD	RS232 Inverter Receive	Normally connected to pin 3 of DB9 connector.
H1	ENC_A	Encoder Channel A input	
H2	/PROG	Program Enable	If grounded at power up inverter will go into bootloader mode for use with C2prog software.
H3	DIN4	DIN4	Digital Input 4 – STG
H4	RS232_TXD	RS232 Inverter Transmit	Normally connected to pin 2 of DB9.
J1	ENC_B	Encoder Channel B input	
J2	ENC_PWR	5V power for encoder	
J3	HVIL_IN	High Voltage Interlock Input	When all high voltage plugs are installed HVIL_IN will be connected to HVIL_OUT
J4	HVIL_OUT	High Voltage Interlock Output	See HVIL_IN
K1	ENC_Z	Encoder Channel Z input (Index)	
K2	DGND	Digital Ground	Ground return for encoder signals.
K3	XDCR_PWR	5V power for transducers	Used with sensors connected to analog inputs.
K4	AGND	Analog Ground	For use with analog inputs.
L1	RLY1	High Side Driver	If pre-charge function is used this output serves as the pre-charge contactor output.
L2	RLY2 (Main)	High Side Driver	If the pre-charge function is used this output serves as the main contactor output.
L3	RLY3	Lo-Side Relay Driver	OK Indicator Drive / 12V Power Relay Drive
L4	RLY4	Lo-Side Relay Driver	Fault Indicator Drive
M1	KL30_BATT	12V/24V Constant Voltage	Constant 12V power, when in the off state input current is less than 1mA
M2	KL15	Switched 12V/24V	Turns on internal power supplies to power up the inverter and start communications.
M3	KL15_EN	Safety Switched 12V/24V	If voltage is removed then inverter will declare a hardware gate fault, a completely hardware based disable of the PWM from the inverter.
M4	KL31_GND	12V/24V System Ground	12V/24V system return.

Figure 9: Example Wiring Diagram

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Wilsonville, OR 97070
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sales@cascadiamotion.com

C Vehicle State Machine (VSM) Mode

The majority of use cases for CM inverters is now via CAN communication. VSM Mode offer a method of control via analog and digital inputs, given it is less common it has been moved to this appendix.

Documentation coming soon, for now refer to the legacy manual.

D Position Sensor Input Options

The CM200DX/DZ and CM350DZ offer single ended analog encoder and hall sensor inputs for position sensing through different hardware offerings (Contact BorgWarner Portland (formerly Cascadia Motion) for support). The CM350SiC offers the same options though software based option enable. Refer to the CM Software Users Manual for support on this.

Pin Number	Standard Pin Name	CM200 and CM350DZ Options	CM350SiC Options
H1	ENC_A	Digital Encoder Channel A input: Standard	Digital Encoder Channel A input: Standard
		Analog Encoder Sin Input: Hardware Selected (different p/n)	Analog Encoder Sin Input: Software Selected
		Hall A Input: Hardware Selected (different p/n)	Hall A Input: Software Selected
J1	ENC_B	Digital Encoder Channel B input: Standard	Digital Encoder Channel B input: Standard
		Analog Encoder Cos Input: Hardware Selected (different p/n)	Analog Encoder Cos Input: Software Selected
		Hall B Input: Hardware Selected (different p/n)	Hall B Input: Software Selected
K1	ENC_Z	Digital Encoder Index input	LIN communication channel

E Revision History

Version	Description	Updated By	Date
0A-0162-01	Base Manual	Christian Tigges	10/23/2024
0A-0162-02	ECO 1104	Christian Tigges	1/31/2025
0A-0162-03	Updates for 6532 release, ECO 1106.	Christian Tigges	2/6/2025