NEW GENERATION MOTORS CORPORATION

Washington, D.C. U.S.A

NGM-EV-C200 series Controller
OPERATING MANUAL
Version 1.10D

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Appendices

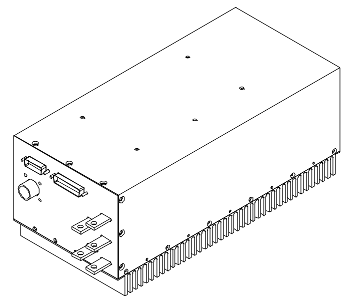
1. Specifications and features

The NGM-EV-C200-XX2 controller can power and control 3-phase DC brushless electric motors with advanced capabilities and superior efficiency. The controller has programmable logic to optimize and match it with nearly any 3-phase brushless permanent magnet DC motor. Basic features include:

◊ Selectable speed or torque control

◊ Selectable serial or discrete control interface

◊ Motor Current Limiting (MCL) logic senses battery voltage and motor & controller temperatures to limit current input or output



ISOMETRIC VIEW
(REFERENCE ONLY)

◊ Internal power supply for cooling fans activated by the controller's on-board thermal sensors for full thermal and power optimization

Specifications (w/o fans & connectors)

	EV-C200-042	**EVC-C200-092**
Peak current (amps)	260	150
Nominal bus voltages (volts)	42-54	66-108
Maximum operating voltage (volts)	68	135
Minimum operating voltage (volts)	30	50
Maximum voltage (volts)	75	160
Input capacitance (mf)	39,600	12,000
Height (in.)	5.29	5.29
Width (in.)	6.13	6.13
Length (in.)	13.06	13.06
Weight (lbs.)	10.8	10.8

Key features of the EV-C200-XX2 controller:

- ❋ Ultra high efficiency
- ❋ Compact design
- ❋ Synchronous switching
- ❋ Hysteresis control
- ❋ Regenerative braking
- ❋ Torque control
- ❋ Speed control
- ❋ Variable fan speed
- ❋ Reverse and brake light control
- ❋ Full I/O isolation
- ❋ Digital and analog inputs mutually isolated
- ❋ Isolated speed pulse output
- ❋ Configurable analog inputs
- ❋ Multiple hall sensor placement recognition
- ❋ Active discharge circuit

- ❋ Built in safety features
  - Continuous self diagnostics
  - FET drive under voltage lockout
  - Extreme over/under voltage protection
  - Motor interface connection verification
  - Phase lead connection verification
  - Thermal limiting protection
  - Over- and under- voltage current limiting with soft shutdown
  - Abrupt start-up inhibition
  - Stator short detection
- ❋ Data available
  - Voltage measurement
  - Speed measurement
  - Motor temperature sense
  - PWM frequency measurement
  - Logic supply current measurement
  - Drive state
  - Heatsink Temperature sense
  - Logic supply current measurement fault

Front panel interface information of the EV-C200-XX2 controller

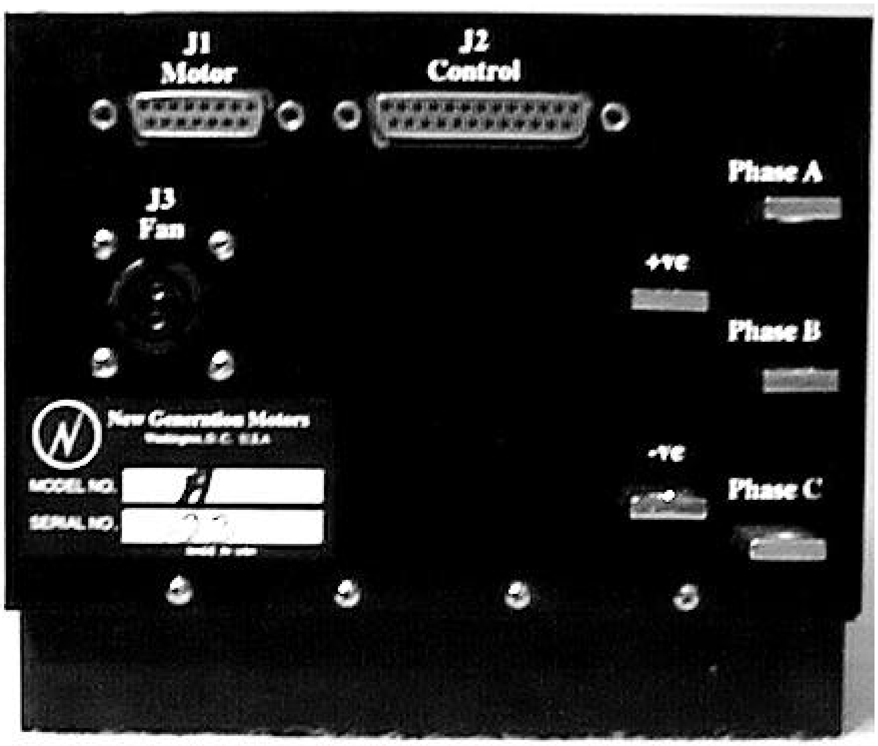


Fig. 1

<u>Controller connections:</u>

J1 – Motor communication link,
15 pin female D-Sub. connector

J2 – Control signals (vehicle)
25 pin female D-Sub. connector

J3 – Fan power for cooling
AMP Series 1 CPC 11-4, reversed sex
(*mating connector provided*)

+ve & -ve – Positive & negative power
bus bar with ¼ in. diameter through hole

Phase A,B,C – Phase lead connections for the motor
bus bar with ¼ in. diameter through hole

2. Parts list:

Qty.	Item
1	NGM-EV-C200-092 controller
1	NGM-EV-C200-092 controller Manual
1	CPC Series 1 11-4 plug
2	Series 1 pins
2	Muffin fans
5	¼ in. 20 UNC low head bolts
10	¼ in. flat washers
5	¼ in. 20 UNC narrow lock nuts
5	Rubber boots

NOTE: If you have not received all of the above items, please contact NGM.

3. Mechanical installation

3.1 Physical mounting

The Controller should be mounted by a method that minimizes the vibration and protects it from the elements during operation. High impact loads or excessive moisture and dirt could shorten the life span of the controller. There are several 4-40 UNC screw holes on the side of the controller that may be used for mounting. *Do not remove* any of the existing screws.

There are five types of connections that must be performed before operation of the controller:

- motor phase
- motor sense
- control
- fan power
- power

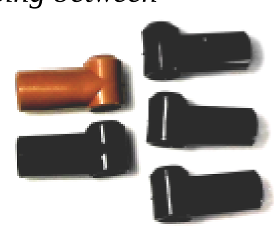
It is recommended that they be performed in the order as listed.

> ***Safety* Note**: The controller can retain a charge due to its high capacitance. Check the voltage before servicing the controller. **DO NOT** short the positive and negative buses together

.

3.2 Motor phase connection

This unit has three phase bus bars located on the right hand side; phase A, phase B and phase C. These phases must be properly connected to the corresponding phases of the motor. These connections must be made with *no less than* AWG 6 gage (4.11 mm) wire, although AWG 4 (5.18mm) is preferred. The connections can be made using properly sized ring terminals for the corresponding wire width and inner diameter of 0.25 in. Low head bolts, ¼ in. UNC no longer than 0.625in. should be used. They must be securely fastened with lock nuts and washers. Rubber boots should then be placed over each connection point to ensure no shorts between phases (a set of hardware is provided). *Visually check the spacing between connections and ensure the leads can not be rotated.* There should be a minimum of 3/16in. between connection points. Great care should be taken in applying proper strain relief for these cables. Additionally, ensure there exists enough slack in the cables for movement, especially for those connected to “in the wheel” motors.



In combination with NGM-SC-M100 & NGM-SC-M150 motors, RED corresponds to Phase A, GREEN to Phase B and BLACK to Phase C.

3.3 Motor sense connection

The motor sense connection requires a 15 pin D-sub male to be inserted into *J1* on the front of the controller and secured tightly. Take care to strain-relieve this cable properly on both ends to prevent any damage. (See Appendix A for pin out information)

Most NGM motors have a pre-installed cable for connection to the controller. However the NGM-SC-M100 motor, requires the *rotor retrofit package* to have been installed. For further information, contact NGM. Once the retrofit package is installed, the connection is similar to the others.

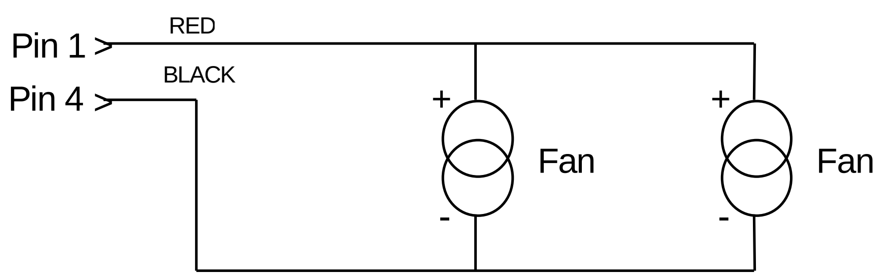
NOTE: *The retrofit package only allows use of the Hall and temperature sensors.*

3.4 Control input connection

The control cable must be plugged into *J2,* a DB25F connector. See appendix A for pin information.

3.5 Fan connection

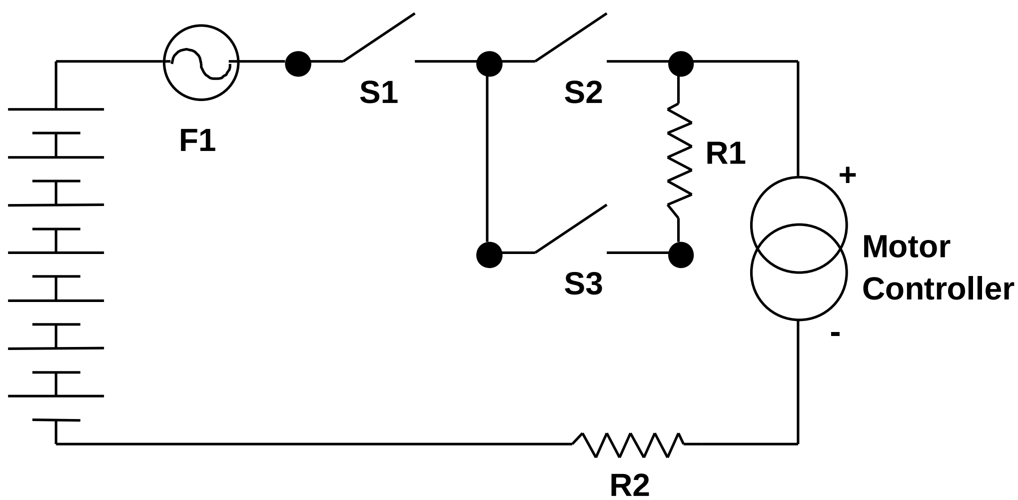
Fan power should be connected to *J3*. A series 1 CPC Amp 11-4 plug and two pins are provided with the controller. Splice the ground of each fan wire (Black) into one single wire long enough to reach the front panel of the controller. Do the same with the positive (Red) wires of each fan. Crimp the pins (CPC, series 1) on to the end of the positive and negative leads of this cable. The positive must be placed into position 1 of the plug and the negative into position 4 (See Fig. 3). Then mate the plug to *J3* on the controller's front panel.



Fan power circuit (Fig. 3)

3.6 Power connection

A pre-charge circuit *(see Fig. 4) must* be used to connect the motor controller to the power system. Resistor R1 and switch S3 form a "pre-charge" for the motor controller. The input capacitance of the controller is very high, large in-rush currents will eventually destroy the controller and switch S2. R1 should have a resistance such that the current through it at turn-on is at most 30A. Resistor R2 is an optional high current shunt for measuring the motor controller current. The DC ratings of all components must exceed the maximum bus voltage.



Pre-Charge circuit schematic (Fig. 4)

Low head bolts ¼ in. UNC with a lock nut and washer (provided) should be used to connect to the positive and negative posts of the controller. A *minimum* of AWG 6 gage (4.11 mm) or larger should be used (AWG 4 (5.18mm) preferred). Visually check the spacing between connections to ensure that the leads can not be rotated. After connection, each post should have a rubber boot covering it. Take care to strain-relieve each wire properly to ensure that no damage is done by the force on the connections.

4. Communication formats

The motor controller can be controlled by either discrete or serial communication. All communication is conducted through connector *J2* on the front panel. See Appendix A for pin out diagram. From the factory the controller's default setting is "discrete interface."

4.1 Via Discrete interface

The term "discrete interface" refers to all of the I/O except for the serial interface lines.

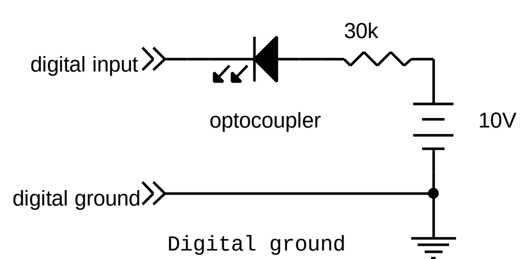
4.1.1 Digital inputs

<u>Forward/Reverse</u>**:** The *for/rev* input and its corresponding *gnd*, use pins 5 and 18, respectively, on *J2*. Forward corresponds to open circuit and reverse to closed. It is recommended that the direction signal be wired directly to a switch for maximum safety and reliability. The [CG_INVERTDIR] register is used to define whether forward is clockwise rotation or counter-clockwise rotation. The direction may differ depending upon the type of motor being used. When [CG_INVERTDIR] is False, forward is defined as a counterclockwise rotation when looking at the rotor of the NGM single-stator motors.

<u>Enable:</u> The *enable* input signal (pin 3 on *J2*) must be connected to *gnd* (pin 16, on *J2*) for the controller to enable. An open circuit immediately disables all torque production, and reduces the controller's quiescent power consumption. As part of an extra safety feature the controller will not enable unless there is a closed circuit between pins 2 and 10 on *J1* of the controller. This is normally performed inside of the motor acting as a motor sense circuit.

<u>Throttle enable:</u> The *threnable* signal (pin 4 on *J2*) must be connected to *gnd* (pin 17 on *J2*) for the controller to produce accelerating torque. When open-circuited, the maximum throttle current is set to zero, but the controller can still operate in regen. It is suggested that this input be wired to a switch on the brake pedal.

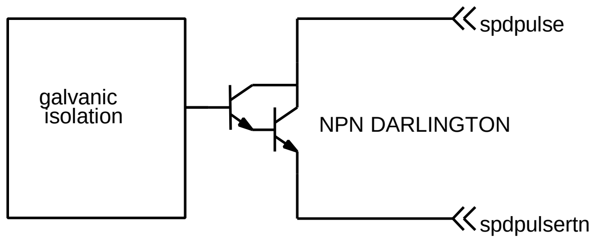
Electrical equivalent of *direction*, *enable*, and *throttle enable* inputs



(Fig. 5)

4.1.2 Digital outputs

Speed pulse: Speed *pulse* (pins 6 and 19 on *J2*) is an isolated open-collector, low drive, pulse stream output that is proportional to the commutation rate, and thus the rotational velocity. The output changes state every two consecutive commutations (i.e. never after forward and backward movement), producing a 50% duty cycle. The electrical equivalent of the speed pulse output is shown in Fig. 6.



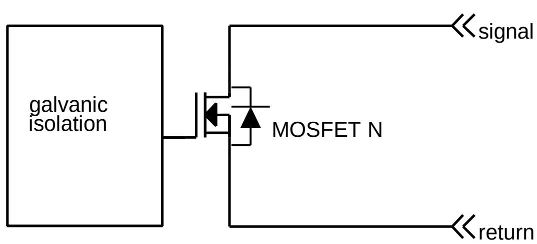
Speed pulse schematic (Fig. 6)

The output frequency f_{out} equals (3*P)/4 * f_{motor}, where P equals the motor pole count and f_{motor} equals the motor's revolutions per second.

Reverse detection: *Reverse* (pins 8 and 21 on *J2)* can be used as an activating switch that corresponds to the controller operating in the reverse direction. It is on (conducting) when the input direction is reverse (i.e. when [IN_FORWARD] = 0), regardless of the actual direction the motor is spinning or the state of [SV_FORWARD] (the direction in which the controller is operating).

Regenerative braking detection***:*** *Brake* (pins 7 and 20 on *J2*) can be used as an activating switch that corresponds to the controller when in a "braking" mode. It is on (conducting) when [IN_DESIREDPHASEI] is negative, even if the drive state is not in regen mode [DS_RGN]. This includes any case where [SV_MAXRGNI] is zero.

The electrical equivalent of the reverse and brake outputs is:

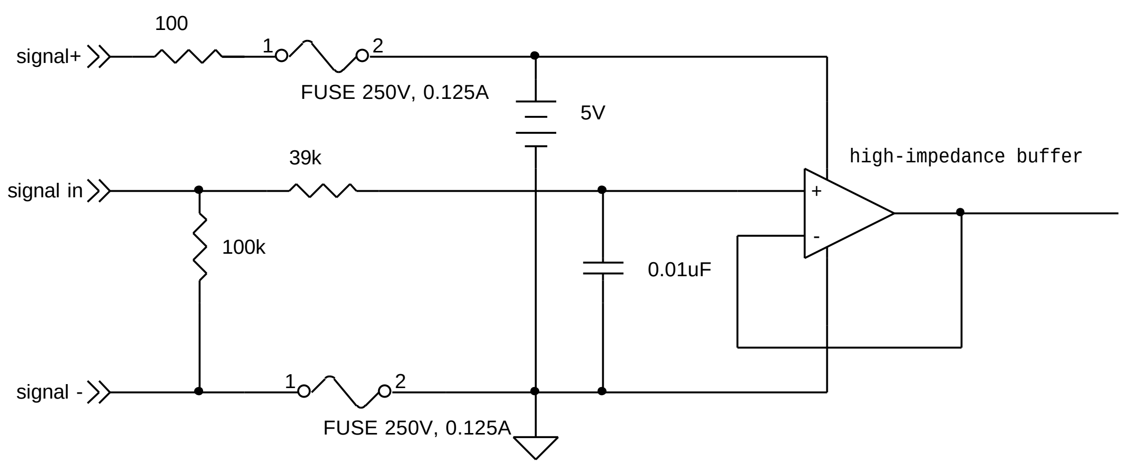


(Fig. 6)

> *NOTE:* The D connector *reverse* and *brake* pins can sustain a maximum of 20V and 100mA.

4.1.3 Analog inputs

There are two analog inputs, *throttle* and *regen*. Each input has an associated +5V reference and ground, labeled sig+ and sig- respectively, where "sig" is either throttle or regen. The signals can be coupled with potentiometers, having a resistance at 4k to 20k Ohms, to create a scaling effect from 0-5 V max. Each voltage on the scale then equates to a desired signal for the given range. The signals are user defined including the gains as well as maximum and minimum desired values of the scale. An electrical equivalent of the circuit is shown in Fig. 7.



Throttle & regen internal circuit schematic (Fig.7)

<u>Filtering</u>

There are two types of filtering on the analog inputs. First, the maximum rate of change (in bits/sample) is limited to 32 for [AM_THR] and [AM_RGN]. Second, all of the analog inputs are capable of exponential filtering. The level of filtering is set by [RT_(INPUT NAME)], which may vary from 0 (no filtering) to 4 (maximum filtering, slowest response). The formulas for these are:

0: Value = newvalue
1: Value = ½(oldvalue) + ½(newvalue)
2: Value = ¾(oldvalue) + ¼(newvalue)
3: Value = 7/8(oldvalue) + 1/8(newvalue)
4: Value = 15/16(oldvalue) + 1/16(newvalue)

The analog inputs are sampled 10 times per second.

Deadbands

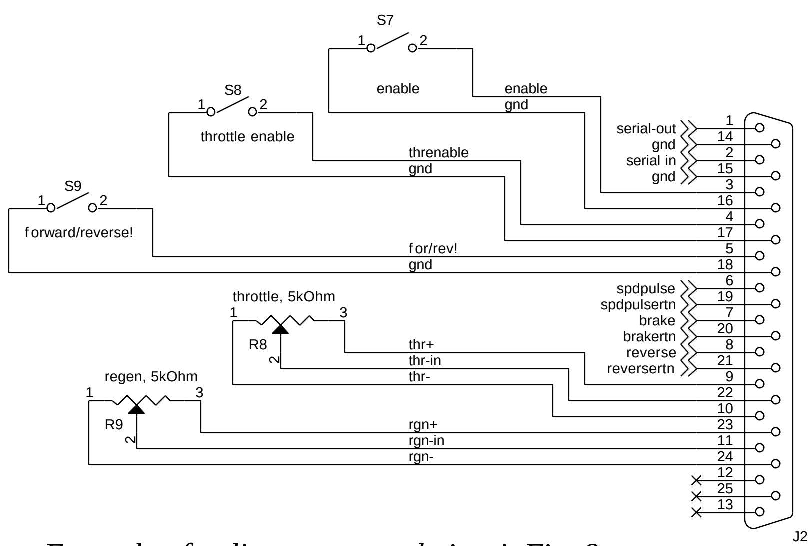
The deadbands are similar to offsets, but any input less than the deadband is set to zero. The deadband value range is from 0 to 255, corresponding to the controller's eight-bit A-D converter.

The following pseudo-code illustrates how [AM_THR] and [AM_RGN] are computed:

> X = Output from A to D converter // 0-255 counts
>
> if ((X – oldXvalue) > 32 counts) then
>   X = oldXvalue + 32
> elseif ((X – oldXvalue) < 32 counts) then
>   X = oldXvalue – 32
>
> if (X < CG_XDEADBAND) then
>   X = 0
>
> oldXvalue = X
>
> AI_X = (AI_X * (2^{RT_X} – 1) + X) / 2^{RT_X}
>
> if (X equals 0) and ((AI_X < CG_XDEADBAND * 16)) then
>   AI_X = 0

Enables

DF_SPEEDCONTROL	Sets speed control as default by setting [SV_SPEEDCONTROL] at power-up.
CG_ENDISCRETE_THR	Enables the discrete throttle & regen inputs for either torque or speed control. Otherwise, the serial input registers are used.
CG_ENDISCRETE_DIR	When set, the discrete direction input is used, otherwise the serial input register is used.
CG_ENDISCRETE_THRENABLE	When set, both the discrete and serial throttle enable inputs are used. Otherwise, only the serial input register is used.



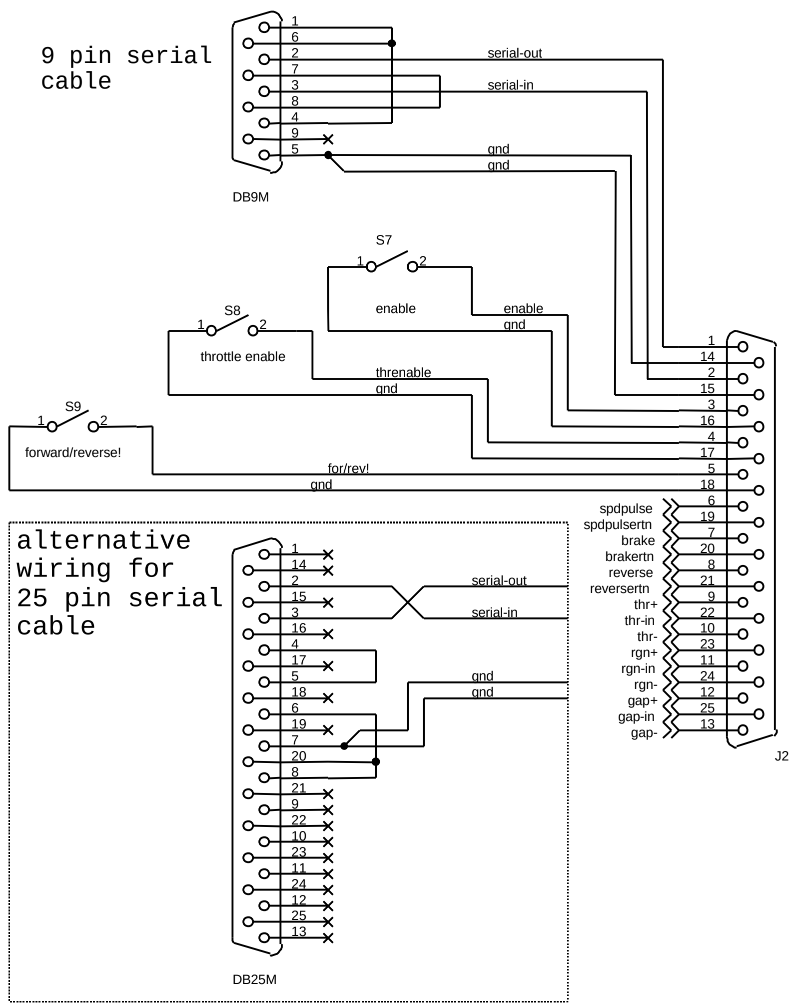
Example of a discrete control circuit Fig. 8

4.2 Via Serial interface

Serial I/O is performed using an RS-232 three-wire interface. All communication is performed through pins (1, 14) and (2,15) serial out and in, respectively. The serial interface serves three functions:

1). Provides control inputs to the controller
2). Receives measurements and status information from the controller
3). Configures the controller for specific applications and settings

A sample schematic of wiring the controller to a 9 pin serial port or an alternative 25 pin.



4.2.1 RS-232 settings & syntax

Default serial settings:			
Flow Control	None *fixed*	Baud rate	9600 *(factory default)*
Data Bits	8 *fixed*	Echo	enabled *(factory default)*
Stop bits	1 *fixed*		

There are three types of serial input messages, commands, queries, and assignments. All are terminated with either a carriage return or carriage return and line feed combination. They take the following forms:

<u>*Command:*</u>
Commands are used for setting forward or reverse, enabling, entering and exiting program mode, and similar operations.

XX! (CR)

Where **XX** is the hexadecimal command number and **(CR)** is a carriage return character.

The controller replies with either **Ok** (**CR)** or an error message.

<u>*Query:*</u>
Queries may be made of either RAM variables (inputs, measurements and the like) or EEPROM variables (configuration values). The operation character determines which memory area is accessed as follows:

From RAM:

XX? (CR)

From EEPROM:

XX>(CR)

In both cases **XX** is the memory location to be returned. The controller replies with a text string of the decimal value of the register.

<u>*Assignment:*</u>
Assignments may also be of either RAM or EEPROM registers. Note that it is necessary to enter the program mode to make assignments to EEPROM register. This allows the controller the time to program the memory location and prevents accidental changes.

To RAM:

XX=#(CR)

To EEPROM:

XX<#(CR)

In the example, # stands for the text string of the decimal value to be assigned. For unsigned long registers, this string may be ten digits long. Note that for the most, part range checking is not performed. The controller responds with either **Ok (CR)** or an error message.

4.2.2 Serial commands

Command	Name	Description
00!	Enable	Clears [CB_DISABLE]
01!	Disable	Sets [CB_DISABLE] disabling the controllers output
02!	Throttle enable	Sets [CB_THRENABLE]
03!	Throttle disable	Clears [CB_THRENABLE], forcing throttle input to zero
04!	Reverse	If [CG_ENDISCRETE_DIR] is false, clears [IN_FORWARD]
05!	Forward	If [CG_ENDISCRETE_DIR] is false, sets [IN_FORWARD]
06!	Torque control	Clears [SV_SPEEDCONTROL]
07!	Speed control	Sets [SV_SPEEDCONTROL]
08!	Coast	Forces desired current to zero Sets [IN_DESIREDPHASEI] to zero
0A!	program	Sets controller in PROGRAM drive state
0B!	operate	Exits program drivestates
FA!	Reset microcontroller	Performs a hard reset (similar to a power cycle)

4.2.3 EEPROM Registers

00_H	CG_BAUDRATE	I/O baud rate
90	CG_ECHO	When true, echo characters as they are received
91	CG_TEXTERRORS	When true, send text messages for errors, else send two digit codes. *See Appendix E*
92	CG_LINEFEEDS	When true, use CR-LF combinations at end of lines
93	CG_MAXSCIIDLE	Maximum idle time for serial interface watchdog fault in tenths of a second, 0 disables

5. Control Modes

5.1 Overview

There are two modes that can control the output of the controller; torque and speed control. The *factory default* is set to torque control.

Torque control is the method of controlling the output phase current directly. The phase current is roughly proportional to the torque output of the motor. The relationship will differ from motor to motor and must be determined by the user, especially when the motor's parameters are constantly changing, e.g. the air gap in the NGM-SC motors.

Speed control varies the phase current as a function of the difference between the input desired speed and the actual speed. At the most basic level, it is controlling the motor's electrical frequency, which is directly proportional to the rotational velocity.

5.2 Torque control:

RAM Registers:

10	SV_TARGETPHASEI	Target current (dA)
13	SV_MAXTHRI	Maximum throttle current (dA)
14	SV_MAXPHASEIRGN	Maximum regen current (dA)
1A	SV_HYSTERESIS	Hysteresis level (counts)
61	IN_DESIREDPHASEI	Phase current in (dA)
96	SV_DRIVESTATE	Operating status
A9	SV_STEP	Current commutation step

The controller does not implement torque control per-se. Instead, it operates by controlling the motor phase current that is proportional to the torque. This proportionality is a function of the motor coupling (which varies in adjustable gap motors). The input to the phase current control function is [IN_DESIREDPHASEI]. This value can be set by either the discrete interface or the serial interface. The maximum phase current allowed is determined by the minimum value of the following functions:

1. Motor thermal limiting *(user defined)*
2. Controller thermal limiting *(factory set)*
3. Low supply voltage limit *(user defined)*
4. High supply voltage limit *(user defined)*
5. Soft start limits *(user defined)*
6. Base maximum phase current (throttling or regen). *(user defined)*

In addition, the maximum throttling current is zero when [IN_THRENABLE] is FALSE (set by [CB_THRENABLE] and/or [BI_THRENABLE]). (See Section 7 MCL logic for more information).

5.2.1 Via discrete interface

In the discrete torque control, the desired phase current (which is proportional to torque) is determined by the difference between the throttle and regen analog inputs. The inputs could be references across potentiometers. When the difference is greater than zero, driving torque is produced. When the difference is less than zero, regen is applied. When the difference is equal to zero, the motor coasts. These inputs have independent deadband and scale settings. The deadbands are similar to offsets, but any input less than the deadband is set to zero.

<u>To Engage:</u>

[CG_ENDISCRETE_THR] set to TRUE
[SV_SPEEDCONTROL] set to FALSE

<u>Associated variables:</u>

Desired phase current	= [IN_DESIREDPHASEI]
Analog throttle input	= [AM_THR], on 0-4080 (counts*16) scale

Analog regen input	= [AM_RGN], on 0-4080 (counts*16) scale
Deadband values:	range is 0-255 counts
Throttle	= [CG_THRDEADBAND]
Regen	= [CG_RGNDEADBAND]
Scales:	
Torque	= [CG_SCTHR_TORQUE]
Regen	= [CG_SCRGN_TORQUE]

<u>Calculation:</u>

The controller uses the following formula to calculate the desired phase current:

IN_DESIREDPHASEI = (AM_THR * CG_SCTHR_TORQUE – AM_RGN * CG_SCRGN_TORQUE) / 256
Where;

AM_THR = [(input voltage)* 51 – CG_THRDEADBAND]*16
AM_RGN = [(input voltage)* 51 – CG_RGNDEADBAND]*16

<u>Example:</u> IF CG_THRDEADBAND = 127
CG_SCTHR_TORQUE = 100
AM_RGN = 0

AM_THR = (5 * 51 – 127) * 16 = 2048
(V * counts/V – counts) * count/count

IN_DESIREDPHASEI = (2048 * 100 – (0 * CG_TOAMPSRGN) / 256= 800 dA

The configuration registers are factory set to provide full-scale output phase current over an input voltage range of 0.12 to 5.0 V. If desired, these registers may be altered to accommodate a narrower voltage range. Reducing the voltage range in this fashion also reduces the resolution. Therefore, it is recommended that the input voltage range be at least 1.2 V (1/4 of full range).

<u>Calculation:</u> To find scale and deadband settings:

Desired phase current:	I (in deci-A)
Throttle input voltage:	
Low	Lt, recommend a min value of 0.12
High	Ht
regen input voltage:	
Low	Lr, recommend a min value of 0.12
High	Hr

CG_THRDEADBAND = 51 * Lt

CG_RGNDEADBAND = 51 * Lr

CG_SCTHR_TORQUE = (I / 255) * (Ht – Lt) / 5 * 16 * 1.05
= (16.8/1275)* I * (Ht – Lt)

CG_SCRGN_TORQUE = (I / 255) (Hr – Lr) / 5 * 16 * 1.05
=(16.8/1275)* I * (Hr – Lr)

These settings will allow full regen and throttle current when the two controls are at full travel. It may be desirable to double [CG_SCTHR_TORQUE] and [CG_SCRGN_TORQUE] to reach full throttle or full regen when the difference between the two controls is only half travel.

5.2.2 Via serial interface

In the serial torque control mode, the desired phase current value is set by assigning a value to [SI_DESIREDPHASEI] in deci-amps. A negative phase current corresponds to regen.

To Engage:

[CG_ENDISCRETE_THR] set to FALSE
[SV_SPEEDCONTROL] set to FALSE

Action:
Assign Desired phase current to [SI_DESIREDPHASEI] (deci-Amps)

5.3 Speed Control

The speed control function operates as an outer control loop by controlling [IN_DESIREDPHASEI]. It is implemented with a P^2I control loop with the following parameters:

RAM REGISTERS	NAME	DESCRIPTION
03	SI_KP	Coefficient of the proportional error squared term
04	SI_Ki	Coefficient of the integrated error term
07	SI_MAXSPEEDERROR	Limits the maximum speed error, dampens response to large step changes in the desired speed.
05	SI_Kt	Coefficient multiplied with the phase current and subtracted from the speed error. When non-zero, it allows speed to be decreased at high load, and increased at negative loads (such as a steep hill).

All speed control parameters are stored in RAM registers with power-up values stored in EEPROM. These coefficients are stored in RAM to allow real time adjustment to find the best performance in a given application. The values can then be stored in the EEPROM registers as defaults.

The integrated error term is subjected to the same MCL logic applied to [IN_DESIREDPHASEI].

Speed control is set when [SV_SPEEDCONTROL] is TRUE. The default value is FALSE. "Speed" is in the units of deci-Hz and is the measurement of the electrical frequency. The conversion to RPM is ([AI_SPEED] * 12) / P. P is equal to the motor pole count. If the motor being used had 12 poles, [AI_SPEED] would equal RPM.

The desired speed used in the *PI* control loop can be made a function of the applied torque with [SI_Kt]([CG_Kt]). Basically:

Speed error = Input speed – Actual speed – [SV_PHASEI]*[SI_Kt]

5.3.1 Via discrete interface:

The throttle input sets the desired speed using a 0-5V scale with 0 V =0 speed and 5V equal to the maximum full-scale value allowed by the controller's configuration. The regen input sets the maximum braking torque using a 0-5V scale also.

<u>To Engage:</u>

[CG_ENDISCRETE_THR]	set to TRUE
[SV_SPEEDCONTROL]	set to TRUE

<u>Associated registers:</u>

Desired speed (user def. Units)	= [IN_DESIREDPHASEI]
Analog throttle input voltage	= [AM_THR], on 0-5V scale
Analog regen input voltage	= [AM_RGN], on 0-5V scale
Deadband values:	range is 0-255 (counts)
Throttle	= [CG_THRDEADBAND]
Regen	= [CG_RGNDEADBAND]
Scales:	
Speed	= [CG_SCTHR_SPEED] (<speed unit> / 16 * (counts))
Regen	= [CG_SCRGN_TORQUE]

Calculation: To find scale and deadband settings

Maximum desired speed: S
Maximum regen phase: I (in deci-A)
Throttle input voltage
    Low Lt, recommended a minimum value of 0.12 V
    High Ht
regen input voltage
    Low Lr, recommended a minimum value of 0.12 V
    High Hr

CG_THRDEADBAND = 51 * Lt

CG_RGNDEADBAND = 51 * Lr

CG_K_AD_SPD = (S / 255) * (Ht – Lt) / 5 * 16 * 1.05
= (16.8/1275) * S * (Ht – Lt)

CG_SCRGN_TORQUE = (I / 255)* (Hr – Lr) / 5 * 16 * 1.05
= (16.8/1275) * I * (Hr – Lr)

The input speed is stored in [SI_DESIREDSPEEED].

5.3.2 Via serial interface

In the serial mode, the speed is set by assigning a value to [SI_DESIREDSPEED].

To engage:
    [CG_ENDISCRETE_THR] set to FALSE
    [SV_SPEEDCONTROL] set to TRUE

Action:
Assign desired value to [SI_DESIREDSPEED].

6. Controller fault detection

The controller has continuous self-diagnostics. If a fault occurs, it is recorded into its corresponding register and the controller reacts accordingly. The faults are divided into four types, corresponding with four 8-bit registers, [SV_FAULT1] through [SV_FAULT4].

Type 1: Faults that immediately disable the controller and prevent operation
Type 2: Sensor problems
Type 3: Warnings
Type 4: Conditions that lead to a reduction in the output torque.

Type 1 faults disable the controller, with the effect of clearing the fault registers. There is a fifth register, [SV_FAULT1LATCH], which corresponds one-to-one with [SV_FAULT1]. Bits in [SV_FAULT1LATCH] are set whenever a fault occurs. They are only cleared when the controller is re-enabled. In this way, [SV_FAULT1LATCH] stores the condition that caused a shutdown.

The register stores each fault in its own distinct bit location. To read which fault has occurred, use a mask to determine which bit in the register is set to one.

<u>EXAMPLE:</u>
8 bit REGISTER

SV_FAULT1 = 02_H = $0000\ 0010_B$

If [SV_FAULT1] was read and it showed this. The fault would be Type 1 and correspond to [FA1_OVERVOLT], supply voltage is greater than [CG_ABSMAXV]

Type 1 faults:

Mask	Fault	Description
1_H	FA1_UNDERVOLT	Supply voltage is less than[CG_ABSMINV].
2	FA1_OVERVOLT	Supply voltage is greater than [CG_ABSMAXV].
4	FA1_NOFETDR	Supply voltage to gate drives low, internal fault or low supply voltage spike.
8	FA1_NOPHASELEADS	Most likely a phase is not connected
10	FA1_INVALIDHALLS	A HALL effect input is invalid. Most likely a cable is not connected
20	FA1_LOSTCOMM	Serial I/O watchdog has tripped due to inactivity on serial input.

Type 2 faults:

Mask	Fault	Description
1_H	FA2_MOTORT	Signal from motor temp sensor is < -50C or > 150C.
2	FA2_HEATSINKT	Signal from heatsink temp sensor is < -50C or > 150C.
4	FA2_SUPPLYI	Logic supply current measurement is less than [CG_MINSUPPLYI].

Type 3 faults:

Mask	Fault	Description
1_H	FA3_FAN	The logic supply current is outside the fans MINSUPPLYI and MAXSUPPLYI range. The fan may be disconnected or jammed
2	FA3_STATORSHORT	A stator short to ground or a phase has been detected.
4	FA3_MAXTORQUE	Motor has reached maximum throttle or regen current for the current speed.
10	FA3_SOFTSTART	Controller is soft-starting because [IN_DESIREDPHASEI] was != 0 when controller was enabled.
20	FA3_OBDIRBACKWARDS	The observed direction of rotation is opposite the input direction. Controller is coasting.

The Fault 4 register

Mask	Fault	Description
1_H	FA4_MOTORTLIM	Current limit is due to motor temperature.
2	FA4_HEATSINKTLIM	Current limit is due to heatsink temperature.
4	FA4_UNDERVOLT	Supply voltage being less than [CG_MINVGUARD].
8	FA4_OVERVOLT	Supply voltage being greater than [CG_MAXVGUARD].
10	FA4_ABSLIM	Desired current is greater than either [CG_MAXTHRI] or [CG_MAXRGNI].
20	FA4_SOFTLIMIT	Desired current is greater than either [SV_THRPHASEILIM] or [CG_RGNIPHASEILIM].
40	FA4_THRDISABLED	Throttle current is zero because throttle enable input (either discrete or serial) is FALSE.
80	FA4_BRAKEPHASEILIM	When in discrete speed control, target regen current is greater than limit set by regen input.

7. Motor Current Limiting logic (MCL)

MCL can cause the controller to shut down or limit its output. The parameters that can activate the MCL logic to take place are as follows:

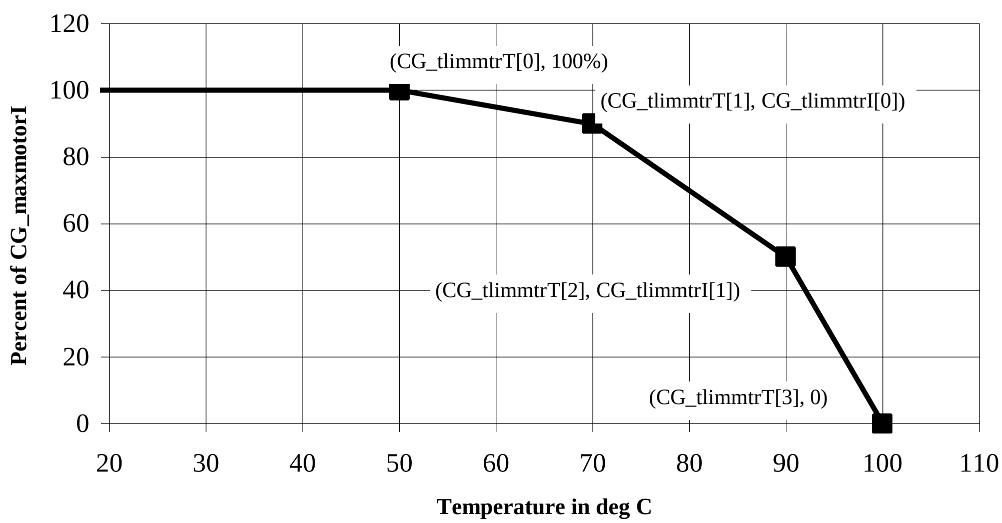
1. Motor temperature
2. Controller temperature
3. Under & over voltage
4. Absolute maximum limits
5. Soft starting
6. Soft maximum limits
7. Throttle enable
8. Discrete Regen limit
9. Observed Direction backwards

These parameters set the maximum phase current levels in throttle and regen according to some pre-set algorithms. Should one of these parameters go out of its predetermined range, causing the desired motor phase current to be greater than the calculated maximum, the MCL logic would take over and limit the controller's output until the point of shut-down.

7.1 Motor thermal limits

Thermal protection is achieved by limiting the phase current as a function of the estimated motor temperature, [AM_MOTORTEST]. The absolute maximum motor current is [CG_MAXMOTORI] and all thermal derating is in proportion to this value. Note that this is completely independent of the motor controller limit. Thus, a 300A capable controller can be safely used with a 100A maximum motor and vice-versa.

The thermal derating is based on a piecewise-linear function as shown below. The values for [CG_TLIMMTRT] are stored in deci-degrees C (consistent with [AM_MOTORTEST]). The [CG_TLIMMTRI] values are stored with an implied denominator of 256, such that 256 = 100% of [CG_MAXMOTORI], 128 = 50% of [CG_MAXMOTORI], etc…



7.2 Controller thermal limits

If the controller reaches a temperature above its set limit it will shut down. Before reaching this temperature, the controller performs current limiting operations to reduce the amount of heat generated internally.

7.3 Under and over voltage

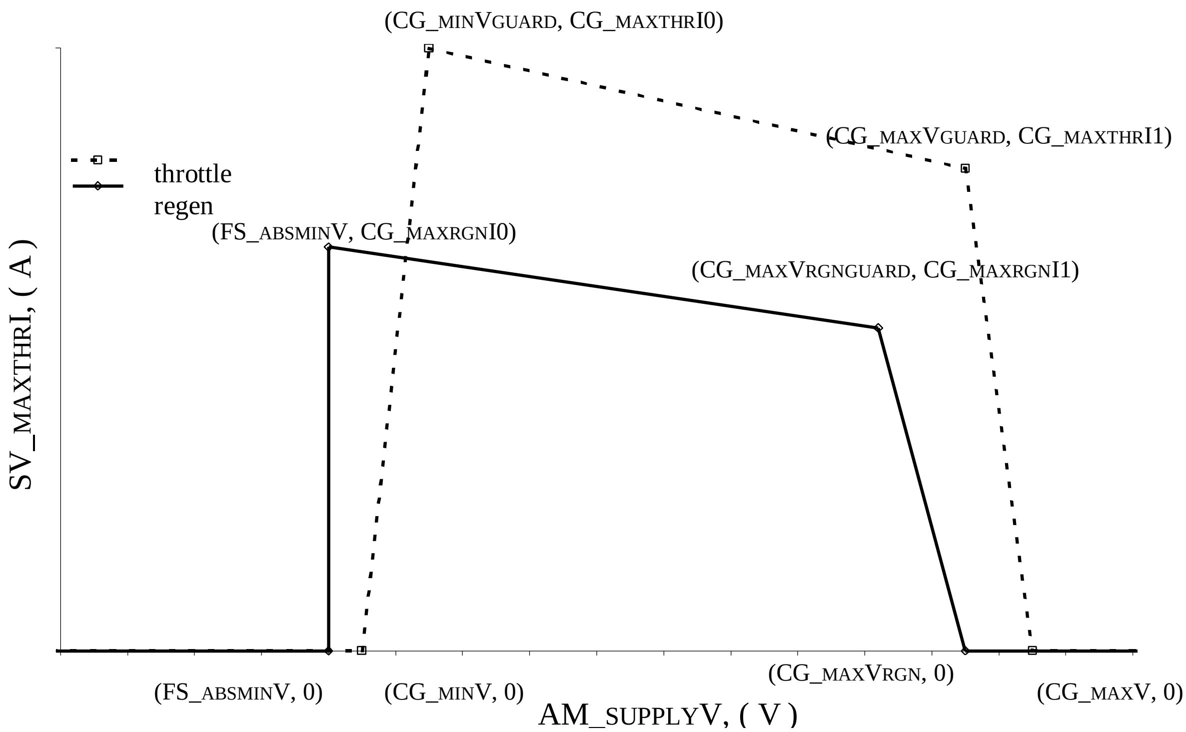
When [AM_SUPPLYV] is less than [CG_MINVGUARD], the maximum throttle current is linearly derated from [CG_MAXTHRI0] at [CG_MINVGUARD] to zero at [CG_MINV] and below. When the controller is limiting the phase current, the resulting [FA4_UNDERVOLT] is set. Note that there is no under-voltage limiting of the regen current until the supply voltage falls to [FS_ABSMINV].

When [AM_SUPPLYV] is greater than [CG_MAXVGUARD], the maximum throttle current is linearly derated from [CG_MAXTHRI1] at [CG_MAXVGUARD] to zero at [CG_MAXV] and above. Similarly, when [AM_SUPPLYV] is greater than [CG_MAXVRGNGUARD], the maximum regen current is linearly derated from [CG_MAXRGNI1] at [CG_MAXVRGNGUARD] to zero at [CG_MAXVRGN] and above. As a result of the controller limiting the phase current, [FA4_OVERVOLT] is set.

7.4 Abslolute maximum

When [AM_SUPPLYV] is between [CG_MINVGUARD] and [CG_MAXVGUARD], the maximum throttle current is limited to a value between [CG_MAXTHRI0] and [CG_MAXTHRI1]. When [AM_SUPPLYV] is between [FS_ABSMINV] and [CG_MAXVGUARDRGN], the maximum regen current is limited to a value between [CG_MAXRGNI0] and [CG_MAXRGNI1]. When the controller is limiting the phase current, [FA4_ABSLIMIT] is set.

The following piece-wise linear graph shows the complete relationship between supply voltage and phase current for both throttle and regens.



7.5 Soft-start limit

When [IN_DESIREDPHASEI] is a non-zero and the controller transitions from disabled to enabled, a soft-start mechanism is employed. During this period, the actual phase current is a fraction of [IN_DESIREDPHASEI]. This fraction is increased linearly until it equals one. The length of this period is set by [CG_SOFTSTARTN] and equals $2^{CG\_softstartN}/62$ seconds. Thus for [CG_SOFTSTARTN] = 6, the soft start period is approximately 1 second. The maximum value for [CG_SOFTSTARTN] is 7.

7.6 Soft maximums (phase current adjustment)

The "soft maximums" are two serial input registers, [SI_THRILIMIT] and [SI_RGNILIMIT], that allow the maximum phase current to be adjusted "on-the-fly," if these limits are less than all other limits. This can be useful for supervisory control of the discrete throttle and regen inputs or for limiting the phase current while in speed control to prevent low efficiency accelerating and braking. When [SV_TARGETPHASEI] is limited by these constraints, the [FA4_SOFTLIMITS] bit is set in the [SV_FAULT4] register.

7.7 Throttle Enable

The state of the throttle enable [BI_THRENABLE] must register TRUE for the controller to produce any accelerating torque. If FALSE the controller sets the maximum throttling current to 0. The controller can still operate in regen mode. See sections 4.1.1 & 4.2.2

7.8 Discrete Regen limit

While operating in Discrete speed control, the controller will use the regen limit set by the Regen “pot”. “pot” referring to the control method of the input signal to the controller.

7.9 Observed Direction backwards

Observed direction backwards is a Fault 3 offense. If the controller should detect that the direction of rotation of the motor is opposite of what is desired, it will go into a *coast* mode. While in coast mode the phase current is set to 0. The threshold is Factory set to 20 deci-hertz of reverse rotation. To translate this into RPM see section 5.3.

8. Controller Cooling

The NGM-EV-C200-XX2 motor controllers are supplied with two high efficiency muffin fans for cooling the controller. These should be hooked up at *all times* during operation of the controller. This will help the controller run cooler and more efficiently. The fans are powered and controlled by an internal temperature sensor built into the controller.

Note: If the controller notices excessive heat, it will slowly decrease its output to reduce heat generated. At this point the temperature would have to decrease before full operation can continue.

NGM Warranty

New Generation Motors Corporation warrants that its NGM-EV-C200 series motor controller will be free from defects in title, materials, and manufacturing workmanship for one (1) year. If an NGM-EV-C200 series motor controller is found to be defective, then, as your sole remedy and as the manufacturer's only obligation, New Generation Motors Corporation will repair or replace the product. This warranty is exclusive and is limited to the NGM-EV-C200 motor controller.

This warranty *shall not apply* to NGM-EV-C200 series motor controllers that have been subjected to abuse, misuse, abnormal electrical or environmental conditions, or any condition other than what can be considered normal use (including, and not limited to, opening of the controller for any purpose).

Warranty Disclaimers

New Generation Motors Corporation makes no other warranties, express, implied, or otherwise, regarding NGM-EV-C200 series motor controllers, and specifically disclaims any warranty for merchantability or fitness for a particular purpose.

The exclusion of implied warranties is not permitted in some States and countries thus exclusions specified herein may not apply to you. This warranty provides you with specific legal rights. There may be other rights that you have which vary from State to State.

Limitation of Liability

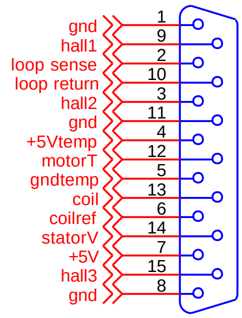
The liability of New Generation Motors Corporation arising from this warranty and sale shall be limited to the replacement of defective parts. In no event shall New Generation Motors Corporation be liable for costs of procurement of substitute products or services, or for any lost profits, or for any consequential, incidental, direct or indirect damages, however caused and on any theory of liability, arising from this warranty and sale. These limitations shall apply not withstanding any failure of essential purpose of any limited remedy.

Appendix A

J1 Pin Out

If another motor is being used, the following connections are possible. As a minimum the 3 hall sensors and the loop back of pins 2 and 10 must be connected for operation.

1. Ground of hall effect sensor for phase A
2. Cable connection sense loop
3. Hall effect signal of phase B
4. +5V for a temperature sensor
5. Ground for the temperature sensor
6. Reference for coil detection circuit
7. +5V for hall effect sensors
8. Ground of hall effect sensor for phase C
9. Hall effect signal of phase A
10. Cable connection sense loop
11. Ground of hall effect sensor for phase B
12. Signal from temperature sensor
13. Coil detection circuit
14. Stator voltage sense
15. Hall effect signal of phase

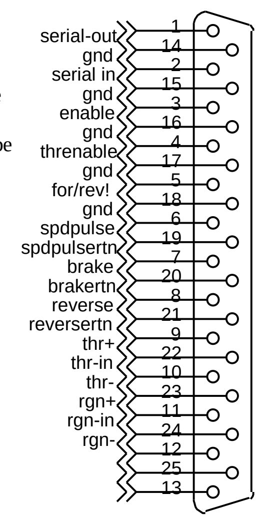


NOTE: Any attempt to adapt or modify signals could nullify any existing warranty. Please consult NGM prior to any such attempts.

J2 Pin Out explanation

PIN #

1. Serial out-The serial communication line for data leaving the controller.
2. Serial in- The serial communication line for data going into the controller.
3. Enable- When it is shorted to pin 16 the controller is *Enabled* for operation.
4. Throttle enable- when it is shorted to pin 17 the controller will act upon the throttle signal given.
5. Forward or reverse- depending whether it is shorted to pin 18 will determine the direction the controller operates the motor in.
6. Speed pulse- Sends out a TTL signal that is taken off of the hall sensor information that can be translated into the speed of operation.
7. Brake- +5V signal is given off when the controller goes into regenerative mode. This signal can be used to trigger brake lights.
8. Reverse- +5V signal is given off when the controller goes into reverse mode. This signal can be used to trigger reverse lights.
9. Throttle positive reference
10. Throttle negative reference
11. Regen in
12. Do not connect
13. Do not connect
14. Serial out ground- the ground line for the serial out communication.
15. Serial in ground- the ground line for the serial in communication.
16. Enable ground- the ground line for the *enable* circuit.
17. Throttle enable ground- the ground line for the *throttle enable* circuit.
18. For/rev ground- the ground line for the *forward and reverse* circuit.
19. Speed pulse return- The return line for the *speed pulse* signal.
20. Brake Return- The return line for the *braking* signal.
21. Reverse Return- The return line for the *reverse* signal.
22. Throttle-in –
23. Regenerative braking positive reference
24. Regenerative braking negative reference
25. Do not connect



Appendix B: Explanation of Register names

B.1 Prefixes

The manual frequently uses names that refer to specific register values, i.e. [SV_FAULT1]. To facilitate understanding, they have been arranged by their prefix's to let the reader know how they can be used. The following table lists the prefixes and what they mean:

EEPROM Prefixes:

FS_	Factory setting. Read only
CG_	Configuration value, user writeable
DF_	Default value for like-named RAM register, user writeable
FD_	Factory default value for like-named RAM register, read-only

RAM Prefixes:

SI_	Serial input register, user writeable
CB_	Command Boolean, set or cleared with command inputs
SV_	State variable, read-only
IN_	Input value set by arbitration logic, read-only
AM_	Analog measurement value, read-only
AI_	Analog input value from discrete interface, read-only
BM_	Boolean measurement value, read-only
BI_	Boolean input value from discrete interface, read-only
PM_	Performance metric, read-only

B.2 Suffixes

The suffixes are not as easily recognizable as the prefixes. However they tend to be abbreviations or full words to dictate their relationship. Some common suffixes are:

General Suffixes:	General meaning
THR	Having to do with the throttle or acceleration
RGN	Having to do with regenerative braking, or negative PHASE current
I	Current
SPD or SPEED	Having to do with speed control or RPM
PH	Having to do with the Phases, out or in
SUPPLY	Having to do with the Supply voltage or current

A register name is recognized by being encased in [].

<u>Example:</u>

[SV_FAULT1] => The ***SV*** as stated in the table denotes that it is a state variable. The second portion, *FAULT1* by recognition is a fault, error, etc.

Appendix C: RAM Registers

RAM Variable	Name	Description
Unsigned Integers		
00_H	SI_DESIREDSPEED	Serial speed in (deci-Hz)
01	SI_THRILIMIT	Serial throttle current limit in (deci-A)
02	SI_BRKILIMIT	Serial regen current limit in (dA)
03	SI_KP	Proportional coefficient for speed control
04	SI_KI	Integral coefficient for speed control
05	SI_KT	Phase current to speed error speed control coefficient
07	SI_MAXSPEEDERROR	Speed error clamping value
09	SI_PHASEIRAMP	Ramp rate for serial phaseI input, deciA/(seconds/60)
0A	SI_SPEEDRAMP	Ramp rate for serial speed input, deci-hz electrical/(seconds/15)
0B	IN_DESIREDSPEED	Desired speed
0C	AM_SPEED	Actual speed (deci-Hz)
10	SV_TARGETPHASEI	Target current (dA)
11	SV_THERMALLIMITMOTOR	Thermal motor current limit (dA)
12	SV_HEATSINKDERATING	Heatsink thermal derating ratio
13	SV_MAXTHRI	Maximum throttle current (dA)
14	SV_MAXRGNI	Maximum regen current (dA)
17	AI_THR	Discrete throttle in
18	AM_RGN	Discrete regen in
1C	IN_RGNILIMIT	Discrete regen current limit I (dA)
Signed Integers		
60	SI_DESIREDPHASEI	Serial phase current in (dA)
61	IN_DESIREDPHASEI	Phase current in (dA)
64	AM_SUPPLYV	Measured supply voltage (dV)
65	AM_MOTORT	Measured motor temp (degrees C * 10)
66	AM_HTSINKT	Measured heatsink temp (degrees C * 10)
67	AM_SUPPLYI	Measured logic supply current (mA)
Unsigned bytes and Boolean		
90	SI_MINFANSPEED	Minimum fan speed (0-3)
96	SV_DRIVESTATE	Operating status
97	BM_OBSERVEDDIR	Observed direction of rotation
98	SV_FAULT1LATCH	Latched values of below
99	SV_FAULT1	Bit-coded fault indications that prevent operation
9A	SV_FAULT2	Bit-coded fault indications of sensor problems
9B	SV_FAULT3	Bit-coded fault indications of warnings
9C	SV_FAULT4	Bit-coded fault indications of current limiting
9D	SV_FANSPEED	Actual fan speed setting
9E	IN_DISABLE	Disable input, equal to [CB_DISABLE] | [BI_DISABLE] | wrong direction

RAM Variable	Name	Description
9F	IN_THRENABLE	Throttle enable input, true when [CB_THRENABLE] AND [BI_THRENABLE]
A0	IN_FORWARD	Input direction
A1	SV_FORWARD	Actual operating direction
A2	SV_SPEEDCONTROL	When true, speed control
AA	BI_DISABLE	State of digital disable input
AB	BI_THRENABLE	State of throttle enable input
AC	BI_FORWARD	State of forward input
AD	CB_DISABLE	Serial disable input
AE	CB_THRENABLE	Serial throttle enable input
Unsigned Long Integers		
F0-F3	SI_UL[4]	Used as input registers
F8	PRODUCT	Returns product string
F9	BUILD	Returns software build string
FA	BUILDDATE	Returns build date string

Power up Values and Access Limits

RAM Variable	Name	Default at start-up	access/range
Unsigned Integers			
00_H	SI_DESIREDSPEED	0	read/write
01	SI_THRILIMIT	65535	read/write
02	SI_BRKILIMIT	65535	read/write
03	SI_KP	DF_KP	read/write
04	SI_KI	DF_KI	read/write
05	SI_KT	DF_KT	read/write
07	SI_MAXSPEEDERROR	DF_MASSPDERROR	read/write
09	SI_PHASEIRAMP	CG_PHIRAMP	read/write
0A	SI_SPEEDRAMP	CG_SPDRAMP	read/write
0B	IN_DESIREDSPEED	0	read only
0C	AM_SPEED	0	read only
10	SV_TARGETPHASEI	0	read only
11	SV_THERMALLIMITMOTOR	-	read only
12	SV_THERMALLIMITRGN	-	Read only
13	SV_MAXTHRI	-	Read only
14	SV_MAXRGNI	-	Read only
17	AI_THR	-	Read only
18	AM_RGN	-	Read only
1C	IN_RGNILIMIT	65535	Read only
1D	SV_LAST	-	Read only

RAM Variable	Name	Default at start-up	Access/range
Signed Integers			
60	SI_DESIREDPHASEI	0	Read/write
61	IN_DESIREDPHASEI	0	Read only
64	AM_SUPPLYV	-	Read only
65	AM_MOTORT	-	Read only
66	AM_HTSINKT	-	Read only
67	AM_SUPPLYI	-	Read only
68	AM_HSINKTEST	-	Read only
69	AM_MOTORTEST	-	Read only
Unsigned bytes and Boolean			
90	SI_MINFANSPEED	0	Read/write
96	SV_DRIVESTATE	-	Read only
97	BM_OBSERVEDDIR	1	Read only
98	SV_FAULT1LATCH	-	Read only
99	SV_FAULT1	-	Read only
9A	SV_FAULT2	-	Read only
9B	SV_FAULT3	-	Read only
9C	SV_FAULT4	-	Read only
9D	SV_FANSPEED	-	Read only
9E	IN_DISABLE	-	Read only
9F	IN_THRENABLE	-	Read only
A0	IN_FORWARD	-	Read only
A1	SV_FORWARD	-	Read only
A2	SV_SPEEDCONTROL	-	Read only
AA	BI_DISABLE	-	Read only
AB	BI_THRENABLE	-	Read only
AC	BI_FORWARD	-	Read only
AD	CB_DISABLE	(maxSCIidle > 0) OR (NOT(CG_ENDISCRETE_DISABLE))	Read only
AE	CB_THRENABLE	1	Read only
Unsigned Long Integers			
F0-F3	SI_UL[4]	-	Read/write
F8	PRODUCT	"EVC-200"	Read only
F9	BUILD	"Build xx"	Read only
FA	BUILDDATE	"YYYYMMDD"	Read only

Appendix D: EEPROM Registers

EEPROM Variable	Name	Description
Unsigned Integers		
00_H	**CG_BAUDRATE**	**I/O baud rate**
02	FS_ABSMINV	Absolute minimum voltage for operation (dV)
03	CG_MINV	Voltage at which max throttle current is zero (dV)
04	CG_MINVGUARD	Voltage at which max throttle current limiting starts (dV)
05	CG_MAXVRGNGUARD	High voltage cut-off start point for regen
06	CG_MAXVRGN	Maximum voltage for regen
07	CG_MAXVGUARD	Voltage at which max phase current limiting begins due to over voltage (dV)
08	CG_MAXV	Voltage at which phase current is zero (dV)
09	FS_ABSMAXVGUARD	Voltage at absmaxthrI1 set point (dV)
0A	FS_ABSMAXV	Absolute maximum voltage for operation (dV)
0B	FS_MINGUARDDELTA	Minimum difference between minV and minVguard, also maxV
0C	CG_MINFREQ	Minimum commutation frequency for speed control
0D	DF_KI	Default value for SI_Ki
0E	DF_KP	Default value for SI_Kp
0F	DF_KT	Default value for SI_Kt
11	DF_MAXSPDERROR	Clamping value for speed error in speed control
12	SC_SUPPLYV	Scale value for supply voltage
13	SC_SUPPLYI	Scale value for supply current
15	FS_SCHTSINKT	Scale value for heatsink temperature
16	CG_SCTHR_SPEED	Scale value for throttle input into speed (speed control)
17	CG_SCTHR_TORQUE	Scale value for throttle input into amps (torque control)
18	CG_SCRGN_TORQUE	Scale value for regen input into amps
1A	CG_SCMOTORT	Scale value for motor temperature
1D	CG_MAXMOTORI	Maximum motor current, throttle or regen (deci-Amps)
1E	DF_PHASEIRAMP	Default value for SI_PHASEIRAMP
1F	DF_SPEEDRAMP	Default value for SI_SPEEDRAMP
21	CG_SPEEDTHRESHOLD	Safe speed for changing motor direction
22	CG_MINSUPPLYI	Minimum supply current when fans are off
23	CG_MAXSUPPLYI	Maximum supply current when fans are off
24	CG_MINFANSUPPLYI	Minimum supply current when fans are on
25	CG_MAXFANSUPPLYI	Maximum supply current when fans are on

EEPROM Variable	Name	Description
2C-2F	CG_FANI[4]	Current thresholds for fan control
36	CG_MAXTHRI0	Maximum throttle current (dA)
37	CG_MAXTHRI1	
38	CG_MAXRGNI0	Maximum regen current (dA)
39	CG_MAXRGNI1	
3A	FS_ABSMAXTHRI0	Factory set maximum value for [CG_maxthrI] (dA)
3B	FS_ABSMAXTHRI1	
3C	FS_ABSMAXRGNI0	Factory set maximum value for [CG_maxrgnI] (dA)
3D	FS_ABSMAXRGNI1	
3E	CG_MOTORITCOEFF	I^2t coefficient for estimating heatsink temp
3F	FS_HSINKITCOEFF	I^2t coefficient for estimating motor temp
Signed Integers		
60	FS_OFSUPPLYV	Offset value for supply voltage
61	FS_OFSUPPLYI	Offset value for supply current
64	CG_OFMOTORT	Offset value for motor temp
65-67	CG_FANTEMP[3]	Temperature transition points for fan control
71	CG_DEFAULT_MOTORT	Assumed motor temp when sensor fails
72-75	CG_TLIMTMTR[3]	Motor Temperature transition points (deci-Celsius)
7C-7D	CG_TLIMIMTR[2]	0-256 % of current at the corresponding Temp. Implied denominator of 256
Unsigned bytes and Boolean		
90	CG_ECHO	When true, echo characters as they are received
91	CG_TEXTERRORS	When true, send text messages for errors, else send two digit codes
92	CG_LINEFEEDS	When true, use CR-LF combinations at end of lines
93	CG_MAXSCIIDLE	Maximum idle time for serial interface watchdog fault in tenths of a second, 0 disables
95	CG_60DEGREEHALLS	When true, assume hall-effect sensor are 60 electrical degrees apart
97	CG_INVERTDIR	When true, reverse definition of forward
98	DF_SPEEDCONTROL	When true, power-up in speed control mode
99	CG_ENDISCRETE_THR	When true, use discrete throttle and regen inputs
9B	CG_ENDISCRETE_DIR	When true, use discrete direction input
9C	CG_ENDISCRETE_THRENABLE	When true, use discrete throttle enable input
9D	CG_ENDISCRETE_DISABLE	When true, use discrete disable input
9E	CG_THRDEADBAND	Offset (in counts) of throttle input
9F	CG_RGNDEADBAND	Offset (in counts) of regen input
A0	CG_GAPDEADBAND	Offset (in counts) of gap input (not used)
A1	CG_RTSUPPLYV	Filtering level for supply voltage (0:none to 4:max)
A2	CG_RTSUPPLYI	Filtering level for supply current measurement
A4	CG_RTHSINKT	Filtering level for heatsink temp measurement
A5	CG_RTHTR	Filtering level for throttle input
A6	CG_RTRGN	Filtering level for regen input

EEPROM Variable	Name	Description
A8	CG_RTMOTORT	Filtering level for motor temp measurement
A9	CG_SOFTSTARTN	Speed of softstart operation (0:fastest ramp to 7:slowest ramp)
AA	CG_NAUTORESETS	Number of automatic reset attempts in four seconds
B9	CG_MOTORTIMEC	Thermal time constant coefficient for motor
BA	FS_HSINKTIMEC	Thermal time constant coefficient for heatsink
BB	CG_AISPDTOPWMFREQMULT	Sets threshold for detecting max torque production
UNSIGNED LONGS		
F0	CG_SPDNUMERATOR	Numerator used for speed calculation

Factory Settings and Access Limits

EEPROM Registers	Name	Access/range	Factory Setting EV-C200-XX2	
			-042	-092
Unsigned Integers				
00_H	CG_BAUDRATE	Read/write	9600	9600
02	FS_ABSMINV	Read only	250	400
03	CG_MINV	Between [ABSOLUTEMINV] and [MINVOLTAGEGUARD]-[MINGUARDDELTA]	280	450
04	CG_MINVGUARD	Between [MINVOLTAGE]+[MINGUARDDELTA] and [MAXVOLTAGEGUARD]	350	550
05	CG_MAXVRGNGUARD	Read/write	630	1220
06	CG_MAXVRGN	Read/write	680	1350
07	CG_MAXVGUARD	Between [MINVOLTAGEGUARD] and [MAXVOLTAGE]-[MINGUARDDELTA]	630	1350
08	CG_MAXV	Between [MAXVOLTAGEGUARD]+[MINGUARDDELTA] and [ABSOLUTEMAXVOLTAGE]	680	1450
09	FS_ABSMAXVGUARD	Read only	630	1350
0A	FS_ABSMAXV	Read only	680	1500
0B	FS_MINGUARDDELTA	Read only	50	50
0C	CG_MINFREQ	Read/write	0	0
0D	DF_KI	Read/write	2600	1500
0E	DF_KP	Read/write	867	150
0F	DF_KT	Read/write	0	0
10	DF_KS	Read/write	0	0
11	DF_MAXSPDERROR	Read/write	60	60

EEPROM Registers	Name	Access/range	Factory Setting EV-C200-XX2	
			-042	-092
12	SC_SUPPLYV	Read only	61	150
13	SC_SUPPLYI	Read only	206	206
15	FS_SCHTSINKT	Read only	139	139
16	CG_SCTHR_SPEED	Read/write	80	80
17	CG_SCTHR_TORQUE	Read/write	207	120
18	CG_SCRGN_TORQUE	Read/write	207	120
1A	CG_SCMOTORT	Read only	139	139
1B	FS_SCPWMFREQ	Read only	122	122
1D	CG_MAXMOTORI	Limit to 0 to 4095	3600	1500
1E	DF_PHASEIRAMP	Read/write	65535	65535
1F	DF_SPEEDRAMP	Read/write	65535	65535
21	CG_SPEEDTHRESHOLD	Read/write	20	20
22	CG_MINSUPPLYI	Read/write	40	40
23	CG_MAXSUPPYI	Read/write	250	250
24	CG_MINFANSUPPLYI	Read/write	200	200
25	CG_MAXFANSUPPLYI	Read/write	950	950
2C-2F	CG_FANI[4]	Read/write	1200,1600, 2000,2400	800,1000, 1200,1400
36	CG_MAXTHRI0	<= absmaxthrI	3010	1770
37	CG_MAXTHRI1		2600	1500
38	CG_MAXRGNI0	<= absmaxrgnI	2060	1200
39	CG_MAXRGNI1		1700	1020
3A	FS_ABSMAXTHRI0	Read only	3100	1800
3B	FS_ABSMAXTHRI1		2600	1500
3C	FS_ABSMAXRGNI0	Read only	2060	1200
3D	FS_ABSMAXRGNI1		1720	1000
3E	CG_MOTORITCOEFF	Read/write	19	73
3F	FS_HSINKITCOEFF	Read only	41	121
Signed Integers				
60	FS_OFSUPPLYV	Read only	7	7
61	FS_OFSUPPLYI	Read only	0	0
63	FS_OFHSINKT	Read only	-611	-611
64	CG_OFMOTORT	Read only	-611	-611
65-67	CG_FANTEMP[3]	Read/write	350,400,450	350,400,450
68-6F	reserved	Read only	0	0
70	FS_DEFAULT_HSINKT	Read only	750	750
71	CG_DEFAULT_MOTORT	Read/write	750	750
72-75	CG_TLIMTMTR[3]	Read/write	500,770,920, 1000	750,850,1000 ,1100
77-7B	FS_TLIMHSINK[5]	Read only	450,680,840, 900,32767	300,500,650, 750,32767
7C-7D	CG_TLIMIMTR[2]	0-256	182,105	230,128
7E-7F	FS_TLIMIHSINK[2]	Read only	179,92	179,92

EEPROM Registers	Name	Description	Factory Setting EV-C200-XX2	
			-042	-092
Unsigned bytes and Boolean				
90	CG_ECHO	Coerced to 0-1	1	1
91	CG_TEXTERRORS	Coerced to 0-1	1	1
92	CG_LINEFEEDS	Coerced to 0-1	1	1
93	CG_MAXSCIIDLE	Read/write	0	0
95	CG_60DEGREEHALLS	Coerced to 0-1	1	1
97	CG_INVERTDIR	Coerced to 0-1	0	0
98	DF_SPEEDCONTROL	Coerced to 0-1	0	0
99	CG_ENDISCRETE_THR	Coerced to 0-1	1	1
9B	CG_ENDISCRETE_DIR	Coerced to 0-1	1	1
9C	CG_ENDISCRETE_THRENABLE	Coerced to 0-1	1	1
9D	CG_ENDISCRETE_DISABLE	Coerced to 0-1	1	1
9E	CG_THRDEADBAND	Read/write	8	8
9F	CG_RGNDEADBAND	Read/write	8	8
A0	CG_GAPDEADBAND	Read/write	8	8
A1	CG_RTSUPPLYV	0-4	2	2
A2	CG_RTSUPPLYI	0-4	4	4
A4	CG_RTHSINKT	0-4	4	4
A5	CG_RTTHR	0-4	1	1
A6	CG_RTRGN	0-4	1	1
A8	CG_RTMOTORT	0-4	4	4
A9	CG_SOFTSTARTN	0-7	6	6
AA	CG_NAUTORESETS	0-64	0	0
B9	CG_MOTORTIMEC	Read/write	2	2
BA	FS_HSINKTIMEC	Read only	15	15
BB	CG_AISPDTOPWMFREQMULT	0-4	0	0

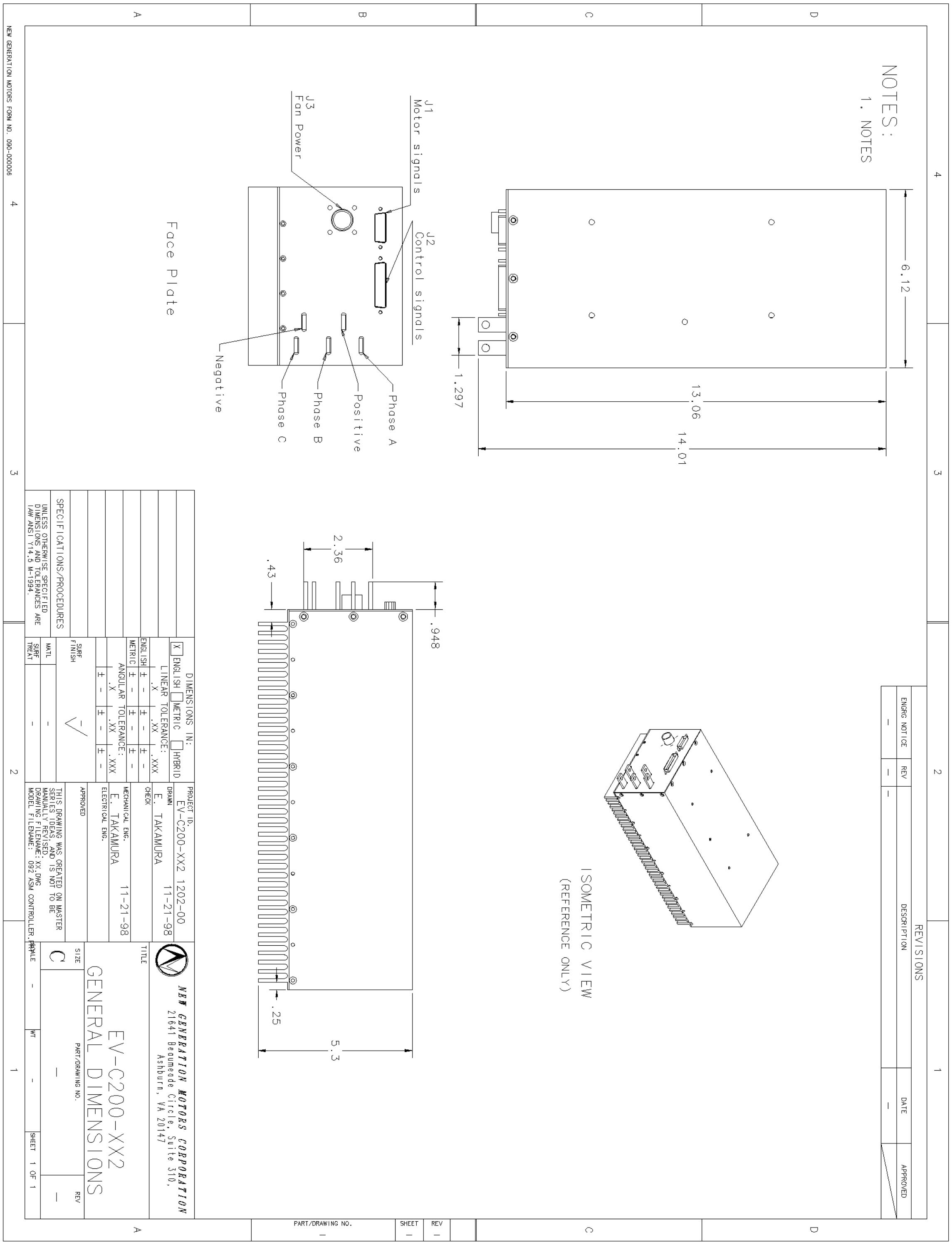
Appendix E: Drive States

Value	Name	Description
32_D	DS_POWERUP	Initial state
33-62		Powering up
63	DS_POWERUPEND	Power-up period over
64	DS_SHUTDOWN	Stopped and disabled
65	DS_DISABLECOAST	Disabled but not stopped
66	DS_INTERLOCK	Type 1 fault detected, waiting for disable command
67	DS_INTERLOCKCOAST	Type 1 fault detected, waiting for disable command, not stopped
74	DS_STOPPED	Enabled but not moving or throttling
75	DS_COASTING	Enabled and moving but not throttling
76	DS_NO_LONGER_THR	Leaving DS_thr mode
77	DS_NO_LONGER_BRK	Leaving DS_brk mode
78	DS_THR	Throttling
79	DS_BRK	Braking
1	DS_PROGRAM	Shutdown with programming enabled

Appendix F: Error Messages and Codes

Number	Message	Description
#00	Ok	Normal completion of a command or set
#02	Bad Command	Command character not !,<,>,=, or ?
#03	SCI Overflow	Input buffer overflow, over 15 characters in input
#04	Bad Input	First two characters not hex digits or input less than 3 characters
#05	Command Failed	Not in the correct mode for command, such as: sending a forward command when discrete direction enabled, sending a speed control signal when in speed control, sending a program control signal when drivestate isn't shutdown
#06	Not PGM Mode	Command requires that the drivestate be program, or attempting to write to an EEPROM variable while drivestate is not program
#09	Read Only	Attempting to write to a read-only variable
#0A	Out of Range	Attempting to write a value to a limited-write setting that is outside the factory limits. This includes attempts to violate the absminV < minV < minVguard < maxVguard < maxV < maxVguard relationship. Changes to these values must be made in the correct order
#0D	Bad Address	Attempting to access an address that does not exist
#0E	MaxthrI0 too hi	When programming, can't set [CG_MINVGUARD] because [CG_MAXTHRI0] is too high
#0F	MaxthrI1 too hi	When programming, can't set [CG_MAXVGUARD] because [CG_MAXTHRI1] is too high
#10	MaxrgnI1too hi	When programming, can't set [CG_MAXVRGNGUARD] because [CG_MAXRGNI1] is too high

Appendix G: Basic Dimensions



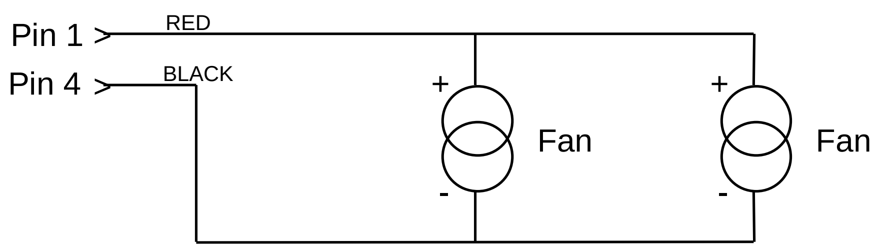
<u>Appendix H: Discrete control Quick Start Guide</u>

The Quick Start Guide is not intended as a replacement to the NGM-EV-C200 series Controller OPERATING MANUAL. The entire NGM-EV-C200 series Controller OPERATING MANUAL must be read before operating the controller.

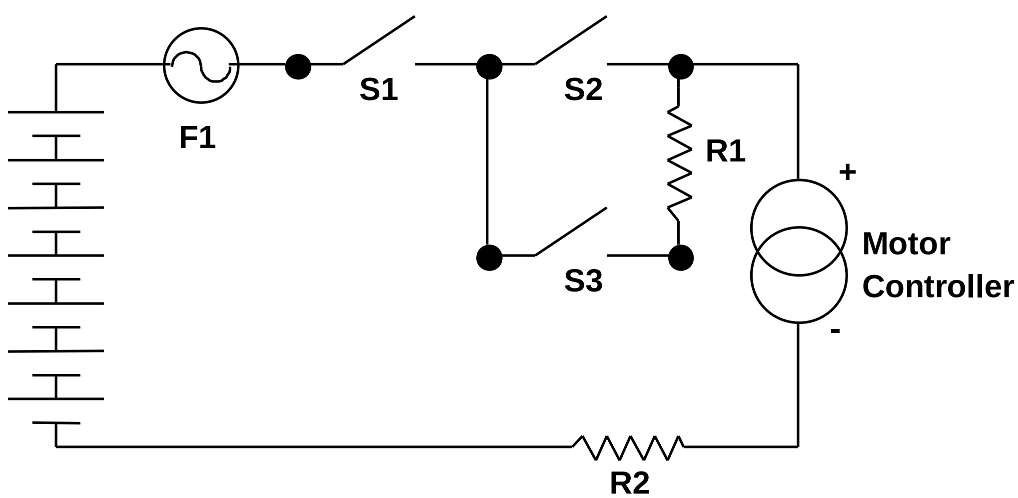
The controller is shipped with its power up defaults set to ***discrete*** control in ***torque control*** mode.

Connections:

1. Motor Phase leads. *No less than AWG 6 gage (4.11mm) wire*, AWG 4 (5.18mm) or larger is preferable.
2. Motor Sense, Connector J1.
3. Control, Connector J2.
4. Fan Power, Connector J3. Below is the schematic for connecting the fans.

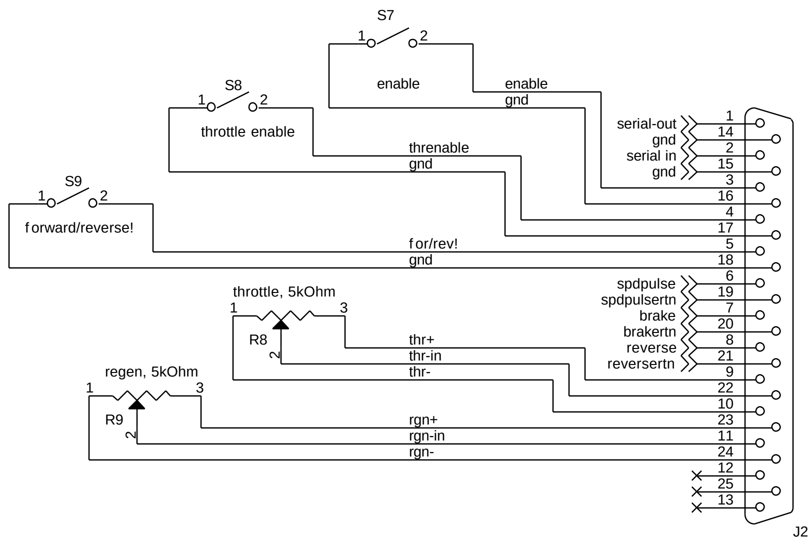


5. Power. *No less than AWG 6 gage (4.11mm),* AWG 4 (5.18) or larger is preferred. A ***Pre-charge circuit must be in place*** to protect the controller. Schematic below.



R1 should have a resistance such that the current through it at turn-on is at most 30A. Resistor R2 is an optional 100 A shunt for measuring the motor controller current.

6. *Example:* Connection for discrete control.



Operation:

1. There are five inputs that must be communicated to the controller as a minimum; Enable, Throttle- Enable, Direction, Throttle, and Regen.

> ***Forward/Reverse***: Forward corresponds to open circuit and reverse to *closed*. It is recommended that the direction signal be wired directly to a switch for maximum safety and reliability
>
> ***Enable:*** An open circuit immediately disables all torque production.
>
> ***Throttle enable:*** When open-circuited, the maximum throttle current is set to zero (i.e. it can not produce accelerating torque, but the controller can still operate in regen. It is suggested that this input be wired to a switch on the brake pedal).

2. When in discrete torque control, the desired phase current, which is proportional to torque, is determined by the difference between the throttle and regen analog inputs. When this is greater than zero, driving torque is produced. When less than zero, regen is applied. When equal to zero, the motor coasts. The inputs could be references across potentiometers having resistance values ~4k-20k.